THE EFFECTS OF A HOME-BASED EXERCISE INTERVENTION ON INDIVIDUALS WITH PARKINSON'S DISEASE

by

JOE ROBERT NOCERA

(Under the Direction of Michael A. Horvat)

ABSTRACT

The purpose of this study was to evaluate a home-based exercise intervention for individuals with Parkinson's disease. Sixteen individuals, eight with Parkinson's disease (74.6 ± 8.3 year) and eight healthy, aged-matched controls (71.0 ± 5.9 year) completed this study and were evaluated on; (1) balance as measured by a NeuroCom EquiTest Sensory Organization Test protocol, (2) a Functional Limitations Assessment measured on the EquiTest long forceplate including a Sit-to-Stand, Step-Up/Over, and a Walk Across and (3) isokinetic strength as measured by the HumacNorm isokinetic dynamometer proir to and after a 10 week home-based exercise intervention. Data were analyzed with mixed model repeated measures MANOVA. Based on data analysis it was concluded that individuals with Parkinson's disease can significantly improve functional task measures with a convenient, home-based exercise intervention.

KEY WORDS: Parkinson's Disease, Balance, Function, Strength

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JOE ROBERT NOCERA

B.A., University of California, Los Angeles 2001

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JOE ROBERT NOCERA

Major Professor:	Michael A. Horvat
Committee:	Bryan McCullick
	Gregory Palardy

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2007

DEDICATION

I would like to dedicate this dissertation to Dr. Gary Dudley who's encouragement and support made this project possible.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Individuals with Parkinson's disease (PD) demonstrate increased difficulties with postural stability and movement when compared to their aged-matched healthy counterparts. As a result, individuals with PD have increased incidence of falls and overall less physical function. Fall-related injuries are the leading cause of physical trauma, restriction of day to day activity, and nursing home admissions in individuals with PD (Giladi et al., 2001). Studies have shown that up to 90% of patients with PD will fall at some stage as a result of postural instability (Koller, Glate, & Vetere-Overfield, 1998). Differences are especially apparent in individuals with PD in terms of functional tasks such as walking, postural control and muscular strength during functional tasks. This is consistent in the literature in which researchers reported reductions in step length and walking velocity in PD patients when compared with controls (Sofuwa et al., 2005). Similarly, Inkster and colleagues reported reduced strength in individuals with PD and contributed it to difficulties with functional tasks such as rising from a chair (Inkster, Eng, MacIntyre, & Stoessl, 2003). From a review of previous research a consistent pattern indicates that individuals with PD demonstrate 1) limited ability to perform functional tasks (i.e. sit-to-stand and walking) 2) postural instability and balance impairments which increases the risks of falls, and 3) lower levels of lower extremity strength.

There has also been evidence to indicate that function can be enhanced with exercise intervention (Hirsch, Toole, Maitland, & Rider, 2003; Scandalis, Bosak, Berliner, Helman, &

Wells, 2001). Bergen and colleagues also showed that exercise reduced the detrimental effects of neuromuscular slowing within the PD population by improving the participants ability to initiate and perform movement tasks following a 16-week exercise intervention (Bergen et al., 2002). Likewise, Ellis and colleagues found improvements, in terms of function, related to activities of daily living including, walking speed and overall quality of life following a physical therapy intervention (Ellis et al., 2005). Although exercise as a therapeutic intervention has been effective the settings are generally in a laboratory, health facility, or physical therapy setting. Due to the difficulties associated with this disease (i.e. health care and medication costs as well as travel limitations) these types of therapy may not be accessible to all individuals living with PD. This provided the rational of providing exercises that could be performed at home. Therefore, it was hypothesized that a home-based exercise intervention would demonstrate similar improvements in overall function while concurrently allowing for accessibility to all individuals with PD.

Purpose of the Study

The purpose of this study was to evaluate a home-based exercise intervention while evaluating functional performance measures following the completion of the intervention in the PD population. More specifically, the purpose of this study was to evaluate the following individuals with PD: 1) balance with the NeuroCom EquiTest Sensory Organization Test (SOT), 2) functional performance measures using the NeuroCom EquiTest Functional Limitations Assessment (Sit-to-Stand, Step Up/Over, and Walk Across) and 3) lower body strength utilizing the HumacNorm isokinetic dynamometry system.

Hypotheses

This study was designed to investigate a home-based exercise intervention on individuals with PD. It was hypothesized there would be a positive relationship between the dependent variable and the independent variables. That is, a 10-week home-based exercise intervention would result in an increase in the participants balance as measured by the NeuroCom EquiTest SOT, three functional performance measures (Sit-to-Stand, Step Up/Over, and Walk Across), and strength as measured by the HumacNorm isokinetic dynamometer system.

1. Home-based exercise will improve the ability to maintain stability under the varying sensory conditions in the NeuroCom EquiTest SOT protocol.
2. Home-based exercise will improve functional movement measures such as standing from a seated position (Sit-to-Stand) , stepping over an object (Step Up/Over), and walking gait cycle (Walk Across).
3. Home-based exercise will improve strength in the lower extremity which will be evaluated utilizing a HumacNorm isokinetic dynamometer.

The Significance of the Study

This study was designed to produce preliminary information about the effects of a home-based exercise intervention on individuals with PD. A review of the literature revealed positive effects of exercise on individuals with PD including an increase in overall function. However, with the difficulties associated in terms of cost of the disease and with the difficulties in terms of transportation for individuals with PD an exercise intervention in the home would allow for greater access to those with PD. In addition to being convenient, it was hypothesized the home-based intervention would improve overall function, and more specifically balance and lower extremity strength.

Limitations of the Study

This study was limited to the range of functional activities performed on the NeuroCom EquiTest and on the HumacNorm Isokinetic Dynamometer. The ability to generalize to the total population of those with PD was limited by factors such as age, age of onset of PD, medication (type and dosage), variability of the sample, and sample size.

Delimitations of the Study

This study was limited to the number of participants living in the northeast Georgia with PD and healthy, aged matched participants. All subjects were between the ages of 64-88.

Definition of Terms

Balance – the ability of an individual to maintain equilibrium in a held (static) or moving (dynamic) position.

Box's M – Indices used to test for violation of the assumption of homogeneity of covariance (Norusis, 1988).

Effect Size – The magnitude of an independents variable's effect, usually expressed as a proportion of explained variance in the dependent variables (Weinfurt, 2000).

Levene Statistic – Test statistic measuring homogeneity of variances between the groups.

Movement Efficiency – The ability to perform tasks of daily living in an expedient and mature manner. The combination of these senses is required to produce efficient movement patterns and provide stability during movement (Horvat, Ray et al., 2003).

Muscular Strength – The maximal amount of force that can be generated by a muscle or muscle group. Measured on the HumacNorm Isokinetic Testing Dynamometer in Newton-meters.

Peak Torque – The force produced by muscular contraction in a joints range of motion. Measured by an isokinetic testing device in Newton-meters.

Pearson r – Statistic reflection of the linear relationship between two variables.

Power – is the amount of time it takes for a muscle to apply force times distance of movement. Measured by an isokinetic testing device measured in watts.

Total Work – is the amount of force produced times distance of rotation a muscle produces through a set of repetitions. Measured by an isokinetic testing device in Newton-meters.

Wilks' Lambda – A multivariate test statistic that expresses the proportion of unexplained variance in the dependent measures (Weinfurt, 2000).

CHAPTER II

REVIEW OF LITERATURE

This chapter will first present the epidemiology and history of PD as well as how PD effects the brain. Following this, the hypothesized causes of PD will be discussed. Subsequent sections will presents a review of the current literature regarding the physiological effects of PD including cardinal signs, postural instability, and muscular strength deficiencies. The chapter will then discusses the diagnosis of PD as well as assessment tools utilized to identify severity of the disease. Next, the current treatments utilized in PD, including drug therapy, surgical interventions, and therapeutic interventions will be discussed. The chapter will also discuss closed chain exercise as it relates to the proposed exercise intervention used in this study. Lastly, the chapter will explain how functional task measures and strength will be assessed in this study.

Epidemiology and History

Currently, PD is the most common neurological disorder with at least 1.5 million Americans affected and 60,000 more being diagnosed each year (National Parkinson's Foundation, 2006). The prevalence of PD around the world is estimated at 0.3% in the general population and about 1% of the population over 60 years of age (Samii, Nutt, & Ransom, 2004). These numbers are expected to increase greatly as the elderly population continues to be the fastest growing segment in America. People of all ethnic origins are affected equally, however, men are slightly more at risk then women (Samii et al., 2004). The mean age of onset is estimated in the mid-to-late 60's (Inzelberg et al., 2004).

The first diagnosis of PD was made in 1817 by a English physician named James Parkinson for whom the disease is named. Dr. Parkinson referred to the disease as "shaking palsy". In his sixty-six page essay he described the disease as "involuntary tremulous motions and lessened muscular power, in parts not in action and even when supported; with a propensity to bend the trunk forward, and the pass from a walking to a running pace, the senses and intellect being uninjured…with very slow progress" (Parkinson, 1817). Although the early description by Dr. Parkinson of PD was accurate, it was not until the 1950's that the neuropathology of the disease was determined.

Parkinson's Disease and the Brain

It was not until over 100 years following Dr. Parkinson's description of "shaking palsy" that PD was linked to the degeneration of the substantia nigra in the midbrain. The substantia nigra produces a neurotransmitter, dopamine, which is essential for the proper transmission of signals throughout the basal ganglia to control movement (National Institute of Neurological Disorders and Stroke, NINDS, 2004). These neurochemical signals are vital for normal movement of the musculoskeletal system. For example, when automatic movement patterns such as walking are initiated information is sent from the parts of the brain, including the basal ganglia, that control motor planning to the striatum. The striatum interacts with other parts of the brain, including the substantia nigra, to send out signals by way of neurotransmitters. These signals then travel to the cerebellum, which controls balance and coordination, and finally down the spinal cord and out to the peripheral nerves. In individuals with PD however, there is injury or degeneration to the dopaminergic projects from the substantia nigra leading to loss of 80% of striatal dopamine (NINDS, 2004). The loss of striatal dopamine results in excessive firing of the

nerve cells within the striatum leading and leads to an imbalance of excitation and inhibition in the circuitry of the basal ganglia and to the inability to control movements (Samii et al., 2004).

Cause and Pathogenesis

As discussed the pathological finding in PD is degeneration of the substantia nigra resulting in decreased dopamine production. However, the underlying cause or causes of the degeneration in the substantia nigra and the resulting loss of dopamine are unknown. There are however, two primary cellular characteristics are common in individuals with PD and may play a role in the degeneration. First, dense clumps of proteins called Lewy bodies are found in the substantia nigra as well as other parts of the brain in individuals with PD (Samii et al., 2004). It is believed that these Lewy bodies in non-motor areas could account for many of non-motor symptoms, including depression. Secondly, swollen nerve fibers called Lewy neurites, which may interfere with neural transmission, are also present in those with PD (Samii et al., 2004). Aside from these two common cellular characteristics the cause of PD is still unknown but is probably a result of multiple factors including aging, genetic susceptibility, and environmental exposures.

Aging is associated with the decline of pigmented neurons in the substantia nigra. For example, McGeer demonstrated serious losses of neurotransmitter synthesis in healthy aging human brains (McGeer, McGeer, & Suzuki, 1977). The most severe loss was seen in striatal tyrosine hydroxylase which is an enzyme used in the synthesis of dopamine. Additionally, Lewy bodies have been found in up to 16% of elderly asymptomatic people at autopsy (Fearnley & Lees, 1991). Although the rates of PD increase with age, aging is not accepted as the sole cause of the disease.

Only about 15% of individuals with PD have a first-degree relative with the disease (Payami, Larsen, Bernard, & Nutt, 1994). However, recent discoveries of five genes and four other gene loci in familial PD has greatly enhanced the interest in genetic contributions to the disease (Samii et al., 2004). Single gene abnormalities identified to date have cause only a few causes, however, these genetic predispositions have expanded to the understanding of the underlying causes of PD.

The last factor that seems to play a role in the incidence of PD is environmental exposures. Pesticide exposure, living in rural areas of industrialized countries, drinking well water, and farming have all been linked to PD (Priyadarshi, Khuder, Schaub, & Priyadarshi, 2001).

Cardinal Signs of Parkinson's Disease

The previously discussed changes in the basal ganglia functioning results in the three primary signs of PD; bradykinesia, rigidity, and tremor. Bradykinesia refers to difficulty in initiating movements as well as slowness of movements. It is the most debilitating symptom of early PD. Both automatic and voluntary movements are affected resulting in a reduction of walking speed, range, and amplitude of movements. This results in impairment of overall coordination, particularly in fine motor tasks like writing and handling small objects (O'Sullivan & Schmitz, 2001). The cause of bradykinesia is believed to be from alterations in motor planning due to the reduction of basal ganglia integration. Because the basal ganglia are responsible for automatic movement patters, an individual with PD must constantly check progress of once automatic movements, such as writing. Due to this, movements must be cortically controlled resulting in intense mental effort (O'Sullivan & Schmitz, 2001).

The next cardinal sign of PD is muscle rigidity. Rigidity is an increase resistance to passive motion which affects all striated muscles. It results from an increase in the static stretch reflexes and excess activation of alpha motoneurons in both the agonist and antagonist muscle groups (O'Sullivan & Schmitz, 2001).

Tremor is involuntary, rhythmic, or alternating burst of movement of the antagonist muscle groups. A resting tremor with a frequency of 3-5 Hz is often the first symptom in 70% of PD patients (Samii et al., 2004). It is theorized that tremor is a result of enhanced activity in the basal ganglia circuitry. Tremor is usually more severe during emotional tension and completely absent during sleep.

Bradykinesia, rigidity, and tremor have a dramatic effect on the individual's independence and quality of life by reducing their capability to perform acts of daily living (ADL's). In addition to these three cardinal signs of PD, other secondary physiological and psychological factors can attribute to overall diminishment of individuals with PD (see Table 2.1). Taken together, as function and independence begin to decline due to the physiological factors the individuals emotional and psychological wellbeing may become negatively affected. Feelings of despair and hopelessness can often invade an individual's outlook leading to additional decreases in function and performance due to a lack of motivation.

