

EFFECT OF QIGONG EXERCISE ON SLEEP QUALITY  
AND GAIT PERFORMANCE IN PARKINSON'S DISEASE

BY

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## *Abstract*

The goal of this study was to investigate the impact of a Qigong exercise intervention on symptoms related to sleep quality, fatigue, and gait function in Parkinson's disease (PD). Subjects participated in a six-week Qigong exercise program, which included performance of the exercise routine twice daily as well as weekly group exercise sessions. Subjects were assessed in sleep quality and fatigue using standard clinical assessments specific to PD. Gait function was tested using three-dimensional motion analysis during the performance of several gait tasks. The performance of these tasks was assessed in three main categories: overall gait function, gait variability, and turning performance. Parameters used to assess overall gait function included stride time, stride length, double support time, and gait velocity. Gait variability was studied using the coefficient of variation of stride time and stride length. Turning performance was evaluated using the total number of steps and total time taken to complete a full turn.

Following completion of the intervention, the Qigong exercise showed a positive impact on several PD symptoms. Measures of sleep quality showed improvement as a result of the exercise therapy. Subjects also demonstrated improvements in gait function. Overall gait performance showed a significant benefit from the exercise. Gait velocity was increased as a result of increased stride length and decreased step time. Additionally, time spent in double support was reduced. There was an improvement in gait variability as well, as stride time variability was significantly reduced in the post-intervention testing. Finally, neither turning performance nor fatigue appeared to benefit from the exercise, as no significant change occurred in either of these parameters. These results suggest that this specific Qigong exercise intervention may be beneficial in the management of sleep and gait related symptoms of PD. Further study is necessary to provide more definitive evidence of these benefits.

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## CHAPTER ONE: INTRODUCTION

### *Background & Motivation*

People suffering from Parkinson's disease (PD) experience a broad range of symptoms. These include a variety of motor and non-motor features that impact the ability for patients to perform daily functions and can have a major impact on quality of life. Two important areas of concern include gait complications and sleeping disorders.

Motor function in PD is largely influenced by four key features of the disease: bradykinesia (slowness of movement), rigidity, postural instability, and tremor [1]. These factors combine to cause several characteristic changes to gait in PD. The most prominent change is a pronounced reduction in gait velocity. This typically occurs as a result of shortened stride length, though in some circumstances reduced cadence may contribute as well [2, 3]. In addition to changes in velocity, parameters related to postural instability are affected. These include double support time and gait variability. Several studies have shown a correlation between increased time spent in double support and increased levels of postural instability [4, 5]. Increased gait variability, assessed through variations in stride length and stride time, also has an association to postural instability and has been shown to correlate to a high incidence of falling in several populations, including PD [6]. Successful management of these issues is a major focus in the treatment of PD.

While motor complications receive a great deal of focus in PD, issues related to sleeping can often be overlooked. Sleeping disorders impact a large portion of patients, with approximately half suffering from insomnia [1]. Other issues related to sleep include increased sleep latency and decreased sleep time and efficiency [7]. One specific sleep disorder, rapid eye



movement (REM) sleep behavior disorder (RBD) impacts a substantial number of patients. This disorder is of particular interest as it has been found to be a possible predictor of PD development and may be associated with more severe motor impairment [8]. In addition to these sleeping difficulties, fatigue occurs in up to 2/3 of patients and may also contribute to worsening of motor symptoms [9].

Currently, PD symptoms are managed using levodopa. This medication has been highly effective at controlling many of the features of PD, especially bradykinesia, rigidity, and tremor [10]. Despite its effectiveness with some of the more prominent symptoms of the disease, there are several issues that tend to resist its therapeutic effect. These include some of the more severe gait complications as well as many non-motor issues, including sleep [10]. As a result, there is a need for additional therapies that may address the limitations of levodopa treatment. Studies of complementary therapies, including those using meditative movements such as Qigong and Tai Chi, have shown some promise in these areas. Reported benefits of these exercises include improvements to gait and motor function as well as sleep, fatigue, and other non-motor symptoms [11].

### *Specific Aims*

The goal of this study was to investigate the potential benefit of a Qigong exercise intervention on PD symptoms related to sleep, fatigue, and gait performance. Subjects participated in a six-week long Qigong exercise intervention, performing the exercise therapy twice daily on their own as well as weekly in group exercise sessions. The potential benefits of the intervention were assessed through changes in the parameters of interest. Sleep quality and

fatigue were measured using standard clinical assessments and questionnaires. The impact on gait performance was studied using three-dimensional motion capture. Measures of gait performance included overall gait function, gait variability, and turning performance. Overall gait function involved analysis of stride time, stride length, double support time, and gait velocity. Gait variability was analyzed in terms of variations in stride length and stride time. Turning performance was assessed by the total number of steps and total time taken to complete a turn.

The short term goal of this study was to determine the potential benefits that may result from implementing Qigong as a complementary therapy in PD and to determine appropriate measures that will allow us to track these outcomes. These results will be used to design a larger scale study that will enable us to measure these effects more definitively. The long term goal of this study is to develop a low-cost mind-body therapy that may allow patients to further manage their PD symptoms beyond what is currently achieved through standard medicinal therapy.

### *Thesis Content*

This document contains four chapters and an appendix. The first chapter consists of an introduction to the area of study as well as the motivation and specific aims. Chapter two contains an extensive survey of literature relevant to the current study. The third chapter consists of a manuscript reporting the details of a study investigating the effects of a mild, mind-body exercise program (Qigong) on sleep quality and gait performance in Parkinson's disease. Chapter four contains a summary of this study.

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## CHAPTER TWO: BACKGROUND

### *Overview*

This section provides a review of relevant information and previous work related to the study being presented. The first portion of this section is a general overview of the topic. This includes a brief introduction to Parkinson's disease and a review of the pathophysiology, common symptoms, and current treatment methods. The remaining portion of this section moves deeper into topics directly related to the current study. Those topics being discussed in greater detail include gait complications, sleep disturbances, and complementary exercise therapies.

### *Parkinson's Disease*

Parkinson's disease (PD), first described by James Parkinson in 1817 as the "shaking palsy", is a progressive neurodegenerative disorder of the basal ganglia that is expressed through a variety of motor and non-motor features [1]. Typical onset of the disease occurs between 50 and 60 years of age and affects approximately 1.5% of the population over the age of 65 [1, 2].

There is currently no definitive test for diagnosing PD; therefore a neurologist or movement disorders specialist must perform an examination to confirm diagnosis. Further, there are no reliable methods for identifying otherwise healthy persons that have a high probability of developing the disease. While several risk factors do exist - including family history and environmental exposures - these increase the potential for developing PD from 1.5% to only

about 4% [2]. A certain sleeping disorder, which will be discussed in more detail in a later section, has shown promise as an early marker of PD, but the factors leading to this disorder are also not well understood. Upon diagnosis, disease symptoms can be managed relatively well with medical therapies; however, it is estimated that the clinical symptoms of Parkinsonism do not develop until 70-80% of striatal dopamine has already been depleted, corresponding to a 30-50% loss of dopaminergic neurons [3].

Generally speaking, the progression of PD is relatively slow with variable levels of impairment. These features are tracked using two common rating scales. The Hoehn and Yahr (H&Y) scale is used as a measure of disease progression. It consists of five stages: 1) unilateral symptoms only; 2) bilateral symptoms with no impairment of balance; 3) mild to moderate disease with balance impairment, but still physically independent; 4) severe disability, but still able to walk or stand unassisted; and 5) wheelchair bound or bedridden unless assisted [4]. The second test – the Unified Parkinson’s Disease Rating Scale (UPDRS) – is a rating system used to quantify the level of impairment. It consists of three subsections, which include evaluations of mentation, behavior, and mood; activities of daily living (ADL); and motor function. Items in these sections are scored from zero (normal) to four (severe impairment). These scores are summed to calculate totals for each subsection as well as an overall score. Higher scores in this assessment indicate more severe disability [5]. The speed of progression and level of impairment seem to be directly related to degeneration in the basal ganglia, which leads to the onset of several common symptoms.

## *The Basal Ganglia*

The basal ganglia are a group of five nuclei situated at the base of the forebrain that act together as an organized functional unit. There is no doubt that these structures play a significant role in movement, as all disorders involving the basal ganglia have motor issues as their primary symptom. However, the basal ganglia are involved in a number of parallel circuits, only a few of which deal strictly with motor function. While the motor pathway is most relevant for the present study and will be the primary focus here, it is important to note that other basal ganglia circuits involve certain aspects of memory and cognition [6, 7].

The five nuclei composing the basal ganglia are the caudate nucleus, putamen, globus pallidus, subthalamic nucleus, and substantia nigra. Together, the caudate and putamen form the largest component of the basal ganglia called the striatum. The globus pallidus consists of two parts with connections to distinctly separate areas of the brain. There is a lateral or external segment (GPe) and a medial or internal segment (GPi). The substantia nigra and subthalamic nucleus (STN) actually sit just outside of the forebrain in the midbrain. Like the globus pallidus, the substantia nigra has two parts connecting to separate areas of the brain. The dorsal region is the pars compacta (SNc) and the ventral region is the pars reticulata (SNr). The striatum serves as the primary input area of the basal ganglia, while the GPi and SNr are often considered homologous and serve as the primary output structures [6, 7].

Regulation of motor control in the basal ganglia occurs by means of direct and indirect pathways. The basal ganglia receive input from the cerebral cortex, particularly the frontal, prefrontal, and parietal regions, and send output by way of the thalamus back to the cortex,

specifically the supplementary motor area (SMA). This process is often considered to act as a sort of funnel, taking inputs from widespread cortical areas and focusing or funneling them to the SMA [6, 7].