Table 2.1: Effects of Parkinson's Disease

Impairment	
Physiological	Psychological
Bradykinesia	Depression
Rigidity	Anxiety
Tremor	Dementia
Muscle weakness	Decreased motivation
Postural instability	Public embarrassment

Postural Instability and Falls

An important component of function that may be debilitated in individuals with PD is postural instability, particularly as the disease progresses. Postural instability refers to the gradual development of poor balance, leading to an increased risk of falls. Postural instability can be demonstrated by an impaired response to perturbation and an inability to make the necessary postural adjustments (Overstall, 1992). Falls are the most serious complication of postural instability in PD and reports have documented individuals with PD who fall varies from 38-90% (Balash et al., 2005; Koller et al., 1998). These falls are the leading cause of physical trauma and restriction of day-to-day activity in individuals with PD (Giladi et al., 2001). In addition to problems with balance and falls, postural instability restricts overall mobility, gait and the ability to initiate movement. These components then lead to loss of overall function and decreased independence.

Based on the work by done by Horak, Nutt, and Nashner (1992), Bronte-Steward, Minn, Rodrigues, Buckley and Nashner (2002) identified three processes required for functional postural stability: 1) sensory organization, in which one or more of the orientation senses (somatosensory, visual, and vestibular) are involved and integrated with the central nervous system; 2) a motor adjustment process involved with executing coordinated and properly scaled neuromuscular responses; and 3) adequate tone of muscles, through which adjustments in postural control are achieved. Because PD is a multifactorial problem, individuals with the disease may have deficiencies in one or more of the three processes required for postural stability. For example, in terms of sensory organization, visual and proprioceptive dysfunction has been documented in individual with PD (Bronstein, Hood, Gresty, & Panagi, 1990; Reichert, Doolittle, & McDowell, 1982). Additionally, Marsden and other have demonstrated that motor

planning and the corresponding motor adjustments are severely affected in persons with PD (Horak, Nutt, & Nashner, 1992; Marsden, 1982). Lastly, lack of muscular strength has been well documented in individuals with PD (Inkster & Eng, 2004; Inkster et al., 2003).

Movement efficiency refers to ability of the central and peripheral nervous systems to perform tasks of daily living in an expedient and mature manner to produce efficient movement patterns and provide stability during movement (Horvat, Ray et al., 2003). Like postural stability, movement efficiency utilizes visual, somatosensory, and vestibular perception. Also, like postural stability, movement efficiency requires motor adjustment processes as well as muscular strength to complete the needed adjustments. These systems are not only used to provide feedback to maintain balance but also initiate the movement (Blasch, Weiner, & Welsh, 1997). The combination of these senses are required to produce efficient movement patterns, such as walking, and provide stability during ambulation or during the performance of activities of daily living.

Other studies have examined the disruption of one or more of the systems causing disturbances in both postural stability and/or movement efficiency. For example, researchers evaluated center of pressure and center of mass as an overall indicator of dynamic balance control during gait in individuals with PD at different levels of involvement based on the Hoehn and Yahr scale. They found that those individuals further along in the progress of the disease (Hoeh and Yahr score greater then 2.5) demonstrated clinically detectable balance impairment as measured by group reaction forces. Additionally, their findings suggested that dynamic postural control (i.e. locomotion) may be more affected then static postural control (Hass, Waddell, Fleming, Juncos, & Gregor, 2005).

Another study evaluated the multiple components of function, including posture, in PD patients. Utilizing computerized dynamic posturography, more specifically the Sensory Organization Test, Nallegowda and colleagues found impaired proprioception, smaller base of support, and visual discrepancies. They concluded that these components of function were the main causes for postural instability in PD patients (Nallegowda et al., 2004). In addition to evaluation of balance the Nallegowda study found quantitative reductions in the muscular strength of the spine, hip, and ankle which were also attributed the postural instability.

Similarly, researchers evaluated postural instability of 50 patients with advanced PD, again using computerized dynamic posturography (Bronte-Stewart, Minn, Rodrigues, Buckley, & Nashner, 2002). Much like the previous studies, they found that the majority of participants had an underlying pathophysiological mechanism responsible for dysfunctional postural control and faulty balance mechanisms.

Muscular Strength in Individuals with Parkinson's Disease

Muscular fitness, including muscular strength, is a key component to overall health and has been documented as deficient in individuals with PD (Brown, Corcos, & Rothwell, 1997; Inkster et al., 2003). This vital aspect of health is important for integrity of both tendons and muscles, which is related to falls and other associated risk of injuries. Likewise, increase muscular strength (i.e. greater lean muscle mass) is important for resting metabolic rate, which is negatively correlated to weight gain and obesity. Lastly, the work capacity of the large muscles, particularly in the lower extremity, are directly related to an individual's ability to perform activities of daily living (Reuter, Engelhardt, Stecker, & Baas, 1999).

As mentioned previously a reduction of muscular strength was shown to cause postural instability and a decrease in overall function (Nallegowda et al., 2004). Other studies evaluating

strength in PD have found similar results. For example Inkster and colleagues (Inkster et al., 2003) evaluated leg muscle strength, as it relates to the ability to rise from a chair, in individuals with PD. They found mean hip and knee extensor torques to be lower in individuals with PD when compared to age and sex matched non-PD participants. They concluded that this reduction in strength might be a factor that contributes to the difficulty of persons with PD to rise from a seated position.

This was also apparent in a study by Paasuke and colleagues who reported evaluated lower limb production in individuals with PD and found lower maximal isometric force and rate of force production compared with healthy controls (Paasuke, Mottus, Ereline, Gapeyeva, & Taba, 2002).

Diagnosis of Parkinson's Disease

Due to the fact the underlying cause of PD is unknown, the process of making a PD diagnosis can be difficult. A definite diagnosis of PD requires an autopsy (Samii et al., 2004). Most often blood tests and brain scans known as magnetic resonance imaging are performed to rule out other conditions that have similar symptoms. Following this a physician, usually a neurologist, arrives at the diagnosis after a thorough examination relying heavily on history, physical examination, and improvement of symptoms with a dopaminergic treatment, such as levodopa (Samii et al., 2004).

Assessment Tools

Following diagnosis there are two primary scales that describe and categorize the degree to which an individual is affect by PD. The first scale was developed at Columbia University by Dr. Margret Hoehn and Dr. Melvin Yahr (Appendix A). The Hoehn and Yahr Staging of Parkinson's Disease is a clinician-rated scale based on general findings of a neurological

examination relating to functional ability, balance, and independence. The test categorizes levels of PD affliction based on a scale from 1-5 with 1 identifying the mildest stage of the disease (Hoehn & Yahr, 2001).

An additional assessment tool for PD is the Unified Parkinson's Disease Rating Scale or UPDRS (Appendix B). The UPDRS is a clinician-rated scale with structured interview and examination. The scale utilizes four sections to describe the stage of the disease (stages 1-5, with 5 being the most severe). The first section covers behavior and mood (intellectual impairment, thought disorder, depression, and motivation and initiative). The second section covers the history of activities of daily living [speech, salivation, swallowing, handwriting, ability to cut up food and use utensils, dressing, self-hygiene, turning in bed and adjusting bed clothes, falling (unrelated to freezing), freezing when walking, ambulation, tremor, and sensory complaints related to Parkinson's]. The third section is a more formal motor examination (speech, facial expression, tremor at rest, action or postural tremor, rigidity, finger tapping, hand movements, rapid alternating movements, leg agility, getting up from a chair, posture, gait, postural stability, body bradykinesia or hypokinesia). Where relevant these motor features are examined and recorded separately for each limb. And finally, the fourth section details the history of complications related to treatment (Fahn & Elton, 1987).

Treatments

Types of treatments for PD include: surgery, drug therapy, and exercise interventions or a combination of the above.

Drug Therapy

Medications for PD fall into three categories. First, those that work directly or indirectly to increase the level of dopamine in the brain. The most common of these include levadopa.

The second category of drugs includes those that affect other neurotransmitters in the body in an effort to reduce symptoms of the disease. An example of these drugs include anticholinergic drugs that alter the ratio of acteylcholine to dopamine resulting in reduce tremors and muscle stiffness. The third and final type of medication for PD includes medications that treat the non-motor symptoms of the disease, for example antidepressants (NINDS, 2004).

Surgical Treatments

Currently there are two surgical treatments for PD, pallidotomy and deep brain stimulation (DBS). Due to risks involved with an invasive surgical procedure, these treatments are usually reserved for those who are severely affected and unresponsive to drug treatment. Pallidotomy, one early form of surgery for PD, involves destroying parts of the brain that are "misfiring" namely parts of the basal ganglia (NINDS, 2004). By destroying these parts of the brain, some symptoms of the disease are alleviated, however, often times this leads to irreversible complications.

More recently, scientists have found that they can mimic the effects of pallidotomy through DBS. DBS involves electrode implantation in one or two sides of the brain. Impulses from the stimulators interfere with, and 'blocks', the brain signals that cause PD symptoms (NINDS, 2004). Unlike pallidotomy the effects of DBS are reversible because the electrodes can be turned off if the patient experiences problems. In addition, the stimulation can be adjusted to match the individuals' needs.

Exercise Interventions

A wide variety of complementary and supportive therapies, including exercise interventions, have been used to benefit those with PD. Among these are standard rehabilitation techniques used to improve gait, decrease tremor and rigidity, as well as assisting with limiting

cognitive decline. Additionally, exercise is often used to improve mobility, increase muscular strength, as well as improving range of motion and balance while concurrently improving overall function.

A number of studies have demonstrated the benefits on physical function following programs of general exercise. Toole and colleagues evaluated a 10-week balance and strength training program on equilibrium as measures by the NeuroCom EquiTest (Toole, Hirsch, Forkink, Lehman, & Maitland, 2000). They found that the program produced positive changes in equilibrium on two controlling mechanisms. The first mechanisms that training altered was the ability to control the motor system when vestibular cues were the primary source of reliable feedback. Secondly, they concluded that training helped subjects override faulty proprioceptive feedback and utilize reliable visual or vestibular cues.

A similar study evaluated the use of resistance training program on gait function in individuals with PD (Scandalis et al., 2001). This study concluded not only that the resistance training program increased strength, stride length, and walking velocity in individuals with PD but also that the gains seen in the PD population were similar to that of the non-PD controls.

Another study conducted by Ellis conducted an additional study examining the effect of therapeutic interventions on individuals with PD (Ellis et al., 2005). This study, conducted in a physical therapy setting, used strengthening exercises, functional training, and gait training on individuals with PD. Following the intervention, they found increases in mobility, walking speed, and activities of daily living.

Exercise interventions have proven to benefit individuals with PD as measured by overall physical function. However, much of these therapies previously discussed were conducted in a laboratory, health facility, or physical therapy setting. With the difficulties associated with this

disease (i.e. health care and medication cost as well as and travel limitations) these types of interventions may not be accessible to all individuals living with PD. Therefore it is hypothesized a well designed home-based exercise intervention can be designed in an effort to allow for accessibility of all PD patients as well as demonstrate improvements in overall physical function.

Utilization of Closed Chain Exercise to Promote Increased Function

The proposed exercise intervention will consists mainly of closed chain exercise. Closed chain exercises are those in which the distal segment is restrained in its movement such as with a squat. This type of exercise is often utilized in rehabilitation because of its more functional, weight bearing approach (Shields et al., 2005). The following is a brief presentation of the neural mechanisms that may underscore the positive effects of a closed chain therapy on strength, motor function, gait and balance of individuals with PD. In addition to being more functional closed chain exercise are believed to minimize stress on a joint through joint compression and agonist/antagonist co-contraction. Joint compression models have indeed shown increased joint compression resulting in decreased antero-posterior translation (More et al., 1993). Additionally, closed chain exercises have been shown to increase co-contraction therefore increasing joint stabilization (Toutoungi, Lu, Leardini, Catani, & O'Connor, 2000). These exercises mimic 'real' everyday body movements in that they are depended on multiple joints and muscle group. For example, when the squat exercise is initiated from the straight leg position with the feet on the floor, afferent information is generated within the knee extensors and forwarded to the hamstrings essentially commanding the knee joint flexors to contract more forcefully than if there was no ground base. Due to the fact these weight bearing exercises result in joint approximation there is stimulation of joint mechanoreceptors that provide proprioceptive

information to the joint. In this context, contraction is manipulated through the specific movement and is vital for promoting dynamic stability and overall function. During rehabilitation, it seems reasonable to suggest that closed chain exercises can re-establish coordination among muscle groups and therefore increase motor function and strength, which is essential to functional balance and gait via an increase in neuromuscular control.

Evaluation of Function and Balance

In order to evaluate the overall function in individuals with PD NeuroCom EquiTest SOT protocol will be utilized. Posture, stability, and overall balance are important components in movement, mobility, and acts of daily living. In the PD population problems with both postural stability and balance become increasingly problematic as the disease progresses and have been well documented (Adkin, Frank, & Jog, 2003). As such, body sway and overall stability can be assessed quantitatively by using the computerized NeuroCom EquiTest SOT test for the isolating sensory and motor components of balance in standing humans (NeuroCom, 2001). In addition to balance measurements taken with the NeuroCom EquiTest SOT a Functional Limitations Assessment was undertaken to quantify the participant's ability to safely and efficiently perform mobility tasks common in daily life, these tasks include: Sit-to-Stand, Step Up/Over, and Walk Across.

Evaluation of Strength

As discussed muscle dysfunction or weakness can be a limiting factor in the movement and gait in individuals with PD. Reductions in muscular strength are a common characteristic in the progression of PD and may also lead to deficits in neuromuscular coordination, balance, and therefore precipitate difficulties in ambulation and increase susceptibility to falls. In order to

measure work capacity of the lower extremity, isokinetic strength assessments will be utilized to determine an individual's ability to produce force

Summary

The symptoms generally associated with PD include; tremor, muscle rigidity, bradykinesia, muscle weakness, postural instability, and depression. Treatment for PD includes the use of medication, surgical intervention, and exercise interventions. Exercise interventions are used to increase functional performance measures such as strength and balance in an attempt to improve quality of life and independence. Many exercise interventions have been successful but are problematic because of travel limitations and other problems associated with the disease. It was hypothesized a home-based, exercise intervention would allow for improvements in function while concurrently being accessible to all individuals with PD.

CHAPTER III

METHODS

This chapter examines the methods and procedures that were used in this study. The chapter outlines the participants, setting, equipment and instrumentation, variables, data collection procedures, data analysis, and human subject concerns.

Participants

Ten participants, categorized at Stage I-III of the Hoehn and Yahr scale by a neurologist, and ten non-PD, age matched controls served as participants for this study. The participants with PD were identified through the Athens Parkinson Support Group. The controls were recruited through other community organizations. Dr. Marta Trieschmann of Athens Neurological Associates was the primary care physician for participants with PD. Individuals with fluctuating responses to medication, functionally disabling dyskinesia or dystonia, pre-existing lung disease, history of cardiac disease, psychiatric illness, dementia, depression and major neurological musculoskeletal or metabolic disorders were excluded from the study. Effects for medication were controlled by requiring the PD participants to be tested and exercised two hours past medicine ingestion and within the same relative temporal period of their drug cycle (Ramsey, Miszko, & Horvat, 2004). Participants received an orientation of the testing and exercise protocol (excluding control) and signed consent forms in conjunction with the standards approved by the Institutional Review Board at The University of Georgia.

Setting

The University of Georgia Movement Studies Laboratory was utilized for all data collection and also was utilized for demonstration and teaching of all exercises that were carried out during the intervention. The exercise intervention took place in the participants own home.

Instrumentation and Equipment

The investigation focused on balance, functional tasks, and strength which were evaluated using the following: 1) NeuroCom EquiTest SOT, 2) NeuroCom EquiTest- Functional Limitations Assessment {Sit-to-Stand, Step Up/Over, Walk Across} 3) HumacNorm Isokinetic Dynamometer for lower body muscle strength.

NeuroCom EquiTest Sensory Organization Test

The outcome measures of stability and balance are important components of posture and mobility. In PD difficulty with posture and balance is apparent and becomes increasingly severe as the disease progresses and have been well documented (Abrams, 2001; Adkin et al.,2003). As such, overall balance was assessed quantitatively by using the computerized posturography on the NeuroCom EquiTest system. The NeuroCom EquiTest is composed of a moveable forceplate on which the participants stand and a moveable surrounding visual screen in which the participants stand within. Both the force plate and surrounding screen rotate about an axis close to that of the ankle joint. The forceplate is equipped with strain gauges to measure anteroposterior sway and center of gravity position. A standardized NeuroCom EquiTest assessment protocol, the SOT, was utilized to evaluate the participants balance.

The SOT protocol requires participants to be tested under six independent sensory conditions. Each condition has three trials each lasting 20 seconds. During the assessment, somatosensory and visual environments are altered systematically and the participant's responses

are measured and recorded. Visual and proprioceptive information is altered by 'sway referencing' the surrounding screen and the forceplate. Sway referencing refers to the forceplate and/or the surrounding screen moving proportionally to the anteroposterior sway of the participant thus altering their visual and proprioceptive feedback (See Table 3.1 for the sensory component of each condition). For example, if the anteroposterior sway of the participant in condition 3 was to move 2 degrees the surrounding screen would move 2 degrees in the same direction while the forceplate would remain fixed. In this example, the visual field is inaccurate therefore requiring the participant to rely on vestibular and proprioceptive information. Similarly, if the anteroposterior sway of the participant in condition 5 was 2 degrees the forceplate would move 2 degrees while the surrounding screen would remain fixed. In this condition, the participants eyes are closed therefore suppressing the visual field. Additionally, the force plate is moving or sway referenced therefore giving the participant inaccurate proprioceptive information. Taken together both the suppressed visual field and the inaccurate proprioceptive information require the participant to rely solely on vestibular information. The remaining conditions are as followed:

1. Eyes open, force plate and surrounding screen fixed
2. Eyes closed, force plate and surrounding screen fixed
3. Eyes open, force plate fixed, surrounding screen sway referenced
4. Eyes open, force plate sway referenced, surrounding screen fixed
5. Eyes closed, force plate sway referenced, surrounding screen fixed
6. Eyes open, force plate and surrounding screen sway referenced

Table 3.1: Summary of Sensory Information for the SOT

	Sensory Information		
SOT condition	Accurate	Inaccurate	Eyes Closed
1	Vest, Vis, Pro	N/A	
2	Vest, Pro	N/A	√
3	Vest, Pro	Vis	
4	Vest, Vis	Pro	
5	Vest	Pro	√
6	Vest	Vis, Pro	

Abbreviations: Vest=Vestibular, Vis=Vision, Pro=Proprioception

Scoring for the NeuroCom EquiTest SOT is determined by comparing the participant's anteroposterior sway to a theoretical sway stability limit of 12.5 degrees (NeuroCom, 2001). The resulting scores range for 0-100 with 100 indicating no anteroposterior sway. In addition, to the equilibrium score provided for each condition a composite score, based on all six conditions, is calculated. Scores on the composite range from 0-100, with 100 being the highest. The SOT has been found to be a reliable tool for detecting instability in older adults and identifying individuals who are at risks for falling by detecting changes in six sensory conditions (Ford-Smith, Wyman, Elswick, Fernandez, & Newton, 1995).

Based on previous research conditions 4-6 (Composite 4•5•6) will be combined to create a single summary balance score. This summary score is created as an indicator of performance under the most difficult test conditions when the support surface is sway-referenced and visual cues are misleading or absent (Hirsch et al., 2003; Toole et al., 2000).

NeuroCom EqiuTest Functional Limitations Assessment

Additional assessments were utilized to quantify the participant's ability to safely and efficiently perform mobility tasks common in daily life (See Table 3.2). This was done utilizing the NeuroCom Equitest Functional Limitations Assessment on a long forceplate. The forceplate measures 18" x 60" and contains four load cells that measure movement symmetry, variation, force production, movement timing, and distance measures (NeuroCom, 2001). The functional test include the Sit-to-Stand, Step Up/Over , and theWalk Across. These measurements are designed 'to quantify limitations in performance of functional tasks resulting from deficits in lower extremity weight distribution, range of motion and motor control, balance and sensory interpretation' (NeuroCom, 2001).

Sit to Stand

Rising from a chair is a physically demanding function that is a common problem in aging, particularly in individual with PD. Brod and colleagues (Brod, Mendelsohn, & Roberts, 1998) found that 81% of individuals with PD self reported having difficulty standing from a seated position. In order to complete this task individuals must have adequate lower body strength and exhibit the ability to control their center of gravity as it shifts from an initial position over the seat to a location centered over the base of support (feet). The test is indicative of the individuals' ability to generate force from a seated position and control the movement once a standing position is achieved. The outcome measures from this assessment include:

1. Weight Transfer- The time in seconds required to voluntary shift the center of gravity forward beginning in the seated position and ending with full weight bearing on the feet.

2. Rising Index- The amount of force exerted by the legs during the rising phase. The force is expressed as a percentage of the patient's body weight.
3. Sway Velocity- Documents control of the center of gravity over the base of support (feet) during the rising phase and for 5 seconds thereafter. Sway is expressed in degrees per second.

Step Up/Over

The ability to avoid and negotiate obstacles in the environment during locomotion is a critical component of overall mobility. This test quantifies the motor control characteristics as an individual steps up with one foot, lifting the body through an erect standing position, swings the other foot over, and then lowers the body to land the swing leg on the force plate. Outcome measurements include:

1. Lift-up Index- Quantifies the maximal lifting force exerted by the leading leg and is expressed as a percentage of the individual's weight.
2. Movement Time- Quantifies the number of seconds required to complete the maneuver, beginning with the initial weight shift to the non-stepping leg and impact of the lagging leg onto the force plate.
3. Impact Index- Quantifies the maximum vertical impact force as the lagging leg lands on the force plate, expressed as a percent of body weight.

Walk Across

One of the greatest difficulties experinced in individuals with PD is overall mobility and gait. This is especially apparent as the disease progresses increasing the risk of falling and decreasing overall mobility (Hass et al., 2005; Sofuwa et al., 2005). The Walk Across provides measurement characteristics of gait as an individuals walks across the length of the forceplate.

The test allows for a measurement of steady state gait by having the patient begin walking 10 feet in front of and continuing beyond the force plate. This measure has been used to predict functional limitations in daily life activities (NeuroCom, 2001).

The outcome measures from this assessment include:

1. Step Width- Lateral distance in centimeters between the left and right feet on successive steps.
2. Step Length- Longitudinal distance in centimeters between successive heel strikes on successive steps
3. Speed- Velocity in centimeters per second of the forward progression

HumacNorm Isokinetic Dynamometer

The ability to generate muscle force is required to maintain postural stability, as well as for stabilizing and propelling the body during all phases of locomotion. In order to evaluate the lower extremity strength in this study isokinetic testing was utilizing the HumacNorm Isokinetic Dynamometer. Isokinetics testing provides variable resistance during a movement at a consistent preset speed with the assistance of specialized equipment, in this case a HumacNorm. Isokinetics testing allows for isolation of the muscles about the knee to gather performance data from the participants while allowing for maximal muscle contraction throughout the full range of motion (Gulick, Chiappa, Crowley, Schade, & Wescott, 1998). Measurements taken included peak torque, power, and total work. For this project concentric peak torque of the knee flexors and extensors at 90 and 180 degrees/second of the dominant leg was utilized as per Kramer (Kramer, 1990). Isokinetic testing has been shown to be a safe, reliable, and valid measure of muscle strength (Gulick, Chiappa, Crowley, Schade, & Wescott, 1997). Additionally, Ly and Handelsman (2002) determined that isokinetic dynamometry is suitable for testing muscle

strength and evaluating therapeutic effects in an older population. The outcome measures are as followed:

1. Concentric peak torque of the knee flexors/extensors at 90 degrees/second
2. Concentric peak torque of the knee flexors/extensors at 180 degrees/second

Summary of Dependent Variables

The following dependent variables were analyzed in this study to document the effects of a 10-week home based exercise intervention on function in the PD population:

- Composite 4•5•6 score derived from the NeuroCom EquiTest SOT
- The NeuroCom EquiTest Functional Limitations Assessment measures which includes the outcomes listed in Table 3.2
- HumacNorm Isokinetic Dynamometer -concentric peak torque of the knee flexors and extensors at 90 and 180 degrees/second of the dominant leg

Table 3.2: NeuroCom EquiTest- Functional Limitations Assessment

Test	Population	Outcome measure	Deficits Addressed
Sit-to-Stand	1) Geriatric 2) Movement Disorders/GVA	1) Weight Transfer 2) Rising Index 3) Sway Velocity	1) Lateral and front/back weight control
Step Up/Over	1) All mobility impaired patients 2) Orthopedics	1) Lift-up Index 2) Movement Time 3) Impact Index	1) Strength 2) Motor Control 3) Safety
Walk Across	1) Geriatric 2) Movement disorders	1) Step Width 2) Step Length 3) Speed	1) Motor Control 2) Balance 3) Safety

Data Collection Procedures

Data collection and procedures were explained to all participants and an informed consent form was signed prior to all data collection. Additionally, prior to beginning any portion of this study PD participants were evaluated and categorized in Stages I-III of the Hoehn and Yahr Scale; indicating the level of involvement which was confirmed by the primary care physician who also cleared the participant for the intervention.

Assessment Procedures

NeuroCom EquiTest Sensory Organization Test

Each participant was fitted for a safety harness which consists of shoulder, waist, and thigh straps. Once placed in the NeuroCom EquiTest device the safety harness were connected to an overhead safety bar to prevent injury should the participant fall. Following this, the participant's medial malleoli of each foot was centered on the platform base. Next the safety straps were adjusted to allow the participants to move freely without gaining support but tight enough to break a fall. Instruction were given throughout testing regarding eyes closed or open depending upon the condition. For conditions 1, 3, 4, and 6 participant's were informed to stand as still as possible with their eyes open, while in conditions 2 and 5 required the participants were instructed to stand as still as possible with their eyes closed. Each condition had 3 trials lasting 20 seconds each.

NeuroCom EquiTest Functional Limitations Assessment

Sit to Stand- Participants were seated on a 17" box placed on the forceplate. The participants were then instructed to "Go" with an audible prompt. They then stood up from the seated position without use of their upper body and remained still until the test ended (< 5 seconds after they reached a standing position). Three trails were performed.

Step Up/Over- Participants stood on the force plate with an 8 inch box in front of them. They were then instructed to "Go", with an audible prompt. Following this the participants stepped up onto the box with their dominant foot, lifted the opposite foot over the box and onto the forceplate. They then brought the dominant foot down on the forceplate stood as steadily as possible for 5 seconds. Three trails were performed.

Walk Across- Participants were positioned ten feet in front of the forceplate. They were then be instructed to "Go", with an audible prompt. The participant proceeded to walk across the forceplate and continue five feet beyond the forceplate. Three trails were performed.

HumacNorm Isokinetic Dynamometer

Participants were seated on the dynamometer and secured by chest and leg hook-and-loop straps according to manufactures recommendations. The axis of rotation of the machine was aligned to the knee joint. The distal pad of the dynamometer arm was placed proximal to the malleoli. Prior to the test beginning participants extended their limb to allow for the weight to be corrected for gravity according to the gravity correction protocol. Peak torque values were recorded in Newton-meters (Nm) at angular velocities of 90 and 180 deg/sec. Participants were allowed 3-5 practice repetitions at each speed to become familiar with the procedures (Dvir, 1995). Participants then performed a maximal effort contraction of the quadriceps (knee extension) followed by a maximal effort of the hamstrings (knee flexion) for 6 continuous repetitions at 90 deg/sec and 180 deg/sec. A two-min rest period was given between each test velocity to minimize the effect of fatigue on torque production. Participants were instructed to push or pull as fast as possible using strong verbal encouragement ("push fast and hard" or "pull

fast and hard") during the test procedures. Peak torque was identified as the highest recorded value among the repetitions.