In more detail, the direct motor loop of the basal ganglia begins when the striatum (primarily the putamen) receives excitatory input from the cortex. From here, inhibitory signals are sent to the GPi and SNr, which have inhibitory connections to the thalamus, specifically the ventral lateral nucleus (VLo). The VLo sends excitatory signals back to the cortex to facilitate the discharge of movement related cells in the SMA. In summary, this loop follows the pathway outlined below, where empty arrows represent excitation and solid arrows show inhibition:

Cortex  $\Rightarrow$  Striatum (putamen)  $\rightarrow$  GPi/SNr  $\rightarrow$  Thalamus (VLo)  $\Rightarrow$  Cortex (SMA).

At rest, neurons in the GPi and SNr are spontaneously active, inhibiting the VLo. When the cortex excites the neurons of the putamen to increase its inhibitory output, the normally active neurons of the GPi and SNr are suppressed and their outputs are reduced. As a result of the lower inhibition acting on the VLo, it becomes active and subsequently sends excitation to the SMA [6].

The indirect motor loop operates in contrast with the direct loop, funneling signal from the motor cortex through the basal ganglia to inhibit the SMA. The loop begins in the same manner as the direct loop with excitation of the striatum by way of the cortex. The loops diverge here, however, and the striatum sends inhibitory signals to the GPe, which has inhibitory connections with the STN. The STN provides stimulation to the GPi and SNr, where the paths of the direct and indirect loops are rejoined. Again, the GPi and SNr provide inhibitory connections to the thalamus. The indirect motor loop appears as follows:

Cortex ⇨ Striatum → GPe → STN ⇨ GPi/SNr → Thalamus ⇨ SMA.

Comparing this with the direct motor loop, the clear difference is the excitation of the GPi/SNr by way of the GPe and STN. This excitation further increases the activity of neurons in these structures, increasing inhibition to the thalamus. This leads to reduced muscular activity generated by the SMA. The appropriate balance of the direct and indirect pathways provides the ability to perform coordinated, voluntary movements [6, 7].

In PD, degeneration of cells in the SNc occurs. This structure is responsible for producing the neurotransmitter dopamine. Dopamine is important in facilitating the direct motor loop by activating cells in the putamen. When dopamine levels are diminished, inhibitory outputs from the striatum are reduced. In the direct loop, this allows the cells in the GPi/SNr to remain active and inhibition to the thalamus remains high, preventing appropriate activation of the SMA. In the indirect loop, reduced inhibition of the STN further excites the GPi/SNr and again the thalamus is not able to adequately stimulate the SMA. It is thought that the primary role of the basal ganglia is to take motor plans from the cortex and provide the SMA with the correct motor set and appropriately timed cues to execute the motor plan completely. The ultimate result of PD related changes to the basal ganglia is a reduction in movement amplitude [8].

In addition to issues arising from the dysfunction of the basal ganglia, related external structures may also potentially contribute to PD symptoms. The pedunculopontine nucleus (PPN) interfaces directly with the basal ganglia through circuitry connecting to the substantia nigra and STN. It also has connections to the thalamus, which is the primary output target for the basal ganglia. The PPN also receives input from the basal ganglia in the form of inhibition from the GPi. Reduced activity of the PPN, whether through increased inhibition from the GPi or neuronal



loss in the PPN, has been linked to issues in cyclic motor control and sleep disturbances. Additionally, the PPN may play an important role in other dopamine resistant symptoms, such as akinesia (motor blocks), complex gait disturbances, and primary sensory symptoms. Animal studies have suggested that the PPN plays an important role in the initiation, acceleration, deceleration and termination of locomotion [9]. These factors are important considerations to help develop a more complete understanding of PD.

### *Symptoms and Progression*

PD affects patients through a relatively wide range of symptoms. A significant amount of research has focused on the motor impairments involved in the disease. Through this research, four cardinal motor features have been identified as hallmark symptoms of PD: tremor, bradykinesia, rigidity, and postural instability. In addition to these, there are also several non-motor symptoms that can significantly impact the patient.

Tremor is perhaps the most easily recognizable symptom of PD. It is a regular, rapid, and rhythmic movement, most often occurring in the hands (often described as “pill-rolling” tremors), but also common in the lips, chin, jaw and legs]. The movements are generally unilateral, occurring while at rest and typically disappear during voluntary movements and sleep. The intensity of the tremor may vary in different conditions, aggravated by emotional stress, fatigue, and attempts to suppress it, but lessened in calm and relaxing situations [1]. Though it is often the primary symptom people link to PD, it does not occur in all patients.

Bradykinesia, or slowness of movement, is the most characteristic feature of PD and often becomes apparent prior to any formal diagnosis. Initially, it manifests as slowness in

completing activities of daily living, slow movement, increased reaction times, and difficulty in tasks requiring fine motor control [10]. Bradykinesia is likely to progress over the course of PD and may represent the most accurate marker of disease progression [11]. In addition to slow movement, some patients experience temporary, complete motor blocks (akinesia), an especially troubling occurrence that is highly correlated with falls.

Another common feature of PD is rigidity, or increased resistance to passive movement. This can be exhibited in several forms. “Clasp-knife” rigidity is characterized by increased resistance during rapid extension of an extremity. “Cogwheel” rigidity displays a catching and releasing motion during passive movement. Finally, “lead pipe” rigidity exhibits uniform resistance throughout the range of motion [1]. As the disease progresses rigidity can lead to postural changes, causing the trunk and head to be fixed forward along with slight flexion in the knees and elbows. These changes result in the stereotypical stooped posture associated with PD [10]. Additionally, facial rigidity is common with reduced eye blinking, leading to a masked appearance with limited expressions [1]. In some patients, rigidity can be associated with pain, especially in the shoulders. When occurring prior to PD diagnosis, this is often overlooked and misdiagnosed as arthritis, bursitis or rotator cuff injury [10].

The final cardinal motor feature of PD is postural instability. This typically surfaces later in the progression of the disease after the onset of other clinical features and is thought to result from a loss of postural reflexes [10]. Postural instability, along with akinesia, is a major cause of falls and contributes significantly to the risk of hip fractures and other injuries among PD patients. Increased reaction times and reduced speed and effectiveness of movements make falls especially troublesome since the ability to recover or protect from more serious injuries is significantly compromised.

Though the primary focus of PD has long been motor impairment, there are a number of non-motor symptoms that impact the quality of life for patients. Perhaps the most significant of these is cognitive impairment. It has been found that up to 50% of PD patients develop dementia, a six fold increase over healthy populations. An additional 84% show evidence of cognitive decline [10, 12]. Other neuropsychiatric issues include depression (58%), apathy (49%) and hallucinations (44%). These cognitive changes may play a role in the observed increases in obsessive compulsive and impulsive behaviors exhibited by PD patients [10]. The autonomic nervous system is also affected, demonstrated by increases in salivation, perspiration, and decreased sexual function [1]. Speech disorders may arise, characterized by monotone, quiet, and breathy speech with variations in rate and regular struggles in finding words. Finally, olfactory dysfunction and sleep disorders are also common and may present possible early markers of PD as these features regularly surface prior to diagnosis [10].

A number of studies have shown that the progression of PD begins with a pre-symptomatic period in which neurodegeneration occurs prior to the onset of any clinically evident symptoms [2]. Imaging studies have estimated this period to range from 3 to as many as 15 years. More recently, patients considered at risk of developing PD (via diagnosis of a specific sleep disorder) were tracked. These patients showed early evidence of abnormal UPDRS scores around 4.5 years prior to clinical diagnosis of PD [3]. It appears that the progression of the disease is non-linear, with a faster rate of deterioration in the early years (generally the first five years). This progression is also thought to vary depending on the primary symptoms [11]. Those primarily affected by akinesia, rigidity, and postural instability tend to lose motor function more rapidly compared to tremor predominant subtypes [13]. Symptoms also seem to progress at different rates by location in the body, becoming evident first in voice and facial akinesia,

followed by rigidity, gait abnormality, bradykinesia, and finally tremor [3]. Understanding the disease progression may assist in determining early markers of PD, which could allow earlier management of the disease in hopes of slowing the rate of progression.

### *Current Therapies*

The central goal of medical therapy in PD has been to boost the levels of dopamine to offset losses due to degeneration of the basal ganglia. To achieve this, the compound L-dihydroxyphenylalanine (L-dopa) is used. This compound is the precursor to dopamine. It is prescribed in the form of a medication called levodopa, which crosses the blood-brain barrier and boosts dopamine synthesis in the remaining cells in the substantia nigra pars compacta [6]. Levodopa was introduced in the late 1960s as the first highly effective treatment for PD and still remains the single most effective therapy for patients today [14]. As a result, the morbidity and mortality rate of PD patients has been significantly reduced and they now have a life expectancy approximating that of the normal population [15]. Levodopa has a relatively rapid onset of effect and significantly improves a majority of the hallmark features of PD. Unfortunately; it does not stop the disease's progression. It was previously believed that treatment with levodopa may hasten the progression of the disease, but evidence has since suggested that this is not the case and that it may in fact slow it to an extent [16].

Levodopa is highly effective at controlling many of the primary symptoms of PD. Of the cardinal features, bradykinesia and rigidity usually respond well to levodopa. This results in dramatic improvements in motor function, especially evident through increases in walking speed. Tremor is more variable, but is often well controlled. On the other hand, postural instability

appears to be somewhat resistant to dopaminergic therapy [14]. In addition to these parameters, levodopa appears to result in more consistent performance as demonstrated by improvements in gait variability [17]. While levodopa has been successful at controlling most of fundamental motor symptoms, more abnormal motor features as well as many non-motor symptoms tend to resist the therapy. Unresponsive motor features include postural instability, speech, swallowing, and freezing of gait (FOG). Non-motor issues such as cognitive dysfunction, depression and autonomic nervous system dysfunction (orthostatic hypotension, thermoregulatory problems, constipation, sexual dysfunction, and urinary complications) occur in PD with variable frequency and severity and also tend to resist medical treatment. Finally, there are a number of sleep related issues in PD (sleep fragmentation, restless leg syndrome, sleep apnea, and rapid eye movement (REM) sleep behavior disorder (RBD)) that not only do not respond well to medication, but may actually be intensified by levodopa [14].

The overwhelming benefit of levodopa therapy is clear, as patients have benefited from improvements in mobility and quality of life since its introduction. However, there are several problematic changes that may occur as the duration of treatment increases. Dyskinesia, exhibited by involuntary movements, becomes more frequent as the duration of levodopa treatment increases. It is estimated that 30-35% of patients on levodopa for five years or more develop dyskinesia [14]. This may be eliminated by reducing levodopa therapy, but at the expense of increasing symptoms sensitive to the medication [15]. Mental changes can also occur as a result of long duration treatment. These changes may include confusion, paranoia, visual hallucinations (particularly in those with cognitive impairment), and dementia. It is suspected that new onset of these mental changes are often a precursor to the development of dementia. Finally, motor fluctuations may occur where the medication loses effectiveness or remains active for shorter

periods. In some cases (e.g. hallucinations) additional medications may be taken in combination with levodopa to control the secondary symptoms [14].

Fortunately, those who develop difficulties with levodopa treatment may have better results with deep brain stimulation (DBS). DBS involves the implantation of a medical device that sends electric signals to specific areas of the brain. In PD, the STN is the common target. Appropriate candidates for DBS are not those whose symptoms do not respond to levodopa, but rather those with fluctuating responses or dyskinesia. Symptomatic improvement resulting from STN-DBS is approximately equivalent to the best levodopa response. Therefore, DBS makes it possible to consistently sustain this response, thus eliminating motor fluctuations. Since levodopa is no longer required with DBS, further issues related to the medication, such as dyskinesia, are halted as well. DBS typically does not improve symptoms that are not affected by levodopa, but tremor may be controlled more consistently with DBS [15].

### *Gait Complications*

Gait complications are common in PD, probably resulting from the progressive loss of dopamine producing cells in the basal ganglia. The absence of dopamine ultimately results in the loss of gait automaticity [18]. The characteristics of PD gait result from the combined effects of the fundamental motor symptoms discussed previously, resulting in a gait pattern with reduced arm swing and trunk rotation; forward stooped posture; reduced motion at the hips, knees, and ankles; slowness; reduced step size; and low ground clearance [19]. Gait changes are not confined in a single aspect of the gait pattern, but occur from scaling down of spatial (i.e. stride length), kinematic (i.e. joint angles), and kinetic (i.e. joint moments) aspects [20]. As a result of

these complications, community ambulation is impaired by reduced endurance; negotiating obstacles and varied surfaces; and monitoring the dynamics of the surrounding environment. This is compounded by impaired balance and postural control, leading to a heightened risk of slips, trips, and falls [19].

One of the most prominent features of PD gait is a significant reduction in gait velocity. Morris, et al. [19] found that PD patients walked with a velocity range between 0.67 – 1.0 m/s, compared to a pace of 1.25 – 1.5 m/s in healthy controls. This is generally thought to be a direct result of significant reduction in stride length. This is a key measure in PD progression. Stride length appears to have a significant correlation to motor UPDRS scores, where more drastic reduction of stride length indicates more severe impairment [21]. Step width is commonly increased in PD when compared to healthy controls. The widening of the stance is likely a compensatory strategy used to enhance postural stability by reducing the magnitude of lateral body sway [22]. These changes, especially in stride length, may be explained in part by abnormal force regulation and kinematic changes. Flat-footed walking and reduced joint range of motion in the lower limbs results in diminished vertical and frontal ground reaction forces, especially during push-off. This results in reduced movement amplitude, which occurs across all joints of the lower extremity [19]. Despite differences in the above gait characteristics, the patterns of movements and movement adjustments are similar to those of healthy subjects. This suggests that the normal motor command from the motor cortex remains intact, but the dysfunctional basal ganglia are unable to maintain and match the required movement amplitude [20].

Shortened stride length plays a major role in the reduction of gait velocity. However, cadence – another major factor in determining gait velocity – appears to remain intact in PD. A majority of studies report cadence values in a normal range of 100 – 110 steps per minute for

patients [17-19, 23, 24]. Conversely, one study reported that early stages of PD (H&Y stages 1 and 2) may exhibit reduced cadence influencing gait speed [21], while another suggested some patients may increase their step frequency to compensate for reduced stride length [17]. A more important temporal variable may be double-support time. It has been shown that PD patients off of medication increase the time spent in double support from the normal 20-30% of the gait cycle to over 35% [19]. This increase in double support time, a measure related to postural instability, is generally improved with dopaminergic medications [24].

Another strong indicator of postural instability is increased stride-to-stride variability. This may be measured in any number of gait parameters, but is most commonly examined in stride length or stride time. In populations without PD, variability of gait has been shown to be a strong predictor of falls. This relationship was also observed in PD where a significant association has been shown between gait variability, fall frequency, and UPDRS scores [17]. A review of studies found a reported incidence of falling for 38 – 62% of PD patients over a one year period [19]. As already mentioned, falls are particularly dangerous in PD since patients are often unable to respond appropriately to recover or reduce injury potential. The reported issues with gait variability may indicate an impairment of the internal clock mechanism responsible for producing the periodic signals that drive event timing in automatic and sequential movements [17]. Similar to stride length, gait variability is generally controlled with dopaminergic therapy and performance at peak dose is comparable to that of healthy subjects [19].

One of the most troubling complications in PD is freezing of gait (FOG). FOG is generally a sudden and transient (typically lasting less than 10 seconds) inability to move and is another potent cause of falls in PD. It has been classified into five subtypes of behaviors that commonly induce freezing: gait initiation, turning, confined spaces (e.g. doorways or crowded



environments), reaching a destination, and walking in open spaces [10]. FOG does not occur universally – occurring in about half of all patients – and appears to be linked with greater disturbances to timing and rhythmic control of gait. This is sometimes referred to as a sequence effect, where the magnitude of variability and step shortening are compounded over several steps, ultimately leading to freezing [25]. Additionally, FOG has a strong link to those primarily affected by rigidity, bradykinesia, postural instability and longer disease duration. In contrast, those with early onset of tremor typically have a reduced risk of developing FOG [10].

Of the factors that contribute to FOG, turning is perhaps the most troublesome. It has been estimated that at least two turns are made every ten steps while performing ADL, so the ability to turn during walking is vital to maintaining daily functionality. Patients with PD, including those without FOG, take more steps to complete turns with the total number of steps increasing more steeply in larger turning angles [19]. In research settings, PD patients with FOG have shown significant deviations from those without FOG when making larger turns – in the range of 180 to 360 degrees – and these types of turns have been suggested for provoking FOG episodes in research settings [19]. In most instances, dopaminergic therapy appears to reduce the occurrence and/or the severity of FOG [10].

Cognitive decline is another important factor related to motor function. Evidence suggests that cognitive impairment and dementia are associated with the severity of several motor symptoms. Williams, et al. [12] found that bradykinesia, rigidity, and postural instability show significant correlations to scoring on the Mini Mental State Examination (MMSE) and Dementia Rating Scale-2 (DRS-2). Going further, bradykinesia was discovered to be a significant predictor of cognitive function [12]. This relationship is demonstrated by the introduction of secondary tasks during gait. Gait performance, especially variability, may

deteriorate while performing a secondary task during walking. It has been proposed that there is a functional coupling of cognitive and motor performance, so that challenges in one domain will compromise performance in the other. This may suggest two points. First, while gait is a relatively automatic process in most, it may require more input from the cerebellum and cortical structures to compensate for the dysfunctional basal ganglia. Second, the overall attentional resources in PD patients may be diminished, limiting the ability to perform multiple tasks at once [26]. In addition to issues with simultaneously performing tasks, Marsden and Obeso [27] claim impairments in PD patients in switching from one task to another. Stated more broadly, PD patients may have difficulty in motor planning. Directional changes, whether triggered in a research lab or by an event in a home setting (e.g. ringing telephone), are time-critical tasks that involve rapid perception of a cue followed by rapid modification to the motor program. During the transition to and execution of this modified motor program, postural control and dynamic balance must be maintained [22]. Impaired ability to appropriately ration cognitive resources could result in ineffective transition of motor programs, a potential source of FOG, or worse yet, loss of balance and falls [28].

### *Sleep and Fatigue*

Sleep disturbances are believed to be an integral part of PD, as a majority of patients suffer from some form of sleeping issue. Insomnia, especially sleep fragmentation, occurs in over 50% of patients, though its occurrence is highly variable [10]. It is suggested that sleep quality changes throughout the course of PD. As the disease progresses, sleep latency tends to increase while total sleep time, deep sleep time, rapid eye movement (REM) sleep time, and

sleep efficiency decrease. As a result, excessive daytime sleepiness is a frequent burden of PD patients [11]. There is some thought that dopamine levels may be restored during sleep, suggesting that increased sleep quality and time should result in greater degrees of benefit to dopamine levels. If accurate, this should ultimately result in improvements to dopamine sensitive symptoms [29]. While there are a variety of sleep disturbances in PD, the strong association to REM sleep behavior disorder (RBD) is of particular interest.