Exercise Intervention

The exercise protocol was self-administered 4 days/week for 10 weeks in the participants' residence. Prior to the exercise all participants attended a familiarization session in the Movement Studies Laboratory and were instructed on the proper form mechanics of all exercises. Also during this meeting, participants executed exercises to insure proper form and understanding of exercises. In addition participants were given a take-home folder illustrating the proper form of all exercises as well as data recording procedures (Appendix E). This folder also served as a way for each participant to track their progress by writing down the number of reps complete for each workout. Participants were instructed to warm-up prior to exercise and to complete as many reps as possible in 30 seconds. Additionally they were instructed to rest for two minutes in between each exercise. Exercises sessions were supervised via telephone with each participant (Cox, Bennett, & Dudley, 1986; Bickel, 2005).The exercises consisted of the following:

- Abdominal crunch
- Wall squats
- Lunges
- Standing calf raises
- Knee flexion
- Seated knee extension
- Step-ups (6" box)

Data Analysis

This study was designed to study the effects of a home based exercise intervention on individuals with PD. Statistical analyses was selected to detect group differences as well as time differences, on a battery of tasks utilizing a NeuroCom EquiTest SOT protocol, NeuroCom EquiTest Functional Limitations Assessment (Sit-to-Stand, Step Up/Over, Walk Across,), and the HumacNorm isokinetic dynamometer for strength assessment. The research design was a pretest-post test design. Because the units were not randomly assigned the pretest data was utilized to take into account or 'adjust' for the initial differences that may have existed among the units on the pretest variable (Huberty & Olejnik, 2006). All analyses were conducted using SPSS® version 14.0 software.

The NeuroCom EquiTest accounted for differences in weight all measures (SOT, Sit-to-Stand, Ste Up/Over, Walk Across,) by displaying the weight values as a percentage of body weight. All strength values on the HumacNorm Isokinetic Dynamometer were collected and reported as a percentage of the participants' body weight as well. These steps were taken to allow values from both male and female participants to be compared. Descriptive statistics (e.g., means, standard deviations) were calculated for all variables of interest. Both multivariate analysis of variance (MANOVA) and multivariate analysis of covariance (MANCOVA) were utilized to evaluate differences among variables.

The MANOVA approach was utilized based on its capacity reduces the problems associated with the violations of assumption. The MANOVA treats the repeated measures as multiple dependent variables therefore allowing for a multivariate significance tests to evaluate to the treatment effects. The assumptions required for this are equality of the variance-covariance matrices between groups. However, the within-subjects effects of Time and Time x

Group require no sphericity assumption. Often times a MANOVA deals with more then one dependent variable at the same time, however, the MANOVA can still be utilized with one dependent variable. The multiple dependent variables are the repeated measures i.e. pre and post test. Therefore a structured MANOVA amounts to two analysis of variance (ANOVA) models where the first analysis yields the between-subjects and the second analysis yields the within subject analysis. The strengths and weaknesses for this design are outlined:

Strengths:

- Common subject pool is more economical and allows for partitioning therefore decreasing the error term
- The assumptions are not as strict as the univariate ANOVA
- Can be used to examine several distinct dependent variables to show differences among groups (Kappel, 2004).

Weaknesses:

- Because it a pre/post test design sequence effects and practice effects may be encountered
- Exhibits relatively low power when the sphericity assumption is valid (Everitt, 1995).
- Not sensitive to assumptions violations when the groups are not equal

An additional design that was utilized in this research is a MANCOVA. Utilizing an MANCOVA in this design allowed for the pretest score to be utilized as a covariate and post test as the dependent variable (O'Brian, 1985). Additional covariates were utilized as per previous research to control for factors that account for variation in the outcome not due to the dependent variables. These covariates included duration of PD, age at initial diagnosis, and number of fall during the SOT (Conditions 4-6). This allows for a reduced error in variance and elimination of

systematic bias. Therefore, variations in base-line measurements are taken into account by using the mean of the base-line value for each subject as a covariate in a linear model for the comparison of post-treatment means (Everitt, 1995). In regard to the previously discussed MANOVA, the MANCOVA is really a MANOVA performed on the adjusted dependent variable score. This analysis tests whether the change between pre and post tests is zero, 'conditional' on the initial values of the groups on the pretest (Bijleveld, 1998). This particular design is attractive for nonrandomized because post test means for differences among groups on pretest scores are likely to occur with intact groups, such as with the PD group. Obviously this is beneficial because when the pretest scores are not reliable the treatment effect can be seriously biased. The assumptions for MANCOVA include a linear relationship between pretest and post test and homogeneity of regression slopes. The strengths and weaknesses for this design are outlined:

Strengths:

- In a pretest-post test design an MANCOVA will remove any bias in the dependent variable means caused by chance group differences
- Try's to explain part of the "unexplained" variability in terms of a covariate, for example pretest score.
- When the regression slope does not equal 1, which is common, MANCOVA is a more powerful test then MANOVA on gained scores.
- If there is no linear relationship between pre and post test MANCOVA can include a quadratic or cubic component (Dimiter, 2003).
- Statistically controls the within group variance allowing for greater precision of the test. Therefore this tests adjusts the within group variance and also

statistically equates the groups with regard to initial pretest which is essential for non-randomized studies.

Weakness:

- Pretest differences (systematic bias) between groups can affect the interpretations of post test differences.

Sensory Organization Test

This analysis had two groups of subjects (PD and non-PD), measured on one variable (Composite 4•5•6) at two different time points (pre and post). Since there was only two time points the sphericity assumption waas not violated (Bijleveld, 1998) therefore, a repeated measures MANCOVA was utilized. This allowed for inspection of group and time changes as well as the analysis of group x time for evaluation of group change. Therefore the design for the SOT for balance was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measure of interest was the Composite 4•5•6 score from the SOT.

The ANCOVA was deemed important based on the prior research which indicates high levels of variability in persons with PD on balance and strength measures. Therefore, an effort was made to control for the factors that account for variation in the outcome not due to balance. The covariates selected included age at initial diagnosis, disease duration, and number of falls during conditions 4-6. These covariates were chosen based on empirical evidence that has shown: 1) deterioration of balance and strength in individuals who are older at the onset of PD (Hirsch et al., 2003), 2) longer disease duration is associated with increased risk of falling (Hirsch et al., 2003; Toole, Park, Hirsch, Lehman, & Maitland, 1996), and 3) frequency of falls

seen in the NeuroCom EquiTest SOT in individuals with limited lower extremity muscle strength (Schenkman & Butler, 1989).

Sit-to-Stand

This analysis had two groups of subjects (PD and non-PD), measured on three variables (Weight Transfer, Rising Index, Sway Velocity) at two different time points (pre and post). Because there were multiple dependent variables a repeated measures MANCOVA was utilized. Since there were only two time points the sphericity assumption was not a factor. The design for the Sit-to-Stand was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measure of interest were Weight Transfer, Rising Index, and Sway Velocity.

The reason for running a MANCOVA and avoiding running multiple univariate ANCOVA's, was due to the fact when multiple dependent variables are added to the model the tests more accurately reflects the multivariate reality that the research is trying to model (Liu, 2002). Also, the three variables measured in the Sit-to-Stand are closely related a more accurate depiction of what is occurring can be measured with all variables in the model. Additionally, since the different variables may be correlated with each other, there would be no way of knowing which of the ANCOVA results gave new and independent information about the hypothesis and which univariate ANCOVA was redundant with one or more of the analysis (Bijleveld, 1998). Lastly, the problem with running separate univariate ANCOVAs with a more critical significance level ($\alpha = 0.05/T$) there would be a reduction the power (Bijleveld, 1998). Therefore, in this case the MANCOVA method was utilized to allow for detection of groups differences along a combination of variables (Field, 2000).

Step Up/Over

This analysis had two groups of subjects (PD and non-PD), measured on three variables (Lift-up Index, Movement Time, and Impact Index) at two different time points (pre and post). Again because there were multiple dependent variables a repeated measure MANCOVA was utilized for the same reasons as previously stated. The design for the step up/over was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measures of interest were Lift-up Index, Movement Time, and Impact Index.

Walk Across

This analysis had two groups of subjects (PD and non-PD), measured on three variables (Step Width, Step Length,Speed) at two different time points (pre and post). Again, since there was only two time points the sphericity assumption was not a problem. Because there are multiple dependent variables a repeated measures MANCOVA was utilized for the same reasons listed above. The design for the Walk Across was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measures of interest were Step Width, Step Length, and Speed.

Isokinetic Strength

This analysis had two groups of subjects (PD and non-PD), measured on four variables (peak torque knee flexion and extension at 90 degree/second and peak torque knee flexion and extension at 180 degrees/second.) at two different time points (pre and post). Therefore a repeated measures MANCOVA was utilized like the previously discussed models. The design for the isokinetic strength was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measure of interest were knee flexion and extension at 90 degree/second and knee flexion and extension at 180 degrees/second.

Human Subject Concerns

Stretching and warm-up procedures were strictly followed. The data including identifiers pertaining to each participant remained confidential, with only the researchers having access to the information. The data was stored on the computers in the Movement Studies Laboratory at The University of Georgia. All data was removed at the conclusion of the study. The participants obtained a functional task evaluation and lower body strength assessment. Each obtained their individual balance, functional task and strength assessment scores and how they scored in relation to age-related norms. Prior to beginning any aspect of the study participants received verbal explanation of the protocols and signed consent forms in accordance with the Institutional Review Board procedures and ethical standards set forth by The University of Georgia Institutional Review Board.

CHAPTER IV

RESULTS

The research design utilized repeated measures to assess the benefits of a home-based exercise intervention on balance (SOT), functional performance measures (Sit-to-Stand, Step Up/Over, Walk Across) and lower extremity strength (isokinetic dynamometry) in individuals with PD. A non-exercised, non-PD control groups was utilized to control for the learning effect of repeated testing. The statistical analysis for this study are presented in this chapter. Means and standard deviations are reported on the balance, performance measures, and strength. MANCOVA and MANOVA were used to identify differences between the PD and the non-PD control group as well as from pre to posttest. The assumption of independence was addressed by having each participant tested individually without any other participants being present during data collection. Box's test for equality of the covariance matrices was utilized although the present design was balanced therefore minimizing the threat to statistical validity for that hypotheses tests. Additionally, Mauchly's test for sphericity was ignored based on the fact this design utilized only two time points (pre and post) therefore limiting the threat of non-sphericity.

Definition of Statistical Terms

Box's M – Indices used to test for violation of the assumption of homogeneity of covariance (Norusis, 1988).

Effect Size - "The magnitude of an independents variable's effect, usually expressed as a proportion of explained variance in the dependent variables (Weinfurt, 2000 p. 274)."

Wilks' Lambda – "A multivariate statistic that expresses the proportion of unexplained variance in the dependent measures (Weinfurt, 2000 p. 274)."

Demographics

A convenience sample (N=8) composed of individuals with PD participated in this study. A non-exercised, age matched, control group (N=8) composed of individuals without PD were utilized to control for the learning effect of repeated testing. Two PD participants were unable to complete the exercise intervention and therefore were not included in analysis. Additionally, two non-PD controls were unable to attend posttesting. Means and standard deviations of participant demographic are calculated and are included in Table 4.1 for both groups.

Table 4.1: Participant Demographics

Group	Age (Mean ± SD)	Height (in) (Mean ± SD)	Weight (kg) (Mean ± SD)	BMI (Mean ± SD)
PD	74.50 ± 8.04	68.13 ± 2.75	77.57 ± 8.72	25.80 ± 2.31
non-PD	71.00± 5.95	67.75 ± 4.95	78.35 ± 16.20	25.54 ± 2.97

PD = Parkinson's disease
non-PD = non-Parkinson's disease

A MANOVA was performed to determine significance group differences on the three demographic measures [age, height, weight and body mass index (BMI)]. Box's test indicated that the covariance matrices of the dependent variables were equal across groups, $M = 13.28$, $F(10, 937.05) = 0.906$, $P = 0.527$. The MANOVA yielded no significant differences between groups Wilks = 0.864, $F(4, 11) = 0.434$, $P = 0.782$ on any of the demographic characteristics.

NeuroCom EquiTest Sensory Organization Test

Balance was assessed using the NeuroCom EquiTest SOT. This test was performed by all participants during both pre and post-testing. During the assessment, somatosensory and

visual environments were altered systematically and the participant's responses were measured and recorded. Visual and proprioceptive information is altered by 'sway referencing' the surrounding screen and the force plate. Sway referencing refers to the force plate and/or the surrounding screen moving proportionally to the anteroposterior sway of the participant thus altering their visual and proprioceptive feedback. The test required participants to be tested under six independent sensory conditions (see Table 3.1 for description of each). Each condition had three trials each lasting 20 seconds. Averages for each are presented in Table 4.2.

Table 4.2: Averages for the NeuroCom SOT (Mean ± SD)

	PD		non-PD	
	Pre	*Post*	*Pre*	*Post*
Condition 1	91.04 ± 3.81	92.04 ±1 .85	94.71 ± 1.13	94.30 ± 1.29
Condition 2	89.91 ± 3.70	90.58 ± 3.81	91.38 ± 2.28	91.30 ± 2.61
Condition 3	90.58 ± 4.05	91.71 ± 1.92	92.46 ± 3.49	92.52 ± 2.78
Condition 4	60.37 ± 11.89	80.00 ± 4.70	74.29 ± 12.12	76.71 ± 8.41
Condition 5	41.59 ± 10.16	54.21 ± 16.05	50.33 ± 15.83	53.66 ± 8.80
Condition 6	50.00 ± 3.57	55.83 ± 14.42	56.88 ± 12.27	62.76 ± 6.54
Composite 4•5•6	50.65 ± 5.81	63.35 ± 9.69	60.50 ± 11.41	64.38 ± 5.69

Previous research has shown conditions 4-6 to be highly correlated (Hirsch et al., 2003; Toole et al., 2000; Toole et al., 1996). Therefore, in accordance with Hirsch et al. (2003) conditions 4-6 (Composite 4•5•6) were combined to create a single summary balance score. This summary score was created as an indicator of performance under the most difficult test conditions when the support surface is sway-referenced and visual cues are misleading or absent and has been shown to be an accurate indicator of balance in the PD population (Hirsch et al., 2003; Toole et al., 2000). Therefore the design for the SOT for balance was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measure of interest was the Composite 4•5•6 score from the SOT.