During normal REM sleep, muscle tone is abolished (sleep atonia). In RBD, this inhibition is impaired resulting in simple or complex motor behavior during REM sleep associated with the enactment of vivid dreams [11]. In addition to the loss of sleep atonia, an increase in violent dream content is common. As a result, the enactment of these dreams often involves grabbing, punching, kicking, jumping, and other dramatic movements. This generates significant injury potential to the patient as well as the bed partner [10]. Additionally, talking and yelling during sleep is increased in RBD as well. It is estimated that 1/3 of PD patients have RBD, with an additional 1/3 demonstrating loss of REM atonia but lacking other symptoms to warrant diagnosis of RBD [2]. Not only is RBD common in PD, but in many cases it may precede diagnosis of PD by as many as 13 years. Further, it is estimated that over 50% of people with RBD will develop neurodegenerative disorders, almost exclusively PD, multiple systems atrophy, or dementia with Lewy bodies [3]. De Cock, et al. [29] found that 22% of patients developed RBD prior to being diagnosed with PD, 23% had diagnoses at the same time, and 55% were diagnosed after onset of PD. In this particular study, the latency period ranged from a few months to four years. Those with RBD typically demonstrate the non-tremor predominant form of PD, higher mean dosage and duration of dopaminergic therapy, and higher occurrence of dyskinesia [30]. The combination of high correlations between RBD and PD and the onset of

RBD prior to PD diagnosis suggest RBD could be a strong predictor and potential early marker for identifying PD.

Another unique feature of RBD is observed during the periods of activity in REM sleep. Bed partners of PD patients with RBD consistently report significant improvements in movement and speech quality during sleep. They have reported that the speed, strength, and coordination of motion as well as the volume and articulation of speech are much better than when awake. Further, patients with unilateral impairment were more active with the affected side during RBD performing more symmetrical movements. These changes are observed while patients are typically off of dopaminergic therapy, occurring with no presence of tremor or bradykinesia, and even involve patients with the most severe motor impairment. The mechanism of this unique condition is still unknown, but may suggest that the normal functioning of the basal ganglia is restored in REM sleep. Alternatively, the upper motor neurons, specifically the SMA, may no longer be submitted to the inhibitory influence of the dysfunctional basal ganglia. This second thought is supported by observation of broken, jerky, and rough movements. This might suggest these movements are an expression of the primary motor cortex and are relieved from the filtering and smoothing control in the basal ganglia [29].

Despite the observed improvements in motor control during sleep in those with RBD, studies have not been able to consistently show a significant difference in gait and postural control of PD patients with RBD to those without the sleep disorder. A study by Benninger, et al. [31] reported that gait variability was significantly greater than healthy controls in PD groups with and without RBD. While the RBD group had greater variability than the non-RBD group, this finding was not significant. The reported conclusion of this study was that PD patients with RBD could not be discerned from those without on the basis of gait and postural control.

Bugalho, et al. [32] suggest that there is a higher degree of dysfunction in PD populations with RBD. This occurs as a result of the specific PD motor subtype as well as executive deficits, visuo-spatial dysfunction, and mild cognitive impairment. In this study, the non-tremor motor subtype appeared to be related to RBD symptoms history rather than the presence of RBD clinical criteria at the time of evaluation. This finding suggests that although the RBD symptoms can fluctuate over time and even disappear completely in some instances, the pathophysiological changes that associate RBD and degree of motor disability remain. The exact relation between RBD and gait impairment remains unclear, but existing evidence warrants further examination of this association.

Fatigue – a symptom often considered with sleep issues – is common in many chronic brain disorders, including PD. Up to 2/3 of PD patients report an overwhelming sense of tiredness, lack of energy and feeling of exhaustion. As a result, fatigue is considered by many patients to be the most debilitating feature of the disease [33]. Fatigue increases during disease progression and does not seem to be explained by the co-occurrence of other issues such as depression or daytime sleepiness. Rather, it is thought to be a sign of the pathological progression of the disease [11]. There appears to be some connection between fatigue and motor function. In a study by Hagell and Brundin [33], 48% of the patients were fatigued and 74% of those patients experienced a worsening of motor symptoms as a result. Motor fluctuations were experienced by 53% of the fatigued patients, and 83% of this group reported worsening of fatigue when off of levodopa. Motor symptoms found to be associated with fatigue were axial, postural and gait related while tremor, rigidity, and bradykinesia were not impacted. In addition to the motor symptoms, Hagell and Brundin [33] reported an association of fatigue with depression, anxiety, reduced motivation, and pain. It was found that anxiety tends to be a

stronger predictor of fatigue than depression, and that lack of motivation is also a strong indicator. While it seems logical to link fatigue with poor sleep, it has been demonstrated that fatigue cannot be explained by excessive daytime sleepiness or poor sleep. This distinction between the two is important, suggesting different neurobiological backgrounds that require different treatment strategies [33].

### *Alternative Exercise Therapies*

The value of exercise for general health benefit is well known. This holds true for patients with PD and there is evidence that different forms of exercise and physiotherapy can be effective in some aspects of disease management [34]. Because of the chronic and debilitating symptoms of PD, patients often use complementary therapies [35]. It is estimated that 1/3 of adults in the United States use some form of alternative therapy. This proportion is higher in PD, where approximately 40% of patients use some form of alternative therapy for treatment of PD symptoms [36]. These therapies may include aerobic exercise, strength training, Tai Chi, Qigong, Yoga, acupuncture, and dance among others. This particular review of alternative therapies will focus on the practice of Qigong, including its close relationship to Tai Chi from a research perspective.

Traditional Chinese Medicine (TCM) describes a broad range of wellness practices that have been developed over thousands of years. One area of TCM is known as meditative movement. This consists of three key elements – focus on regulating the body (movement and posture); focus on regulating the breath; and focus on regulating the mind (consciousness) – to achieve a meditative state [37]. According to TCM, health is believed to be a state of natural

balance achieved through regulation of the three elements of meditative movement, the spirit, and Qi (life energy) [38]. Qigong falls into this category of meditative movement. Qigong means, roughly, to cultivate or enhance the inherent functional (energetic) essence of the human being. There are many branches of Qigong that have a health and medical focus, which have been refined for well over 5000 years. The practice of Qigong consists of a series of orchestrated practices that involve body posture and movement, breath practice and meditation, all designed to enhance Qi function – that is, drawing upon natural forces to optimize and balance energy within the body through the attainment of deeply focused and relaxed states. From the perspective of Western thought and science, Qigong practices activate naturally occurring physiological and psychological mechanisms of self-repair and health recovery [37].

Qigong and Tai Chi share common theoretical roots, operational components, and similar links to wellness and health-promoting aspects of TCM. Traditionally, Tai Chi is performed as a highly choreographed, lengthy, and complex series of movements, whereas Qigong is typically a simpler, easy-to-learn, repetitive practice. While Tai Chi has become a well-known and studied aspect of TCM, it is important to note that in many medical applications, particularly when applied to research studies, the Tai Chi being implemented is a simplified version of the traditionally complex forms. The result is an exercise that falls more in line with forms of Qigong. An extensive review of health related benefits indicates that the implementation of Qigong and Tai Chi programs result in similar patient outcomes in a variety of measures. As a result of this discovery, along with the similarity in theoretical roots and implementation into research studies, Jahnke, et al. [37] suggest Qigong and Tai Chi may be treated as equivalent in terms of studying health benefits when implemented as a complementary medical therapy.

There has been a significant amount of research concerning the impact of Qigong and Tai Chi on physical performance and motor control. Perhaps the most consistent finding in interventions involving Qigong and Tai Chi is improved postural stability and balance. A majority of studies concerning balance reported significant improvements as a result of meditative movement interventions. Comparisons of Tai Chi with alternative forms of exercise, including axial mobility, walking, and stretching programs, showed significant improvements in balance assessments (Timed Up and Go, chair rise) and fall frequency in the Tai Chi groups. This was evident in elderly, sedentary, arthritic, and frail populations [37]. Resistance training, on the other hand, resulted in no significant difference in these measures when compared to Tai Chi in elderly populations [37]. When considering the outcomes of meditative movement specific to PD, similar trends were found. Tai Chi showed significant improvements in balance (Berg Balance Scale and Timed Up and Go) and fall frequency in patients with mild to moderate PD when compared to inactive controls [34, 39]. In addition to these observed changes, those participating in meditative movements, both in PD and non-PD populations, reported significant improvement in fall self-efficacy and reduced fear of falling [37, 40]. It is possible that this increase in confidence may allow the patients to participate in activities they may have previously withdrawn from, having positive effects on quality of life.

In addition to postural stability, gait and mobility appear to be positively impacted by Tai Chi and Qigong, though these results are less consistent. Comparisons of Tai Chi with wellness education, stretching programs, and vestibular rehabilitation showed a significant improvement in gait velocity associated with the meditative movement therapy. This was observed in elderly and frail populations, as well as those with vestibulopathy [37]. However, other studies of similar populations comparing Tai Chi with stretching/calisthenics, resistance training, and no



interventions found no significant changes in velocity between the groups [37]. It also appears that meditative movement therapy may be beneficial at improving step length and stance time in elderly and vestibulopathic populations, with improvements similar to those seen in resistance training and vestibular rehabilitation [37]. The available data for changes in gait quality in PD populations as a result from meditative movement is limited. One study of Tai Chi in PD showed a significant improvement in gait velocity from baseline performance, while a second study failed to show a significant difference in the intervention group compared to a non-exercising control group [39]. In general, Tai Chi has received the most attention when considering gait performance, however a study involving PD groups involved in Tai Chi and Qigong showed no significant difference in changes to gait performance, including velocity, stride length, stance time and double support time [35]. As a result of the inconsistent findings in previous studies, the effects of meditative movement therapy on gait are still inconclusive, but there is reason to believe these exercises may have a positive influence and further studies are warranted to determine the impact.