A repeated measures MANCOVA on Composite 4•5•6 was utilized to evaluate group differences from pre to post-testing. The MANCOVA was deemed important based on the prior research which indicates high levels of variability in persons with PD on balance and strength measures (Hirsch et al., 2003). Therefore, an effort was made to control for factors that account for variation in the outcome not due to balance. The covariates selected included age at initial diagnosis, disease duration, and number of falls during conditions 4-5. These covariates were chosen based on previous research that has demonstrated: 1) deterioration of balance and strength in individuals who are older at the onset of PD (Hirsch et al., 2003), 2) longer disease duration is associated with increased risk of falling (Hirsch et al., 2003; Toole et al., 1996), and 3) frequency of falls on the SOT in individuals with limited lower extremity muscle strength (Schenkman & Butler, 1989).

The test for the interaction between the grouping variable (PD and non-PD) and the repeated-measure variable provided evidence to indicate that the pre to post test measures on Composite 4•5•6 were significantly different for individuals with PD and the non-PD controls whom were not part of the exercise intervention, Wilks = 0.623, $F(1, 11) = 6.656$, $P = 0.026$. Over the testing periods, the PD group had a significantly higher increase on the Composite 4•5•6 score then that of the non-PD group, 50.65 ± 5.81 to 63.35 ± 9.69 and 60.50 ± 11.41 to 64.38 ± 5.69 respectively (Figure 4.1). The multivariate effect size (η^2) [1] equals 0.351 and the observed power was moderate at 0.652.

[1] $\eta^2 = \frac{SSH}{SSH + SSE}$ (Huberty & Olejnik, 2006)

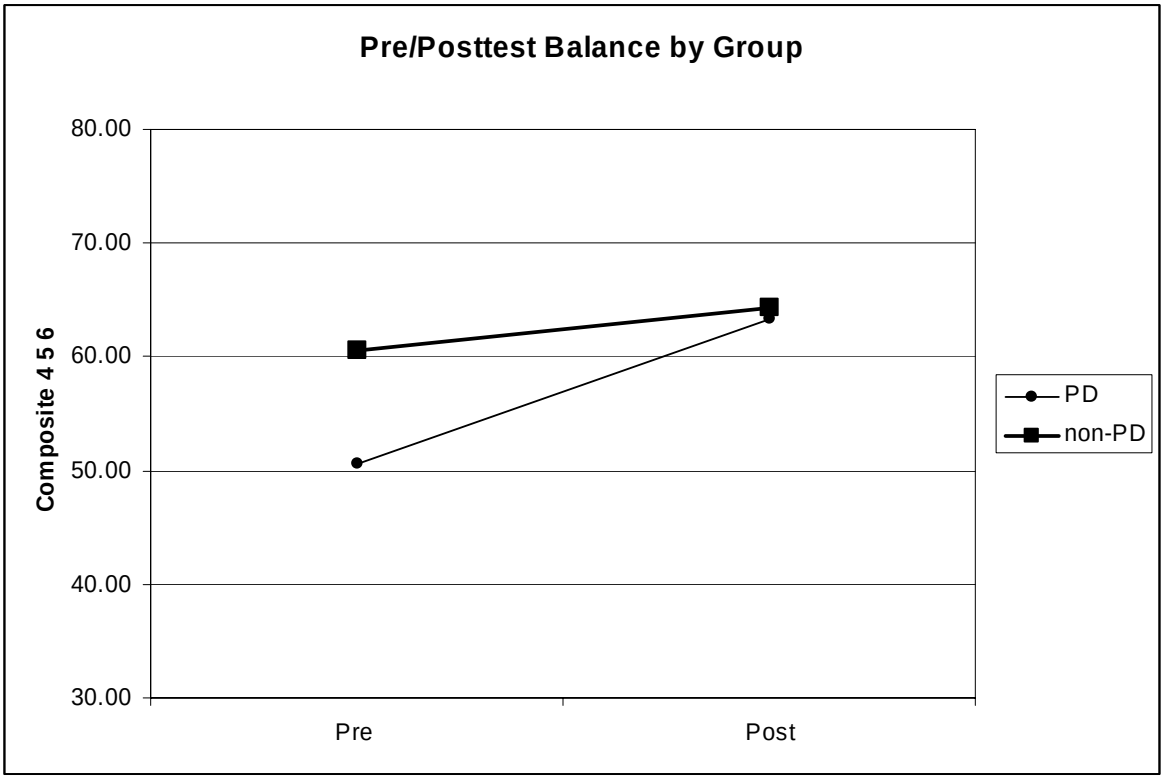

Figure 4.1: Mean Composite 4•5•6 score of the NeuroCom EquiTest SOT.

Sit-to-Stand

The Sit-to-Stand was performed by all participants during both pre and post testing. The test consisted of three trials and the mean score for each was utilized. During each trial the participant was instructed to stand from a seated position, on the forceplate, and hold that standing position for 5 seconds. The outcome measures of interest for this test were:

1. Weight Transfer- The time in seconds required to voluntary shift the COG forward beginning in the seated position and ending with full weight bearing on the feet.
2. Rising Index- The amount of force exerted by the legs during the rising phase. The force is expressed as a percentage of the patient's body weight.

3. Sway Velocity- Documents control of the center of gravity over the base of support (feet) during the rising phase and for 5 seconds thereafter. Sway is expressed in degrees per second.

Averages for each are presented in Table 4.3.

Table 4.3: Averages for the Sit-To-Stand (Mean ± SD)

	PD		non-PD	
	Pre	*Post*	*Pre*	*Post*
Weight Transfer	0.56 ± 0.29	0.54 ± 0.22	0.46 ± 0.25	0.42 ± 0.24
Rising Index	15.47 ± 2.60	15.20 ± 4.68	16.67 ± 3.27	15.29 ± 3.18
Sway Velocity	4.54 ± 0.81	3.67 ± 1.00	4.22 ± 1.00	4.46 ± 1.32

The design for the Sit-to-Stand was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measure of interest were Weight Transfer, Rising Index, and Sway Velocity.

A repeated measure MANCOVA on the three outcome variables was utilized to evaluate group differences from pre to post-testing. To be consistent with the balance analysis the same covariates were utilized. Because the significance level was not below .05, no significant difference was evident for the interaction between the grouping variable (PD and non-PD) and the repeated measures (Weight Transfer, Rising Index, and Sway Velocity), Wilks = 0.527, $F(3, 9) = 2.689$, $P = 0.109$. These results do not provide sufficient statistical evidence of a treatment effect.

Step Up/Over

The Step Up/Over was performed by all participants during both pre and post testing. The test consisted of three trails and the mean score for each was utilized. During each trail the participant was instructed to step-up on to a 4-inch platform, situated on the forceplate, with their dominate leg. The participant would then continue moving the non-dominate foot over the

platform and on to the forceplate. The movement was discontinued once the participant moved the dominate leg from the platform on to the force plate and held that standing position for 5 seconds. The outcome measures of interest for this test were:

1. Lift-up Index- Quantifies the maximal lifting force exerted by the leading leg and is expressed as a percentage of the individual's weight.
2. Movement Time- Quantifies the number of seconds required to complete the maneuver, beginning with the initial weight shift to the non-stepping leg and impact of the lagging leg onto the force plate.
3. Impact Index- Quantifies the maximum vertical impact force as the lagging leg lands on the force plate, expressed as a percent of body weight.

Averages for each are presented in Table 4.4.

Table 4.3: Averages for the Step Up/Over (Mean ± SD)

	PD		non-PD	
	Pre	*Post*	*Pre*	*Post*
Lift-up Index	16.35 ± 3.81	20.08 ± 3.67	23.14 ± 5.93	19.71 ± 6.35
Movement Time	1.78 ± 0.35	1.79 ± 0.35	1.45 ± 0.21	1.82 ± 0.31
Impact Index	26.19 ± 8.16	26.58 ± 4.63	24.62 ± 4.38	22.19 ± 6.52

The design for the Step Up/Over was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measures of interest were Lift-up Index, Movement Time, and Impact Index.

A repeated measure MANCOVA on the three outcome variables was utilized to evaluate group differences from pre to post testing. To be consistent with other analyses the same covariates were utilized. Because the significance level was not below .05, no significant difference was evident for the interaction between the grouping variable (PD and non-PD) and the repeated measures (Lift-up Index, Movement Time, and Impact Index), Wilks = 0.925, F(3,

9) = 0.242, $P = 0.865$. This provided no evidence to indicate there were changes from pre to post test within either group.

Walk Across

The Walk Across was performed by all participants during both pre and post-testing. The test consisted of three trails and the mean score for each was utilized. During each trail the participant was instructed to walk across the length of the forceplate. Participants were instructed to begin walking 10 feet in front of the forceplate and continue 5 feet beyond to assure a normal walking cadence. The outcome measures of interest for this test were:

1. Step Width- The lateral distance in centimeters between the left and right feet on successive steps.
2. Step Length- The longitudinal distance in centimeters between successive heel strikes on successive steps
3. Speed- The velocity in centimeters per second of the forward progression

Averages for each are presented in Table 4.5.

Table 4.5: Averages for the Walk Across (Mean ± SD)

	PD		non-PD	
	Pre	*Post*	*Pre*	*Post*
Step Width	18.58 ± 4.04	20.48 ± 4.37	16.72 ± 2.64	13.73 ± 6.73
Step Length	40.58 ± 12.85	40.79 ± 16.41	62.98 ± 9.49	56.10 ± 21.19
Speed	57.91 ± 16.88	53.78 ± 21.85	78.17 ± 11.03	66.24 ± 27.37

The design for the Walk Across was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measures of interest were Step Width, Step Length, and Speed.

A repeated measure MANCOVA on the three outcome variables was utilized to evaluate group differences from pre to post testing. To be consistent with other analysis the same

covariates were utilized. Because the significance level was not below .05, no significant difference was evident for the interaction between the grouping variable (PD and non-PD) and the repeated measures (Step Width, Step Length, and Speed), Wilks = 0.870, $F(3, 9) = 0.449$, $P = 0.724$. This provided no evidence to indicate there were changes from pre to post test within either group.

Isokinetic Strength

Isokinetics testing was utilized for isolation of the muscles about the knee to gather performance data from the participants while allowing for maximal muscle contraction throughout the full range of motion. The outcome measures of interest for this test were:

1. Concentric peak torque of the knee flexors at 90 degrees/second
2. Concentric peak torque of the knee extensors at 90 degrees/second
3. Concentric peak torque of the knee flexors at 180 degrees/second
4. Concentric peak torque of the knee extensors at 180 degrees/second

Averages for each are presented in Table 4.6.

Table 4.6: Average Peak Torque for Isokinetic Strength (Mean ± SD)

	PD		non-PD	
	Pre	Post	Pre	Post
90 degrees/second				
Flexion	13.75 ± 5.15	15.13 ± 6.36	16.50 ± 3.96	16.00 ± 7.37
Extension	20.75 ± 10.36	22.13 ± 11.34	20.25 ± 9.21	24.38 ± 8.21
180 degrees/second				
Flexion	10.88 ± 3.76	12.38 ± 6.46	12.13 ± 3.27	14.38 ± 5.01
Extension	11.25 ± 4.56	16.38 ± 8.68	15.13 ± 7.61	16.63 ± 6.09

The design for the isokinetic strength was a 2x2 [group (PD, non-PD) by time (pre, post)] mixed model with repeated measures on the last factor. The dependent measure of interest were knee flexion and extension at 90 degree/second and knee flexion and extension at 180 degrees/second.

A repeated measure MANCOVA on the four outcome variables was utilized to evaluate group differences from pre to post testing. To be consistent with other analysis the same covariates were utilized. Because the significance level was not below .05, no significant difference was evident for the interaction between the grouping variable (PD and non-PD) and the repeated measures, Wilks = 0.377, $F(4, 8) = 3.311$, $P = 0.070$. These results did not provide sufficient statistical evidence of a treatment effect.

CHAPTER V

DISCUSSION

This study attempted to increase functional performance measures in individuals with PD through the use of a 10 week home-based exercise intervention. It has been well documented that individuals with PD demonstrate decrease ability to perform many functional task with compared to their non-disease counter parts. Additionally, it has been documented that individuals with PD can improve their performance through the use of traditional therapies. What is less known however, is if these improvement can be mimicked in a home setting therefore decreasing the overall cost of the disease.

It was hypothesized that a 10 week home based intervention would result in significant improvements in various performance outcome measures. These measures included: balance with the NeuroCom EquiTest SOT protocol, functional measures including Sit-to-Stand, Step Up/Over, and the Walk Across, and lastly strength utilizing isokinetic dynamometry.

NeuroCom EquiTest Sensory Organization Test

In order to evaluate balance in individuals with PD the NeuroCom EquiTest SOT was utilized. Posture, stability, and overall balance are important components in movement, mobility, and acts of daily living. In the PD population problems with both postural stability and balance become increasingly problematic as the disease progresses and have been well documented (Adkin et al., 2003). As such, body sway and overall stability was quantitatively assessed by using the computerized NeuroCom EquiTest SOT for the isolating sensory and motor components of balance in standing humans. The NeuroCom EquiTest SOT has been

found to be a reliable tool for detecting instability in older adults and identifying individuals who are at risks for falling by detecting changes in six sensory conditions (Ford-Smith, Wyman, Elswick, Fernandez, & Newton, 1995). The NeuroCom EquiTest SOT protocol required participants to be tested under six independent sensory conditions. Each condition has three trials each lasting 20 seconds. During the assessment, somatosensory and visual environments were altered systematically and the participant's responses were measured and recorded. Based on this previous research a composite score for conditions 4-6 (Composite 4•5•6) was created as an indicator of performance under the most difficult test conditions when the support surface is sway-referenced and visual cues are misleading or absent (Hirsch et al., 2003; Toole et al., 2000).