Tai Chi and Qigong have shown beneficial effects on several non-motor symptoms as well. The meditative movements appear to have a significant impact on psychological aspects of quality of life. Interventions led to significant improvements in anxiety, depression, and stress – including the perceived ability to deal with stressful or novel experiences [37, 41]. Outcomes related to cardiopulmonary measures showed positive responses to meditative movement as well, particularly in lowering blood pressure. Qigong and Tai Chi interventions showed significant benefit to lowering blood pressure in subjects with hypertension when compared to controls receiving usual care or wellness education [37]. Along with the cardiovascular effects, sleep and fatigue were also improved following participation in Tai Chi and Qigong interventions. While

actively participating in these exercise therapies, sleep quality showed significant improvement [37, 39]. In a study involving PD patients participating in Qigong exercise, this improvement in sleep quality returned to pre-intervention levels following cessation of the exercises; however, there was a lasting reduction of daytime sleepiness following the intervention [42]. Liu, et al. [41] implemented the “six healing sounds” form of Qigong in a study involving patients with fibromyalgia. Results from this study indicate significant improvements in level of fatigue and improved sleep quality when compared to a sham Qigong group, though the sleep measure fell short of significance ( $p = 0.058$ ) due primarily to a small sample size.

Evidence of potential changes to both motor and non-motor aspects of PD as a result of participating in meditative movement therapies suggests that these types of exercises can provide significant benefit to those suffering from the disease. The underlying mechanism responsible for these changes is still unclear, but there are several possible features of the exercise that may help understand the benefits. First, a majority of the interventions implemented in research involve some sort of group exercise session. Social support has been shown to play a major role in the ability for patients to deal with PD and its related symptoms. Activities that improve social networking and encourage social interactions can have a significant impact on self-efficacy – the sense of ability to deal with a situation. Improved self-efficacy can positively impact many aspects of quality of life, including depression, anxiety, stress, and confidence in physical performance [40, 43]. Another potential benefit may be the biochemical response that occurs as a result of exercise. It is claimed that physical activity may help protect dopamine-producing cells from degeneration, maintaining or even increasing dopamine levels in the brain [34]. Another study claims that exercise may induce a sense of well-being through the release of serotonin [38]. This is particularly interesting when considering the link between PD and RBD. One drug used

in the treatment of sleeping issues in RBD is thought to provide its effect through the increased synthesis of serotonin [30]. The observed changes in sleep quality resulting from these alternative therapies may provide additional support for this claim. Finally, it is thought that the characteristics of meditative movement generate a variety of benefits through its dynamic quality, body-part connectedness, and mental intention of practice. This may improve muscle recruitment within stabilizing muscles and slow twitch fibers of primary movers, increasing strength, balance, and coordination of movement [38].

Meditative movement therapies have demonstrated numerous potential benefits to a variety of populations and may be of special interest to those with PD. The potential benefits of complementary therapy in the management of motor and non-motor symptoms make these exercises a promising option for improved function and quality of life. These exercises have been shown to be easy to implement in a variety of groups, both healthy and chronically ill. Overall, those participating have indicated they are satisfied with the perceived benefits and enjoy participating in the therapy [37, 39, 44, 45]. Many report an intention to remain involved in the exercises, either by joining new groups following the completion of an intervention or by continuing on their own. Regardless of the measured outcomes, these exercises may prove beneficial to overall health by increasing the level of activity social support for those involved.

### *Summary*

Parkinson's disease can have a major impact on the quality of life of those with the disease as well as their families, friends, and caretakers. There are a number of symptoms, both motor and non-motor, that lead to these difficulties. Gait impairment and reduced sleep quality

are highly important components of the disease and its impact on those affected by it. The loss of ability and confidence in gait, both in home and community settings, can lead to a loss of independence and a tendency to feel more isolated and alone. Poor sleep quality can lead to a lack of energy and stamina throughout the day, further decreasing the motivation to engage in activities. Current medications have been very successful in treating some of the most debilitating aspects of the disease, but troubles with sleep and some aspects of gait tend to resist standard therapies and remain unchanged. Discovering a complementary therapy that addresses these symptoms could be a major benefit to patients and their loved ones.

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## CHAPTER THREE: STUDY

### *Abstract*

*Background:* Parkinson's disease (PD) involves a variety of motor and non-motor symptoms. Current medical therapy has been successful at managing a majority of these features; however, several issues, including gait complications and sleeping disorders, may involve impairments not fully resolved by standard therapy. This study aimed to determine the impact of Qigong as a potential complementary therapy in the management of gait and sleep related symptoms in PD.

*Methods:* Seven subjects (age  $66.86 \pm 8.13$  years) with PD participated in a six-week Qigong exercise intervention. Pre- and post-intervention testing was performed to assess sleep quality, fatigue, and gait performance in these subjects. Standard clinical assessments specific to PD were used for the assessment of sleep quality and fatigue. Gait performance was assessed using three-dimensional motion capture during the completion of several tasks. Overall gait performance (stride time, stride length, double support time, and velocity), gait variability (stride time variability and stride length variability), and turning performance (number of steps and total time to turn) were analyzed in the gait tasks.

*Results:* Following the intervention, subjects showed a general trend of improvements in sleep quality. Fatigue remained unchanged. Assessment of gait performance showed significant improvement in overall gait function and gait variability, and no apparent change in turn performance. Gait function was improved by a significant reduction of stride time and a slight increase in stride length. Together these changes resulted in significant improvements to gait velocity. Additionally, time spent in double support was reduced following the intervention.

Overall gait variability improved significantly, particularly in the reduction of stride time variability.

*Conclusions:* These results suggest that the Qigong intervention implemented for this group may provide potential benefits to people with PD in regards to gait performance and sleep quality. Further studies are required to provide a more definitive measure of these results with increased statistical power.

### *Introduction*

Parkinson's disease (PD) is a neurodegenerative disorder of the basal ganglia that affects approximately 1.5% of adults over the age of 65 [1, 2]. The disease is expressed through a variety of motor and non-motor symptoms. It is generally associated with four primary features of motor impairment. These include tremor, bradykinesia (slowness of movement), rigidity, and postural instability [3]. These symptoms result in a broad range of motor difficulties and are especially apparent in gait. Non-motor features of the disease are quite variable, but symptoms commonly experienced include cognitive impairment, depression, apathy, impaired speech, olfactory dysfunction, and sleeping disorders [1, 3, 4]. PD is a progressive disease, with the occurrence and severity of symptoms typically worsening with disease duration. Because of the slow progressive nature and gradual onset of symptoms, a significant amount of degeneration typically occurs prior to diagnosis of PD [2]. Because of this, early identification of the disease is vital in order to implement therapies to address disease symptoms and potentially slow its progression.



*Gait Complications:* The cardinal motor features of PD combine to create a characteristic gait pattern. This includes reduced arm swing, reduced trunk rotations, stooped posture, reduced range of motion in the lower extremity, slow gait speed, reduced step size, and low ground clearance [5]. This pattern is a result of changes in all aspects of gait, including spatial, kinematic, and kinetic parameters [6]. These changes likely occur due to diminished levels of dopamine in the brain caused by the degeneration of the basal ganglia.

The most apparent change in PD gait is reduced walking speed. Gait speed is primarily determined by the interaction of stride length and cadence. Previous studies suggest that the primary contributor to low velocity is shortened stride length. This likely occurs due to reduced range of motion in the lower extremities and diminished vertical and frontal ground reaction forces during push off [5]. Further, stride length appears to have a significant correlation with motor UPDRS scores, with more severe impairment showing a more drastic reduction of stride length [7]. The other contributor to gait speed, cadence, seems to remain relatively intact in PD. Most studies have found people with PD to maintain a cadence in the normal range of 100 to 110 steps per minute [5, 8-10]. With temporal control remaining relatively normal, it is hypothesized that the motor command is unaffected in PD, but the dysfunctional basal ganglia cause the inability to match and maintain the required movement amplitude necessary to generate normal gait velocity [6].

Postural instability is another major feature of gait in PD. One indicator of this is time spent in double support [10]. Typically, this falls in the range of 20% to 30% of the gait cycle, but may be increased to over 35% in PD patients [5]. Another parameter highly correlated to postural instability is stride variability. This has been associated with increased fall frequency and UPDRS scores in PD patients [5]. In addition to these variables, some patients experience

complete motor blocks, or freezing of gait (FOG). These episodes occur in about half of all patients [11]. Together, these three parameters lead to a high incidence of falling, ranging from 38% to 62% of patients over a one year period [5, 12]. Falls are especially dangerous to PD patients due to their increased reaction times and reduced movement amplitudes, which hinder their ability to recover or protect themselves from serious injury.

Finally, cognitive function plays a significant role in motor control. Many motor features, including bradykinesia, rigidity, and postural instability show a strong correlation to cognitive decline [4]. This becomes increasingly evident during cognitively challenging situations, such as dual task performance or switching from one task to another (set-shifting) [13, 14]. There appears to be a functional coupling of cognitive and motor performance, and in PD where these domains are already impaired, challenges in one area can further compromise performance in the other [14].

*Sleep Complications:* Sleeping disorders impact a large number of PD patients. It is estimated that over 50% of patients have insomnia, usually presenting as sleep fragmentation [3].

Additionally, there is a general trend towards increased sleep latency and reduced total sleep time, deep sleep time, rapid eye movement (REM) sleep time, and sleep efficiency as the duration of disease increases [12]. There is some belief that sleep helps to restore dopamine levels in the brain, suggesting that improved quality of sleep and total sleep time may help alleviate some dopamine sensitive symptoms [15].

One specific disorder that is of particular interest in PD is REM sleep behavior disorder (RBD). People with RBD experience a loss of muscle tone inhibition (atonia) during REM sleep.

This leads to the occurrence of simple or complex movements associated with the enactment of vivid, and often violent dreams during REM sleep [3, 12]. It is estimated that 1/3 of PD patients have RBD, while another 1/3 experience some loss of REM atonia [2]. RBD may also be an important early indicator of PD. Studies have estimated that over 50% of people with RBD will develop some form of neurodegenerative disorder, a large portion of them PD. This may precede diagnosis of PD by as many as 13 years [16]. Additionally, there are conflicting claims that RBD may be associated with more severe motor symptoms in PD [17, 18]. Though this particular association remains unclear, the apparent relationship of RBD and PD make this an interesting topic for continued study.