Based on the work by done by Horak, Nutt, and Nashner (1992), Bronte-Steward, Minn, Rodrigues, Buckley and Nashner (2002) identified three processes required for functional postural stability: 1) sensory organization, in which one or more of the orientation senses (somatosensory, visual, and vestibular) are involved and integrated with the central nervous system; 2) a motor adjustment process involved with executing coordinated and properly scaled neuromuscular responses; and 3) adequate tone of muscles, through which adjustments in postural control are achieved. Because PD is a multifactorial problem, individuals with the disease may have deficiencies in one or more of the three processes required for postural stability. For example, in terms of sensory organization, visual and proprioceptive dysfunction has been documented in individual with PD (Bronstein et al., 1990; Reichert et al., 1982). Additionally, Marsden and others have demonstrated that motor planning and the corresponding motor adjustments are severely affected in persons with PD (Horak et al., 1992; Marsden, 1982).

Additionally a lack of muscular strength has been well documented in individuals with PD and may play a role in inadequate balance (Inkster & Eng, 2004; Inkster et al., 2003).

Previous research examining strength training and balance training programs for individuals with PD has shown increases in the SOT and overall postural stability. For example, Hirsch and colleagues examined the effectiveness of two types of training regiments of balance. One regiment consisted of balance training in conjunction with resistance training and the other regiment consisted of only balance training. This study concluded that each form of training improved balance as measured by the Sensory Organization Test, all be it there was a greater improvement in balance was seen in the balance and resistance training group (Hirsch et al., 2003). Similarly, utilizing the SOT protocol, Toole and colleagues showed improvements in balance following a similar 10-week resistance training and balance program. However, in the Toole study a non-treatment PD control group was utilized showing no improvement in balance (Toole et al., 2000).

The results of our study were similar to each of the above studies. Like the Hirsch study our 10-week intervention did significantly increase balance as measure by a composite score consisting of conditions 4, 5, and 6. Additionally, like the Toole study, our intervention consisted of a non-exercised control group to control for the learning effect of repeated testing. And, like the Toole study, our study showed significant improvements in balance in the treatment group but not in the non-exercised control group indicating a treatment effect. The results of our study and the two previous discussed differ in 1) our study was home-based and 2) our study did not involve balance training per se. Although we demonstrated significant improvements in balance our study was limited to lower body and trunk strengthening exercise.

The improvements in balance as a result of this type of training are thought to be a result

of more efficient sensory afferent and efferent information processing. We propose the exercises stimulated sensory-motor coordination in the basal ganglia therefore making the entire system more effective. The exercises utilized in this study (particularly the forward lunge and wall squat) were designed to challenge the vertical position of the body and increase the limits of stability in order to improve equilibrium. Therefore it is believed, that although the use of balance training was excluded in our study, the exercises themselves facilitated use of the proprioceptive, visual, and vestibular cues and therefore increased the ability of individuals with PD to increase their composite score on the NeuroCom EquiTest SOT protocol and their overall balance.

The mechanisms for this increased ability to control balance are thought to be a result of positive changes in two different control mechanisms. In addition to more efficient afferent and efferent pathways previously discussed, a second mechanism may be seen in how this information is utilized. Balance not only requires accurate sensory input but additionally requires motor adjustment processes to control the body under varying environmental conditions. These processes are utilized to make the necessary adjustments to maintain balance (Blasch et al., 1997). It is hypothesized that our intervention trained individuals with PD to override faulty proprioceptive feedback and utilize reliable visual and vestibular (Toole et al., 2000).

Sit-To-Stand

Rising from a chair is a physically demanding function that is a common problem in aging, particularly in individual with PD. In order to complete this task individuals must have adequate lower body strength and exhibit the ability to control their center of gravity as it shifts from an initial position over the seat to a location centered over the base of support (feet). In order to evaluate this task in the PD population the sit-to-stand test was performed. The sit-to-

stand was performed by all participants during both pre and post-testing. During this test the participant were instructed to stand from a seated position, on the forceplate, and hold that standing position for 5 seconds.

Previous research has shown detriments in this task in individuals with PD. For example, Brod and colleagues found that 81% of individuals with PD self reported having difficulty standing from a seated position (Brod et al., 1998). In addition, Inkster and colleagues found compensatory motor strategies in individuals with PD when rising from a seated position. They concluded it was due to reduced ability to generate force in the lower extremity (Inkster & Eng, 2004). As such our exercise protocol was designed to address this strength limitation seen in the PD population.

It was hypothesized that the demand placed on the large muscle groups of the lower extremity during the home-based exercise intervention would be sufficient enough to induce change in sit-to-stand movement pattern. However, our results indicate no change from pre to post and do not provide sufficient statistical evidence of a treatment effect in either the exercised PD group or the non-exercised control group.

Although not statically significant at .05 we believe there was a mild treatment effect on the exercised PD group that was not seen in non exercised non-PD group. For example, our results show that the PD group decreased their Sway Velocity on the Sit-to-Stand measure by nearly 1 degree, from 4.54 to 3.67, a decrease of 24 percent (Figure 5.1). Note the non-exercised control group actually had a mild increase in sway from 4.22 to 4.46. Ideally, center of gravity sway during the rise and immediately following should be minimized, therefore low score are good and higher score are negative (NeuroCom, 2001). Because Sway Velocity indicates the average amount of center of gravity sway during the rise to stand and for the first five seconds

following the rise we believe the change induced has clinical significance. During the standing phase of rising from a chair the center of gravity must move forward to relocate from "over the seat" to "over the feet". Once this occurs movement must be limited in order to prevent to prevent falling back into the chair or falling forward.

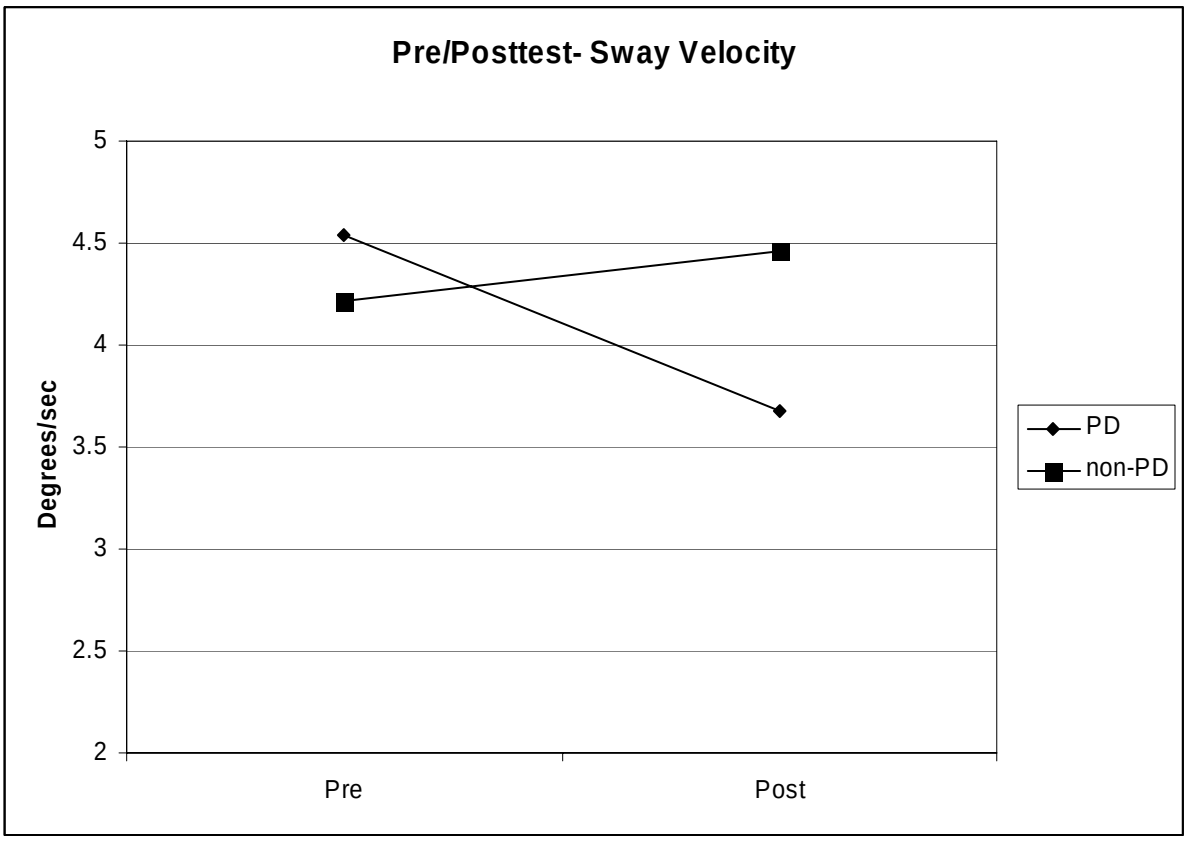

Figure 5.1: Pre to posttest mean sway velocity score of the Sit-to-Stand Test

Step Up/Over

The ability to avoid and negotiate obstacles in the environment during locomotion is a critical component of overall mobility. The Step Up/Over test quantified the motor control characteristics as an individual steps up with one foot, lifting the body through an erect standing position, swings the other foot over, and then lowers the body to land the swing leg on the force plate. This test was performed by all participants during both pre and post-testing. During

testing the participant was instructed to step up on to a 4-inch platform, situated on the forceplate, with their right leg. The participant would then continue moving the left foot over the platform and on to the forceplate. The movement was discontinued once the participant moved the right leg from the platform on to the force plate and held that standing position for 5 seconds.

It was hypothesized that the demand placed on the large muscle groups of the lower extremity during the home-based exercise intervention would be sufficient enough to induce change in this movement pattern. However, our results indicate no change from pre to posttest in either the exercised PD group or the non-exercised control group. After finding no significant change in the Step Up/Over test it was concluded that the intensity and/or duration of the home-based exercise intervention was not at a sufficient level to induce change in this movement pattern.

Walk Across

Overall mobility/gait is also compromised in PD and as such was evaluated with the walk across. As the disease progresses, this vital aspect for function diminishes, increasing the risk of falling and decreasing overall mobility (Hass et al., 2005; Sofuwa et al., 2005). The Walk Across provided measurement characteristics of gait as an individuals walks across the length of a forceplate. The test allows for a measurement of steady state gait by having the patient begin walking 10 feet in front of and continuing beyond the forceplate.

It was hypothesized that the home-based exercise intervention would increase lower extremity strength and therefore lead to a more efficient gait pattern. However, our results indicate no change from pre to posttest in either the exercised PD group or the non-exercised control group. After finding no significant change in the walk across test it was concluded that

the intensity and/or duration of the home-based exercise intervention was not at a sufficient level to induce change in this movement pattern.

Isokinetic Strength

The ability to generate muscle force is required to maintain postural stability, as well as for stabilizing and propelling the body during all phases of locomotion. Isokinetic strength testing was utilized for isolation of the muscles about the knee to gather performance data from the participants while allowing for maximal muscle contraction throughout the full range of motion.

It was hypothesized that the home-based exercise intervention would increase lower extremity strength. However, our results indicate no change from pre to posttest and do not provide sufficient statistical evidence of a treatment effect in either the exercised PD group or the non-exercised control group.

That being said the results are 'close' to significance ($P = 0.070$) and given our sample size and inherent power problem it is believed that the treatment did indeed have an effect on the PD population. For example, the exercised PD populations' isokinetic peak torque for knee flexion at 90 degrees/second increased 10 percent from 13.75 to 15.13 from pre to post test respectively, whereas the non-exercise, non-PD group exhibited no increase in peak torque going from 16.50 on the pre test measurement to 16.00 on the post test measurement (Figure 5.2). Similarly, the isokinetic strength test for extension at 180 degrees/second showed an increase of peak torque in the exercise PD group of 46 percent (11.25 to 16.38) whereas the non-exercised, non-PD control group only showed at 9 percent improvement (15.13 to 16.63) (Figure 5.3). Therefore, although the results did exhibit statistical significant, most likely do to our limited

population sample size, it is believed that the treatment did have an effect on lower extremity strength as measured by isokinetic dynamometer.

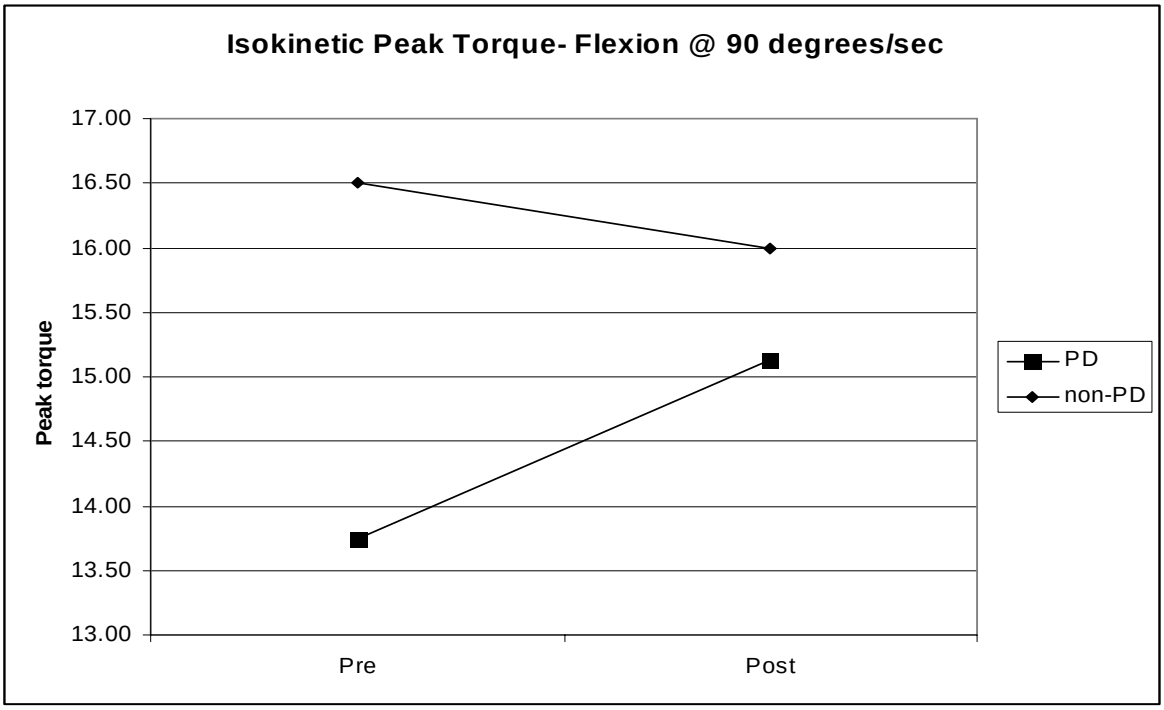

Figure 5.2: Pre to posttest measure- peak torque for flexion at 90 degrees/sec.

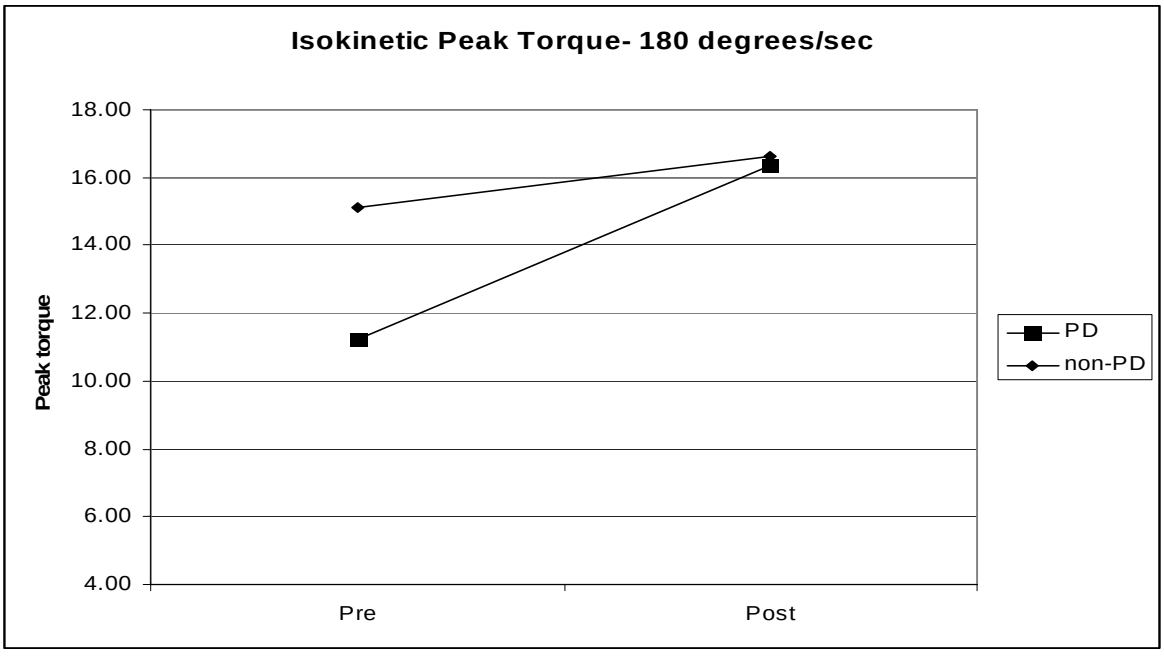

Figure 5.3: Pre to posttest measure- peak torque for extension at 180 degrees/sec.

Clinical Implication

Despite limited clinical significance in many of the outcome measure used to evaluate our home-based exercise program we believe this study has significant clinical importance. First and foremost the home-based exercise intervention did significantly improve balance in the PD population as measured by the NeuroCom EquiTest SOT. This is extremely important considering falls are one of the most serious complication of in PD and reports have documented individuals with PD who fall varies from 38 percent to as high as 90 percent (Balash et al., 2005; Koller et al., 1998). These falls are the leading cause of physical trauma, fear of falls, and restriction of day-to-day activity in individuals with PD (Giladi et al., 2001). The results of our study therefore provide 1) additionally research supporting the notion that individuals with the progressive degenerative disease can improve their balance, and 2) these improvement can be induced in a home setting with little to no equipment required.

A basic premise for this study was that a great deal of research has been shown to support the notion that exercise increases overall function in individuals with PD. The problem lies in that much of this research has been done in a lab or physical therapy setting. Due to the factors associated with this disease (i.e. health care and medication costs as well as travel limitations) these types of therapies may not be accessible to all individuals with PD. We proposed that a home-based intervention would allow for similar achievements in overall function while concurrently being accessible to all individuals with this disease. The intervention we designed was simple, low to no cost, as well as accessible and was shown to increase overall balance in individuals with PD.

Another aspect of clinical significance we deemed important was the positive feedback we received from multiple participants. Although no qualitative data or quality of life

information was formally collected we did receive general information on the participants' feelings of health following the intervention. For example, one participant reported that they were less reliant on their 'walking stick' following the ten week intervention. This participant had reported that the stick was used as a crutch when walking for balance and as a result of the intervention he was using the stick more infrequently. Additionally, one participant reported that they were able to rejoin a water aerobics class they had previously discontinued do lack of fitness. Again this data was not formally collected and may be a limitation of study however, we do believe these voluntary discussions gave insight to the benefits of the study for individuals with PD.

Limitations of the Study

The primary limitation of this study is the sample size. Due to the demographics of The University of Georgia surrounding area, the nature of the disease, travel limitations, as well as age and PD stage limitations, recruitment was especially difficult. The extent to which the home-based exercise intervention can be evaluated is limited and warrants further investigation utilizing a larger sample size. An additional limitation in this study can be seen in the demographical variation of the subjects. The PD group age range was from 67 to 87 years of age. Additionally, individuals with PD included in this study were diagnosed from stage I to stage III. Future studies may utilize a more homogenous sample, same stage and similar duration of disease for example, to control some of the overall variability seen in this population. Lastly, qualitative data may be utilized as a way to explore individuals quality of life following an intervention.

Conclusion

The results of this study indicate that a 10 week home-based exercise intervention can induce positive changes in balance in individuals with PD as measured by the Sensory Organization Test. However, this intervention was not shown to produce statistical significant changes in functional tasks including the sit-to-stand, the step-up/over, and the walk across. Additionally, this study did not produce statistically significant changes in lower extremity strength as measured by isokinetic dynamometry. However, we believe that there was indeed a treatment effect on the sway velocity measurement of the Sit-to-Stand test and isokinetic strength tests. We believe that this study has clinical significance based on the fact that falling is one of the leading causes of injury in the PD population. Future studies examine a longer intervention are needed to conclude if a home based intervention can produce significant statistical changes in functional task measures and strength measures. Additional, future studies may utilize a more homogenous PD group to avoid some of the variation seen in the population.

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APPENDIX A

HOEHN AND YAHR STAGING OF PARKINSON'S DISEASE

1. Stage One
    1. Signs and symptoms on one side only
    2. Symptoms mild
    3. Symptoms inconvenient but not disabling
    4. Usually presents with tremor of one limb
    5. Friends have noticed changes in posture, locomotion and facial expression
2. Stage Two
    1. Symptoms are bilateral
    2. Minimal disability
    3. Posture and gait affected
3. Stage Three
    1. Significant slowing of body movements
    2. Early impairment of equilibrium on walking or standing
    3. Generalized dysfunction that is moderately severe
4. Stage Four
    1. Severe symptoms
    2. Can still walk to a limited extent
    3. Rigidity and bradykinesia
    4. No longer able to live alone
    5. Tremor may be less than earlier stages
5. Stage Five
    1. Cachectic stage
    2. Invalidism complete
    3. Cannot stand or walk
    4. Requires constant nursing care

APPENDIX B

UNIFIED PARKINSON'S DISEASE RATING SCALE

I. MENTATION, BEHAVIOR AND MOOD

1. Intellectual Impairment
0 = None.
1 = Mild. Consistent forgetfulness with partial recollection of events and no other difficulties.
2 = Moderate memory loss, with disorientation and moderate difficulty handling complex problems. Mild but definite
impairment of function at home with need of occasional prompting.
3 = Severe memory loss with disorientation for time and often to place. Severe impairment in handling problems.
4 = Severe memory loss with orientation preserved to person only. Unable to make judgements or solve problems.
Requires much help with personal care. Cannot be left alone at all.

2. Thought Disorder (Due to dementia or drug intoxication)
0 = None.
1 = Vivid dreaming.
2 = "Benign" hallucinations with insight retained.
3 = Occasional to frequent hallucinations or delusions; without insight; could interfere with daily activities.
4 = Persistent hallucinations, delusions, or florrid psychosis. Not able to care for self.

3. Depression
1 = Periods of sadness or guilt greater than normal, never sustained for days or weeks.
2 = Sustained depression (1 week or more).
3 = Sustained depression with vegetative symptoms (insomnia, anorexia, weight loss, loss of interest).
4 = Sustained depression with vegetative symptoms and suicidal thoughts or intent.

4. Motivation/Initiative
0 = Normal.
1 = Less assertive than usual; more passive.
2 = Loss of initiative or disinterest in elective
3 = Loss of initiative or disinterest in day to day
4 = Withdrawn, complete loss of motivation.

II. ACTIVITIES OF DAILY LIVING (for both "on" and "off")

5. Speech
0 = Normal.
1 = Mildly affected. No difficulty being understood.
2 = Moderately affected. Sometimes asked to repeat statements.
3 = Severely affected. Frequently asked to repeat statements.
4 = Unintelligible most of the time.

6. Salivation
0 = Normal.
1 = Slight but definite excess of saliva in mouth; may have nighttime
2 = Moderately excessive saliva; may have minimal drooling.
3 = Marked excess of saliva with some drooling.
4 = Marked drooling, requires constant tissue or handkerchief.

7. Swallowing
0 = Normal.
1 = Slightly slow or small.
2 = Moderately slow or small; all words are legible.
3 = Severely affected; not all words are legible.
4 = The majority of words are not legible.

8. Handwriting
0 = Normal.
1 = Slightly slow or small.
2 = Moderately slow or small; all words are legible.
3 = Severely affected; not all words are legible.
4 = The majority of words are not legible.

9. Cutting food and handling utensils
0 = Normal.
1 = Somewhat slow and clumsy, but no help needed.
2 = Can cut most foods, although clumsy and slow; some help needed.
3 = Food must be cut by someone, but can still feed slowly.
4 = Needs to be fed.

10. Dressing
0 = Normal.
1 = Somewhat slow, but no help needed.
2 = Occasional assistance with buttoning, getting arms in sleeves.
3 = Considerable help required, but can do some things alone.
4 = Helpless.

11. Hygiene
0 = Normal.
1 = Somewhat slow, but no help needed.
2 = Needs help to shower or bathe; or very slow in hygienic care.
3 = Requires assistance for washing, brushing teeth, combing hair, going to bathroom.
4 = Foley catheter or other mechanical aids.

12. Turning in bed and adjusting bed clothes
0 = Normal.
1 = Somewhat slow and clumsy, but no help needed.
2 = Can turn alone or adjust sheets, but with great difficulty.
3 = Can initiate, but not turn or adjust sheets alone.
4 = Helpless.

13. Falling (unrelated to freezing)
0 = None.
1 = Rare falling.
2 = Occasionally falls, less than once per day.
3 = Falls an average of once daily.
4 = Falls more than once daily.

14. Freezing when walking
0 = None.
1 = Rare freezing when walking; may have starthesitation.
2 = Occasional freezing when walking.
3 = Frequent freezing. Occasionally falls from freezing.
4 = Frequent falls from freezing.

15. Walking
0 = Normal.
1 = Mild difficulty. May not swing arms or may tend to drag leg.
2 = Moderate difficulty, but requires little or no assistance.
3 = Severe disturbance of walking, requiring assistance.
4 = Cannot walk at all, even with assistance.

16. Tremor
0 = Absent.
1 = Slight and infrequently present.
2 = Moderate; bothersome to patient.
3 = Severe; interferes with many activities.
4 = Marked; interferes with most activities.

17. Sensory complaints related to parkinsonism
0 = None.
1 = Occasionally has numbness, tingling, or mild aching.
2 = Frequently has numbness, tingling, or aching; not distressing.
3 = Frequent painful sensations.
4 = Excruciating pain.

III. MOTOR EXAMINATION

18. Speech
0 = Normal.
1 = Slight loss of expression, diction and/or volume.
2 = Monotone, slurred but understandable; moderately impaired.
3 = Marked impairment, difficult to understand.
4 = Unintelligible.

19. Facial Expression
0 = Normal.
1 = Minimal hypomimia, could be normal "Poker Face".
2 = Slight but definitely abnormal diminution of facial expression
3 = Moderate hypomimia; lips parted some of the time.
4 = Masked or fixed facies with severe or complete loss of facial expression; lips parted 1/4 inch or more.
(head, upper and lower extremities)

20. Tremor at rest (head, upper and lower extremities)
0 = Absent.
1 = Slight and infrequently present.
2 = Mild in amplitude and persistent. Or moderate in amplitude, but only intermittently present.
3 = Moderate in amplitude and present most of the time.
4 = Marked in amplitude and present most of the time.

21. Action or Postural Tremor of hands
0 = Absent.
1 = Slight; present with action.
2 = Moderate in amplitude, present with action.
3 = Moderate in amplitude with posture holding as well as action.
4 = Marked in amplitude; interferes with feeding.

22. Rigidity (Judged on passive movement of major joints with patient relaxed in sitting position. Cogwheeling to be ignored.)
0 = Absent.
1 = Slight or detectable only when activated by mirror or other movements.
2 = Mild to moderate.
3 = Marked, but full range of motion easily achieved.
4 = Severe, range of motion achieved with difficulty.