*Fatigue:* Fatigue is considered by many patients to be one of the most debilitating features of PD. Previous work suggests as many as 2/3 of patients experience an overwhelming sense of tiredness, lack of energy, and feeling of exhaustion as a result of the disease [19]. There has been some association between fatigue and motor impairment. Of patients that were fatigued, 74% reported worsening of motor symptoms as a result. This is primarily linked to axial, postural, and gait related symptoms while tremor, rigidity, and bradykinesia seem to be less affected [19]. Fatigue does not appear to be linked to other symptoms such as depression, excessive daytime sleepiness, or poor sleep quality, but rather appears to be a sign of the pathological progression of the disease [12, 19].

*Complementary Therapies:* The current standard in the treatment of PD, levodopa, was introduced in the late 1960s. Since that time, it has been highly effective at controlling many

symptoms of PD, especially those related to bradykinesia, rigidity, and tremor [20]. Despite the overwhelming benefit of the medication, it still has several limitations. Postural instability, FOG, and many non-motor symptoms tend to be unaffected by the medication. Some, particularly sleeping related issues, may even be intensified by it [20]. Further, long duration and high dosages of levodopa may lead to additional complications, including dyskinesia, mental changes, and motor fluctuations [21]. These limitations highlight the need for complementary therapies that may better address these aspects of the disease.

It is estimated that 1/3 of adults in the U.S. use some form of alternative therapy, with an even greater ratio of 40% in PD patients [22]. Existing evidence suggests that different forms of exercise and physiotherapy can be effective in the management of some aspects of PD [23]. This includes therapies that fall under the umbrella of Traditional Chinese Medicine (TCM), which consists of a broad range of wellness practices that have been developed for thousands of years. One branch of TCM is meditative movement. Meditative movement therapies, which include exercises such as Tai Chi and Qigong, incorporate three key elements – focus on regulating the body (movement and posture), focus on regulating the breath, and focus on regulating the mind (consciousness) [24]. Following an extensive review of literature, Jahnke, et al. [24] have suggested that due to common theoretical roots, operational components, and patient outcomes of Tai Chi and Qigong, these two therapies may be considered equivalent from a research standpoint.

The practice of Qigong uses the fundamental elements of meditative movement to activate natural physiological and psychological mechanisms of repair and recovery through the attainment of deeply focused and relaxed states [24]. Implementation of meditative movements has shown improvements in several motor and non-motor symptoms common in PD. The most

consistent finding was improvements in postural stability and balance [23-27]. In most cases, these results were similar to those seen in conventional exercise. Improvements in gait function were also seen, though these findings were not as consistent as several studies found no significant changes in gait following meditative movement therapy [23-25, 28]. Non-motor issues improved by meditative movement therapies included psychological (depression, anxiety, and stress), cardiopulmonary (most commonly blood pressure), sleep and fatigue [24, 25, 29]. Liu, et al. [29] implemented the “six healing sounds” form of Qigong – the specific intervention being used in the current study – for a group of fibromyalgia patients. This study showed significant improvements in fatigue and sleep quality ( $p < .0125$ ) following a six week intervention. In addition to these benefits, meditative movement therapies have been shown to be easy to implement and are well accepted and enjoyed by those participating [24, 25, 28, 30]. These results show promise for Qigong and related therapies to provide significant benefit to patients suffering from PD.

*Study Aims and Hypothesis:* This study aimed to explore the impact of implementing Qigong as a complementary therapy for patients with PD. Specifically; parameters relating to gait performance, sleep quality, and fatigue were investigated in depth. It was hypothesized that following completion of a six week intervention, patients would show improvements in gait performance as measured by three-dimensional gait analysis and sleep and fatigue as measured by questionnaires specific to these parameters in PD. This served as an exploratory study to determine the efficacy of a larger scale study that would be designed to provide more powerful statistical evaluation.

## *Methods*

*Subjects:* Twelve subjects with mild to moderate PD were recruited from the Parkinson's Disease and Movement Disorder Center at the University of Kansas Medical Center (KUMC), Kansas City, and completed baseline testing for the study. Five subjects were unable to complete the study in its entirety (two due to loss of contact, two due to transportation issues preventing attendance at weekly group exercise sessions, and one due to a death in the family), and therefore analysis was performed for the seven remaining subjects (**Table 1**). Consistent with previous studies of meditative movement, subjects with mild to moderate PD were chosen as they are still able to perform most daily activities independently, although often slowly [23, 25, 27, 28, 31]. This includes the ability to independently perform the prescribed exercise program.

All subjects provided informed consent to participate in the study as approved by the Institutional Review Board at KUMC. Subjects were screened using a phone interview and assessments performed during their initial visit. They were included if they met the following criteria: a) diagnosis of idiopathic PD; b) men and women between the ages of 40-89 years; c) Hoehn & Yahr (H&Y) stage I – III [32]; d) ability to walk unassisted for the required gait tasks; e) on a stable dose of anti-parkinsonism medication for at least two weeks prior to beginning the study; and f) no known intention of changing anti-parkinsonism medications and/or dosages during the course of the study. Exclusion criteria included: a) score of less than 23 on the Mini Mental State Examination (MMSE) [13, 33]; b) other neurological, orthopedic, or medical conditions that interfere with gait; c) treatment using deep brain stimulation; and d) occurrence of FOG only during the “on” state of medication.

*Testing Procedure:* All testing was performed at the Human Performance Laboratory at KUMC's Landon Center on Aging. All testing was performed after the subjects had withdrawn from their anti-parkinsonism medication for a minimum of 12 hours. This results in a "practically defined off" state that allows for the assessment of the severity of the underlying unmedicated condition [10, 34].

*Clinical Assessments:* Clinical assessments were used to assess level of disease impairment as well as sleep quality and fatigue. The Unified Parkinson's Disease Rating Scale (UPDRS) was performed by an experienced and qualified member of the neurology team at KUMC to assess the level of impairment due to PD [35]. Sleep quality was assessed using the revised Parkinson's Disease Sleep Scale (PDSS-2). This 15 item questionnaire surveys sleep issues related to motor symptoms at night, PD symptoms at night, and disturbed sleep [36]. Fatigue was assessed with the 16-item Parkinson Fatigue Scale (PFS-16) [37].

Because this study served to explore the potential impact of the exercise intervention on PD symptoms, additional measures were taken to assess quality of life, non-motor symptoms, and cognitive function. Assessment of quality of life was done using the 39-item Parkinson's Disease Questionnaire (PDQ-39) [38]. The impact of non-motor symptoms was assessed using the Non-Motor Symptoms Questionnaire (NMSQuest) [39]. Finally, cognitive function was assessed using several methods. The MMSE was used to assess overall cognitive impairment [33]. The Frontal Assessment Battery (FAB) was used for the assessment of executive dysfunction [40]. The Trial Making Test, parts A and B (TMTA and TMTB) were used as assessments of executive function and task-switching abilities [41].

*Gait Testing:* Gait testing was performed using a six-camera Vicon 512 motion capture system (Vicon Peak, Lake Forest, CA). A total of 16 retro-reflective markers were placed on the lower body of the subject. Markers were placed on the sacrum, and bilaterally on the anterior superior iliac spine, thigh, knee, tibia, ankle, heel and second metatarsal head. Motion data was collected at 120 Hz.

To assess gait performance, subjects performed several activities on a walking course. The course consisted of a pathway approximately 10m long. A standard sized open doorframe (0.91m wide by 2.03m tall) stood at the far end of the walkway relative to the starting position. A temporary wall was placed 1.5m behind the doorframe and held lighted cues used to provide instruction to the subject. Photo-sensors were placed at two locations along the edge of the walkway, one at 4 m in front of the doorframe and the other at 1.5 m in front of the doorframe. These were used as triggers to determine when a subject passed by each sensor by detecting a break in a light beam that was directed at each sensor. These triggers were used to activate the light cues mounted behind the doorframe.

The subjects performed two different tasks, each under two different conditions. The first task required the subjects to walk straight through the doorway without stopping (straight task). The second task required the subject to proceed to the area directly in front of the doorframe, make a 360 degree turn, and then continue walking through the doorframe (turn task). This specific task was chosen due to its reported ability to highlight more severe issues with gait impairment [5]. The task to be performed in each trial was determined by lighted cues mounted on the opposite side of the doorframe. These cues were given under two different timing



conditions. The first was given when the subject passed by the first light sensor, 4 m from the doorframe (early cue condition). The second was given when the subject passed the second light sensor, 1.5 m from the doorframe (late cue condition). The timing of cues was implemented due to the reported difficulty in set-shifting for people with PD. A previous study used a short timing cue equivalent to one stride length, which was conservatively approximated here by the 1.5 m distance [13]. Each task (straight and turn) was repeated three times for each condition (early cue and late cue) for a total of 12 trials. The order of task and condition was randomized prior to testing. Before beginning testing, subjects were instructed to walk naturally, at a self-selected pace and respond appropriately to the cue presented.

*Data Measurements and Analysis:* Three dimensional trajectory data and video recordings were collected for the gait trials. The trajectory data was processed using Matlab (Mathworks, Natick, MA) to calculate spatiotemporal parameters for the gait trials. The trajectory data was filtered using a zero-phase 4th order Butterworth filter with a cutoff frequency of 7 Hz. Using the foot-velocity algorithm (FVA) method described by O'Connor, et al.[42], heel strike and toe off events were determined. The FVA uses existing markers to create a foot center point and the vertical velocity of this point is calculated. Foot events are found using appropriate peaks in the vertical velocity of the foot. These events were used for the calculation of spatial and temporal parameters of gait. For the straight task, stride time, stride length, double support time, and gait velocity were measured. Additionally, gait variability was assessed using the coefficient of variation ( $CV = (SD/mean)*100$ ) of stride time and stride length [43]. Analysis of the turn task included the total number of steps and total time taken to complete the turn.

*Timeline of Events:* The testing and intervention period for each group of subjects lasted a total of nine weeks. The first week consisted of pre-intervention testing, including all clinical assessments and gait analysis. In the following week, subjects were taught the qigong exercise over the course of two training sessions. Following training, the six-week intervention period began. During this time the subjects met weekly for group sessions while performing the exercise twice daily at home. In the week following completion of the intervention, the clinical assessments and gait testing performed in week one were repeated.

*Qigong Exercise Intervention:* The “six healing sound” Qigong exercise was used in this study. This specific form was chosen because it is easy to learn and practice and requires minimal physical capacity. The exercise was taught by an experienced and well trained instructor. Subjects learned to perform the Qigong exercise in standing, seated, and lying body positions. Subjects were encouraged to practice in the standing position, but were free to choose the position used, especially when they had difficulty standing or sitting. In any position, the subject should feel relaxed and comfortable with the body having a general sense of ease. The subjects were trained to control deep breathing through a diaphragmatic breathing technique. During exhalation, subjects were instructed to quietly pronounce each of the six healing sounds. Additionally, the subjects were taught smooth body movements associated with each of the six healing sounds. Throughout the training sessions subjects learned to breathe slowly and to synchronize their breathing and movements while trying to clear their minds by concentrating on the feeling of diaphragmatic contraction and expansion.

After the training sessions, the subjects were instructed to continue the Qigong exercise at home twice per day – once in the morning immediately after getting up and again in the evening right before going to bed. Each session took about 15 to 20 minutes to complete. During the six-week intervention period, the subjects met in small groups once per week with the instructor for group exercise sessions. During these sessions, the instructor evaluated and corrected performance of each subject. In addition to the leading the exercise, the instructor answered specific questions and encouraged group discussion of relevant issues. Each weekly session lasted 45 to 60 minutes. Subjects maintained an exercise diary during the intervention period to monitor compliance to the exercise program. These diaries were turned in weekly at the group sessions.

*Statistical Analysis:* Statistical analysis was performed using Matlab. Group differences in pre and post-test scores on clinical assessments and subscales were evaluated using paired t-tests with an alpha level at 0.05. Multivariate analysis of variance (MANOVA) was used to determine whether significant differences existed between pre- and post-test measures for gait tasks. Overall gait performance (stride time, stride length, double support time, and velocity), gait variability (stride time variability and stride length variability), and turn performance (total steps and total time to complete turn) were considered separately. If a significant difference was shown within a group, a paired t-test with a Bonferroni adjustment ( $0.05/4 = 0.0125$  for gait performance;  $0.05/2 = 0.025$  for variability and turning) was used for post-hoc analysis to determine which variables had significant differences. Similar evaluations were performed to determine if there were significant differences between cueing conditions on the gait tasks.

## *Results*

*Clinical Assessments:* Clinical assessments relating to level of disease impairment, cognitive function, quality of life, non-motor symptoms, sleep and fatigue were assessed through pre- and post-intervention testing. There was no significant change in impairment measured by the total UPDRS score ( $p = 0.7746$ ), or any of the subscales, including motor function ( $p = 0.7807$ ). Cognitive function also remained unaffected as measured by the MMSE, FAB, TMTA and TMTB ( $p = 0.2308$ ;  $p = 0.8291$ ;  $p = 0.8333$ ; and  $p = 0.3657$  respectively). There was no significant effect on the total score for the PDQ-39 ( $p = 0.9437$ ) or any of the subscales. The total score for the NMSQuest was also unchanged ( $p = 0.8575$ ) as were the subscales, including one for sleep and fatigue ( $p = 0.9725$ ). Complete data for quality of life and non-motor symptoms measures are presented in **Table 3** and **Table 4**, respectively. An increase in the PFS-16 total score (from 47.14 to 54.14) would suggest worsening of fatigue symptoms, but this change was not significant ( $p = 0.3006$ ). Overall sleep quality showed improvement that neared significance, dropping from 29.29 to 16.29 ( $p = 0.0733$ ). Evaluation of the subscales showed a significant improvement in motor symptoms at night ( $p = 0.0494$ ) and an improvement nearing significance in disturbed sleep ( $p = 0.0634$ ). Complete results for the fatigue and sleep scales can be seen in **Table 5**.

*Gait Performance:* Evaluation of performance in the gait tasks showed no significant difference between the two cueing conditions. Therefore, for further evaluation of gait performance, trials for the early and late cueing conditions were combined and analyzed together. Data for

comparison of the cueing conditions as well as data for individual subjects may be found in Appendix B.

Overall gait performance was assessed in the straight walking tasks using the measured parameters of stride time, stride length, double support time, and gait velocity. A MANOVA comparing these variables found significant changes in the pre- and post-intervention measures ( $p = 0.0001$ ). Post-hoc analysis was used to evaluate changes in gait variables following the intervention. This analysis showed a reduction in stride time (-5.27%,  $p = 0.0001$ ), increase in stride length (4.15%,  $p = 0.0598$ ), shortening of double support time (-9.01%,  $p = 0.0815$ ), and increase in velocity (8.73%,  $p = 0.0104$ ). Complete results for these parameters are shown in **Table 6** and **Figure 1**.

*Gait Variability:* Gait variability was assessed in the straight walking tasks using the coefficient of variation of stride time and stride length. A MANOVA evaluating these parameters indicated a significant change in gait variability from baseline to end intervention testing ( $p = 0.0383$ ). Post-hoc analysis showed a significant reduction of stride time variability (-36.17%,  $p = 0.0058$ ). Stride length variability also appeared to decrease, though this change was not significant (-17.54%,  $p = 0.1311$ ). Complete results for gait variability are shown in **Table 7** and **Figure 2**.

*Turn Performance:* Performance during the turning tasks was assessed by measuring the total number of steps and total time taken to complete the turn. A MANOVA evaluating these variables showed no significant difference from baseline to post-intervention testing ( $p = 0.9783$ ). Complete results for turn performance are shown in **Table 8** and **Figure 3**.

## *Discussion*

This was an exploratory study designed to determine the efficacy of implementing Qigong as a complementary therapy in PD with the goal of improving sleep quality, fatigue, and motor performance in patients. Analysis of measured outcome variables indicates that this specific therapy may be beneficial in improving sleep quality and gait performance, but not fatigue. This apparent relationship between sleep and gait performance was also demonstrated in a study of elderly individuals complaining of sleeping issues. In this population, when compared to a low-impact exercise program Tai Chi showed greater improvement in overall sleep quality, including sleep duration, efficiency, and latency, as well as in gait velocity (50-ft walk) and postural stability (one-leg stance and chair rise) [44]. These initial findings will require further study with greater statistical power to confirm the effects of the intervention. In addition to this primary focus, additional measures were explored to determine other potential benefits that may be related to the exercise.

*Quality of Life and Non-Motor Symptoms:* In this study, the exercise intervention did not appear to result in benefits to any of the outcome measures relating to quality of life and general non-motor symptoms. Evaluation of these outcome measures shows extremely high variability, which makes it difficult to definitively rule out any benefits. Previous studies involving meditative movement therapies have reported improvements to health related quality of life measures following completion of the intervention, suggesting that these outcomes may be impacted and should still be considered in future studies [24, 31]. Despite the lack of measured benefits, one

subject reported a considerable perceived improvement in blood pressure while participating in the study. Though this particular outcome was not directly measured, this occurrence is consistent with previously reported findings [23, 30, 45].

*Sleep and Fatigue:* A major benefit linked to studies involving meditative movement has been the observed improvement in sleep, including overall sleep quality and excessive daytime sleepiness [24, 26, 27, 29]. The current study shows some evidence to further support these findings. Though changes to the overall sleep score and sleep disturbance subscale fell short of significance, the power and significance of these results might be improved with a larger sample size. Regardless, this overall trend could demonstrate that the specific form of Qigong implemented in this study may be beneficial to people with PD suffering from sleep related issues. It has been suggested previously that quality sleep may help to restore dopamine levels in the brain, an occurrence referred to as sleep benefit [15]. If this claim is true, it would suggest that PD symptoms that are sensitive to dopamine levels may be improved as the quality and duration of sleep is increased.

Despite the apparent improvement in sleep discovered in this study, fatigue remained unaffected by the intervention. This contradicts the findings of a previous study implementing this specific form of Qigong on patients with fibromyalgia [29]. This difference could be a product of the specific tools used to assess fatigue in the two populations or simply a difference in disease characteristics and their response to the therapy. Despite this difference, these results are in line with previous studies in PD that show that fatigue and sleep do not appear to be directly related [12, 19].

*Gait Performance:* The specific gait parameters evaluated in this study were selected due to their strong representation of the changes that occur in PD gait compared to healthy populations, as demonstrated in a number of previous studies [7-9, 14, 43]. Reduced gait velocity is often considered the primary characteristic of gait in PD and is typically improved by levodopa. A previous study found patients off of levodopa medication walked at a speed of 0.902 m/s compared to 0.935 m/s while on medication, a 3.65% increase [46]. In the current study, post-intervention velocity increased from 0.8988 m/s to 0.9772 m/s, a change of 8.73%. This improvement, which was measured while patients were off of levodopa therapy, shows a greater magnitude of change than demonstrated in the study on levodopa. This finding could provide some support for the idea of sleep benefit discussed previously. In comparison to other studies of meditative movement, a study of Tai Chi in PD showed a 14% increase in baseline gait speed as measured by the 50-ft walk test [28]. However, one study comparing Tai Chi to an inactive control group was less convincing, finding a 6.2% increase in velocity for the Tai Chi group compared to a 5.4% increase in controls [25]. These findings suggest that, while there appears to be a benefit in gait velocity from the Qigong intervention, further studies comparing these outcomes to a control group are necessary.