23. Finger Taps (Patient taps thumb with index finger in rapid succession.)
0 = Normal.
1 = Mild slowing and/or reduction in amplitude.
2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
4 = Can barely perform the task.

24. Hand Movements (Patient opens and closes hands in rapid succesion.)
0 = Normal.
1 = Mild slowing and/or reduction in amplitude.
2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
4 = Can barely perform the task.

25. Rapid Alternating Movements of Hands (Pronation-supination movements of hands, vertically and horizontally, with as large an amplitude as possible, both hands simultaneously.)
0 = Normal.
1 = Mild slowing and/or reduction in amplitude.
2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
4 = Can barely perform the task.

26. Leg Agility (Patient taps heel on the ground in rapid succession picking up entire leg. Amplitude should be at least 3 inches.)
0 = Normal.
1 = Mild slowing and/or reduction in amplitude.
2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
4 = Can barely perform the task.

27. Arising from Chair (Patient attempts to rise from a straightbacked chair, with arms folded across chest.)
0 = Normal.
1 = Slow; or may need more than one attempt.
2 = Pushes self up from arms of seat.
3 = Tends to fall back and may have to try more than one time, but can get up without help.
4 = Unable to arise without help.

28. Posture
0 = Normal erect.
1 = Not quite erect, slightly stooped posture; could be normal for older person.
2 = Moderately stooped posture, definitely abnormal; can be slightly leaning to one side.
3 = Severely stooped posture with kyphosis; can be moderately leaning to one side.
4 = Marked flexion with extreme abnormality of posture.

29. Gait
0 = Normal.
1 = Walks slowly, may shuffle with short steps, but no festination (hastening steps) or propulsion.
2 = Walks with difficulty, but requires little or no assistance; may have some festination, short steps, or propulsion.
3 = Severe disturbance of gait, requiring assistance.
4 = Cannot walk at all, even with assistance.

30. Postural Stability (Response to sudden, strong posterior displacement produced by pull on shoulders while patient erect with eyes open and feet slightly apart. Patient is prepared.)
0 = Normal.
1 = Retropulsion, but recovers unaided.
2 = Absence of postural response; would fall if not caught by examiner.
3 = Very unstable, tends to lose balance spontaneously.
4 = Unable to stand without assistance.

31. Body Bradykinesia and Hypokinesia (Combining slowness, hesitancy, decreased armswing, small amplitude, and poverty of movement in general.)
0 = None.
1 = Minimal slowness, giving movement a deliberate character; could be normal for some persons. Possibly reduced
amplitude.
2 = Mild degree of slowness and poverty of movement which is definitely abnormal. Alternatively, some reduced
amplitude.
3 = Moderate slowness, poverty or small amplitude of movement.
4 = Marked slowness, poverty or small amplitude of movement.

IV. COMPLICATIONS OF THERAPY (In the past week)

A. DYSKINESIAS

32. Duration: What proportion of the waking day are dyskinesias present?
0 = None
1 = 1-25% of day.
2 = 26-50% of day.
3 = 51-75% of day.
4 = 76-100% of day.

33. Disability: How disabling are the dyskinesias? (Historical information; may be modified by office examination.)
0 = Not disabling.
1 = Mildly disabling.
2 = Moderately disabling.
3 = Severely disabling.
4 = Completely disabled.

34. Painful Dyskinesias: How painful are the dyskinesias?
0 = No painful dyskinesias.
1 = Slight.
2 = Moderate.
3 = Severe.
4 = Marked.

35. Presence of Early Morning Dystonia
0 = No
1 = Yes

B. CLINICAL FLUCTUATIONS

36. Are "off" periods predictable?
0 = No
1 = Yes

37. Are "off" periods unpredictable?
0 = No
1 = Yes

38. Do "off" periods come on suddenly, within a few seconds?
0 = No
1 = Yes

39. What proportion of the waking day is the patient "off" on average?
0 = None
1 = 1-25% of day.
2 = 26-50% of day.
3 = 51-75% of day.
4 = 76-100% of day.

C. OTHER COMPLICATIONS

40. Does the patient have anorexia, nausea, or vomiting?
0 = No
1 = Yes

41. Any sleep disturbances, such as insomnia or hypersomnolence?
0 = No
1 = Yes

42. Does the patient have symptomatic orthostasis?
(Record the patient's blood pressure, height and weight on the scoring form)
0 = No
1 = Yes

APPENDIX C

INFORMED CONSENT

I, _____ agree to participate in the researched project titled "Utilizing Closed Chain Movements to Increase Physical Function in Parkinson Disease", which is being conducted by Dr. Michael Horvat, Department of Kinesiology at the University of Georgia University of Georgia (706) 542-4455 and Joe Nocera, Department of Kinesiology at the University of Georgia University of Georgia (706) 542-3389. My participation is voluntary. I can refuse to participate or I can stop taking part at any time without giving any reason and without penalty. I can ask to have information related to me returned to me, removed from the research records, or destroyed.

The reason for this study is to examine a 10-week home based therapeutic intervention (TI) on physical function in individuals with Parkinson's disease (PD).

The benefits that I may expect include increase strength and balance and increased knowledge of exercise as it relates to PD.

If I volunteer to take part in this study I will be asked to do the following things:

Prior to beginning any portion of this study I will be transported to Athens Neurological Associates to be evaluated and categorized at Stage I-III of the Hoehn and Yahr Staging of Parkinson's Disease rating scale by a neurologist. Additionally at this time I will be cleared for participation in the therapeutic intervention. If not categorized at stage I-III or not cleared for the intervention then I will be excluded from participating in this study. Following being cleared I will report to the movement studies lab at the Ramsey Center for a total of 2 times: 1 day of pre-conditioning testing as well as description and illustration of exercises and post intervention testing. Additionally I will partake in a 10-week TI designed at improving my strength and balance. None of the tests and/or exercises will be done until at least 2 hours following indigestion of any medication I am currently taking related to PD.

Pre-conditioning testing
The first day will include about 1 hour of pre-conditioning testing which will include a strength test of my upper limb. These tests are similar to that of a quad extension machine seen in most weight rooms. Additional testing done the first day will include a standing test designed to measure balance. Lastly, a series of test designed to measure functional performance will be done. These test include the self described sit-to-stand and forward lunge.

Therapeutic Intervention (TI)
The TI will be self-administered 3 days/week for 10 weeks your residence. Prior to the TI you will attend a familiarization session in the lab to view to proper mechanics of all exercises. Also

during this meeting, you will execute movements to insure proper form and understanding of exercises. In addition to this instruction, you will be given take-home cards demonstrating the proper form.

Post-conditioning testing

The final week will consist of a one day post-conditioning testing identical to that of the pre-conditioning tests and will again last for about 1 hour.

The discomforts or stresses that may be faced during this research include possible muscle soreness which may occur during testing and/or during the intervention. To prevent soreness I will be instructed to warm-up and stretch before any testing or conditioning is begun.

As a participant, I assume certain risk of physical injury. UGA will exercise all reasonable care to protect me from harm as a result of my participation. In the event of an injury as an immediate and direct result of my participation, UGA's sole responsibility is to provide immediate, emergency care, and as necessary to transport me to an appropriate facility if additional care is needed. As a participant, I do not give up or waive any of my legal rights. Additionally, I will provide the name and telephone number of the person that must be immediately contacted in the event of a research related injury.

No information individually identifying me, or provide by me during the research, will be shared with others without my written permission, except if it is necessary to protect my welfare (for example, if I were injured and needed physician care) or if required by law. I will be assigned an identification number and this number will be used on all information used regarding me.

The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by phone at (706) 542-4455.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

_____	_____	_____
Name of Researcher	Signature	Date

Telephone: _____

Email:_____

_____	_____	_____
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu.

APPENDIX D

SCREENING QUESTIONNAIRE

Title of study: Utilizing Closed Chain Movements to Increase Physical Function in Parkinson Disease

Principle Investigator: Dr. Michael Horvat

Name: _____

Age:_____

Sex: [ ] Male [ ] Female

Please answer the following questions: Response are subject to evaluation by a medical doctor.

Do you have any of the following: dyskinesia, dystonia, or neurological, musculoskeletal, and metabolic disorders [ ] Yes [ ] No

Have you had or do you currently have any of the following: knee, hip, or ankle trauma, knee, hip, or ankle surgery, knee, hip, or ankle joint disease: [ ] Yes [ ] No

Do you have a pre-existing lung disease, history of cardiac disease, psychiatric illness, dementia, depression: [ ] Yes [ ] No

Do you have any fluctuating responses to the medication you are currently taking:
[ ] Yes [ ] No

Stage of Parkinson's Disease:_____

Age of diagnosis:_____

Current type of medication and dosage:_____

Ht._____ (in) _____ Wt.(lbs) _____ Body Fat %_____ BMI_____

Sit and Reach_____ Dominant leg: R L

APPENDIX E

EXERCISE INTERVENTION

The following exercises are designed to increase your strength and balance as well as functional tasks such as getting up and out of a chair, getting up and out of bed, ascending and descending stairs, and walking. Prior to beginning this workout, you will warm-up for five minutes by walking/jogging at a brisk pace or riding a stationary bicycle. All exercises should be done 4 times a week or every other day. Each exercise should be done for 30 seconds with a 60-second rest in between each exercise. Following each exercise, you will write down to number of repetitions performed for each exercise during the 30 seconds.

Caution: If these or any other stretch/exercise causes pain, tingling, numbness or other discomfort stop immediately.

Exercise 1. The abdominal crunch

STEP 1: Lie on your back with your knees bent and your feet flat on the floor in front of you.

STEP 2: Position your feet as wide as your hips

STEP 3: Place your hands behind your head so that your thumbs are tucked behind your ears.

STEP 4: Hold your elbows slightly out to the sides and keep your chin pointing upward.

STEP 5: Curl up and forward so that your head, neck and shoulder blades lift off the floor. Make sure you are not pulling your head forward with your hands. If your chin is making contact with your chest, the abdominal muscles are not being used in the exercise.

STEP 6: Slowly lower your head, neck and shoulder blades to starting position.

STEP 8: Keep your knees bent, your feet in the same position and your back straight throughout the entire exercise.

Days 1-20

Days 21-40

Exercise 2. Wall Squats

STEP 1: Standing with back against wall with your feet about 12 - 18" away from a wall.

STEP 2: Slowly bend the knees and allow your back to slide down to wall keeping knees behind the toes and your back leaning against the wall.

STEP 3: Slide your back down the wall until the thighs are approximately parallel to the floor. **Note**. If unable to get your thighs parallel to the floor, just bend your knees as much as possible and make a note of it below.

STEP 4: Then, slowly push with the legs, pressing through the heels, to return to the starting position.

Days 1-20

Days 21-40

Exercise 3. Lunges

STEP 1: Stand with the feet shoulder width apart with your side 2 feet from a wall or chair to be used for balance.

STEP 2: Step forward as far as you can with your right foot, descend slowly by bending at the hips, knees and ankles.

STEP 3: Descent slowly while maintaining weight distribution between the heels and mid-foot.

STEP 4: The spine should remain in the same position throughout

STEP 5: Use your hip and thigh muscles to push yourself up and back to the start position

STEP 6: Repeat with the alternate leg

Days 1-20

Days 21-40

Exercise 4. Calf Raises

STEP 1. Stand about one foot behind the back of the chair with feet hip-width apart.

STEP 2. Keep back straight, head in line with spine, and shoulders back.

STEP 3. Using chair for balance, raise heels off floor, pushing straight up onto balls of feet.

STEP 4. Slowly lower heels to starting position.

Days 1-20

Days 21-40

Exercise 5. Knee Flexion

STEP 1: Stand up straight with head in line with spine, legs hip-width apart, and knees slightly bent while placing hands on back of chair for balance.

STEP 2: Maintaining good posture, raise left heel toward buttocks until your calf is parallel to the floor.

STEP 3: Repeat with alternative leg.

Days 1-20

Days 21-40

Exercise 6. Knee Extension

STEP 1: Sit on chair with back and hips against the chair back.

STEP 2: Extend left leg out as straight as possible, pausing for 1 second when leg is parallel to the floor.

STEP 3: Lower left leg back to starting position.

STEP 4: Repeat with alternate leg.

Days 1-20

Days 21-40

Exercise 7. Step-ups

STEP 1. Stand in front of a 4-6” stool with a chair or wall to your side for balance.

STEP 2. Slowly step up with your right leg then with your left.

STEP 3. Slowly step down with your right leg then with your left.

STEP 4. Slowly step up with your left leg then with your right.

STEP 5. Slowly step down with your left leg then with your right.

Days 1-20

Days 21-40

The final aspect of the TI will consist of cool down stretching exercises aimed at increasing lower body range of motion. Each stretch will be held for 30 seconds. The stretches will include the following:

Prone Press-up Lying with your stomach down, the hands underneath the shoulders, the head and shoulders are gently pushed up with the arms. The pelvis is kept to the ground. The stretch is felt in the front of the stomach.

Seated Hamstring - One leg is straight out in front of the body and the heel is rested flat on the floor. Keeping the back straight, and the other leg bent, the hands slide slowly down the shin. The stretch is felt in the middle of the hamstring muscle. The stretch is then repeated on the other leg.

Quadriceps- Lying on the side with the weight of the upper body resting on a bent elbow, the uppermost ankle is pulled towards the buttock. The bent knee is slowly moved backwards. The stretch is felt down the front of the thigh. The stretch is then repeated on the other side with the other leg.

Standing Hip Flexor
Kneel on the floor with one knee bent and one leg behind you. Position your forward knee over your foot. Keep your other knee touching the floor. Slowly push your hips forward until you feel the stretch in the upper thigh of your rear leg. The stretch is then repeated on the other leg.

Standing Gastroc- The feet are placed stride width apart with the front leg slightly bent. The body weight is transferred forward while keeping the heel of the back foot on the ground. The stretch is felt down the back of the calf. The stretch is then repeated on the other side.

Standing Soleus Standing with the feet stride length apart, and with both knees slightly bent, the body weight is transferred forwards whilst keeping the heel of the back foot on the ground. The stretch is felt at the bottom of the calf. The stretch is then repeated on the other side.