In this study, the increase in velocity appears to result primarily from an improvement in stride time, which improved 5.27% from baseline. This result was somewhat surprising, as most previous reports indicate stride time and cadence tend to be relatively unaffected by PD and therefore we did not expect significant changes to this value following the intervention [5, 9, 10, 46]. This observation was similar to results from a study using gait training in PD. In this particular study, an increase in cadence of 6.65% was seen in the intervention group, while



inactive controls also showed an increase of 5.61%. However, in this same study of gait training, velocity was increased 13.28% compared to 0.79% in controls as a result of significant changes to stride length [47]. Another study of a motor rehabilitation program in PD showed a significant increase in gait velocity (18.68%) as a result of significant improvements in both cadence (6.12%) and stride length (12.65%) [48]. In the current study, stride length was increased 4.15%. This change was not significant, possibly because of the small sample size. These observations highlight the need for further study with a larger sample size and a control group for comparison of the outcome measures.

Double support time – a parameter that has been linked to postural instability [5, 10] – also showed a significant improvement following the Qigong intervention. The group decreased from 28.52% to 25.95% of the gait cycle in double support, a change of 9.01% from baseline values. This parameter has not been reported in meditative movement studies, but a study of a motor rehabilitation program in PD showed a non-significant decrease of 6.05% in double support time following that intervention [48]. Previously, other measures of postural instability have been shown to improve as a result of meditative movement. This includes a 13% improvement in the functional reach test following a Tai Chi intervention for people with PD [7], as well as improvements in balance, chair rise, and one-leg stance in balance impaired, sedentary, and arthritic populations following therapy with Tai Chi [24]. The outcomes demonstrated in the current study may lend further support to these claims of improved balance in stability following participation in meditative movement therapies.

*Gait Variability:* Variability in stride length and stride time has been associated with PD gait in several studies [7, 43, 46]. In the current study, variability also showed a significant improvement following the intervention. Upon closer analysis of these individual features, a significant improvement was found in stride time variability. This study also appears to be the first study of meditative movement to measure changes in gait variability. In this study, the coefficient of variation in stride time measures decreased 36.17% from a baseline value of 4.52 to a post-intervention value of 2.88. Several previous studies compared variability for PD patients when on and off medication as well as those with and without FOG. In the study observing variability and medication status, patients improved 39.34% from 6.1 while off of medication to 3.7 on medication [9]. Comparison of patients with and without FOG while off of medication showed a coefficient of variability of 6.1 for those with FOG to 3.3 for those without, a difference of 45.90%. These two groups showed a smaller improvement with medication, improving variability 26.23% and 21.21% in FOG and non-FOG patients, respectively [11]. Previous studies claim that PD might impair the internal clock mechanism responsible for the internal cueing needed to generate and maintain movements in automatic motor functions, such as gait [9]. If true, this would likely be most clearly represented by increased variability in gait timing. Comparison of results from the current study with those previously reported shows meditative movement therapy may provide significant benefits for this particular aspect of the disease.

*Limitations:* This study had several limitations. First, the sample size used in this study was small. Although several significant changes were observed as a result of this intervention, these results should be considered with caution due to the limited number of subjects tested. Further

testing of this particular intervention is suggested in order to determine its effects with a greater degree of confidence. Second, the use of the pre-test post-test design without a control group requires caution when evaluating results. Although the observed changes could be caused by the intervention, this design makes it difficult to test for other variables that could influence results, such as testing effect. Though the gait tasks were designed in a manner to attempt to reduce this effect, familiarity with the tasks being tested as well as the testing environment could contribute to changes in performance. In furtherance of this idea, it also may be difficult to determine what specific aspect of the intervention could have contributed to the observed changes. It could be possible that a single aspect, such as the social interaction, movement, or breathing focus, may be largely responsible for the results. Finally, selection bias may impact results. The subjects involved in this study consisted of those volunteering to participate in the exercise program. As a result, they may have high expectations of the therapy, potentially creating a placebo effect. Additionally, the sample recruited in this manner may not accurately represent the PD population in general.

*Conclusions:* A number of important changes were found as a result of a six-week Qigong exercise intervention. This study demonstrated a trend toward improvements in sleep quality as well as a number of improvements in gait and motor function. These results suggest that the specific form of Qigong exercise that was implemented may provide potential benefits to people with PD. In addition to these benefits, this exercise was shown to be easy to learn, requires minimal physical capacity, uses short duration sessions, and can be performed in a variety of postures. Early outcomes of this intervention are promising for potentially providing additional benefits in the treatment of PD. Further research will be required in order to more clearly

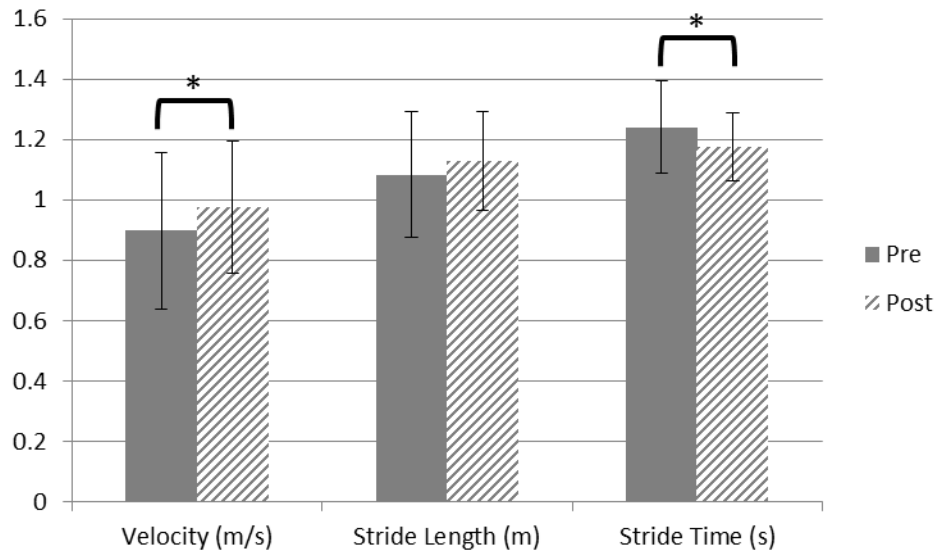
determine the impact of this exercise with greater statistical power. Because there was no apparent effect of cue timing and turning conditions, future studies may consider a simplified, more direct approach to studying gait performance. Additionally, different approaches to assessing outcomes such as quality of life, fatigue, and non-motor symptoms may be explored in order to determine further benefits related to the exercise.

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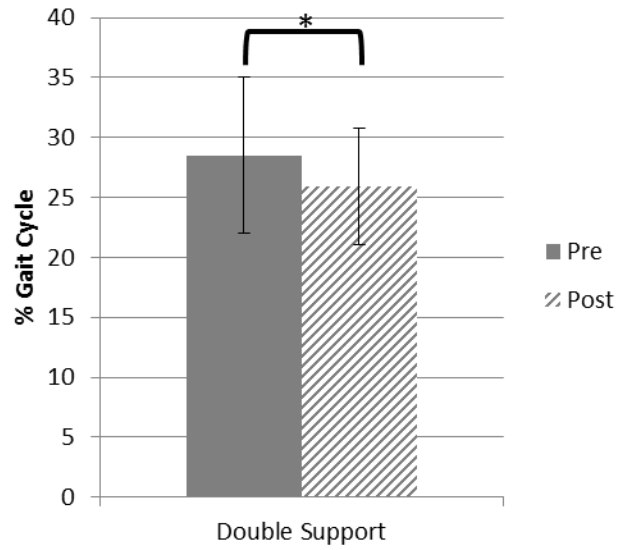
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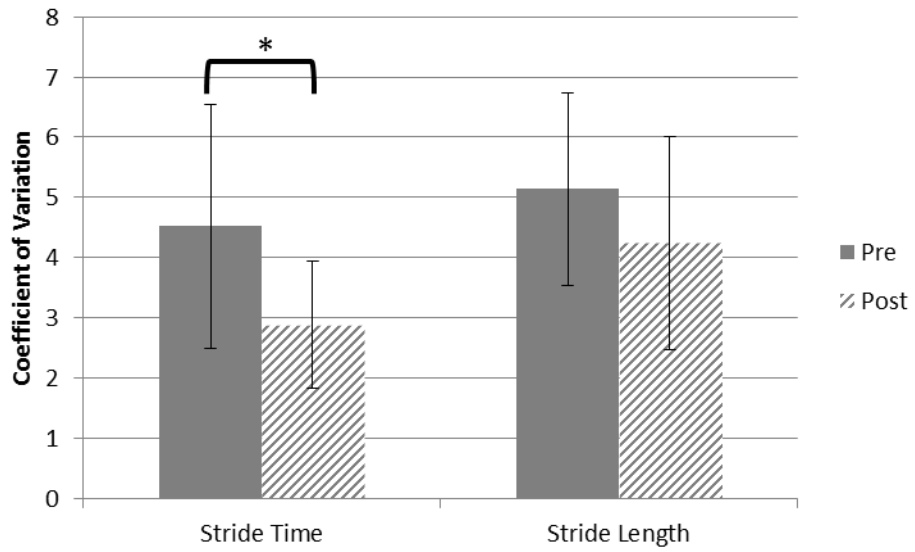


**Figure 1 (a):** Gait performance. Average values with standard deviations of pre- and post-intervention measures of velocity (m/s), stride length (m), and stride time (s) are given. Significant differences in outcome measures as determined by post-hoc t-tests are indicated by an asterisk ( $p < 0.0125$ ).

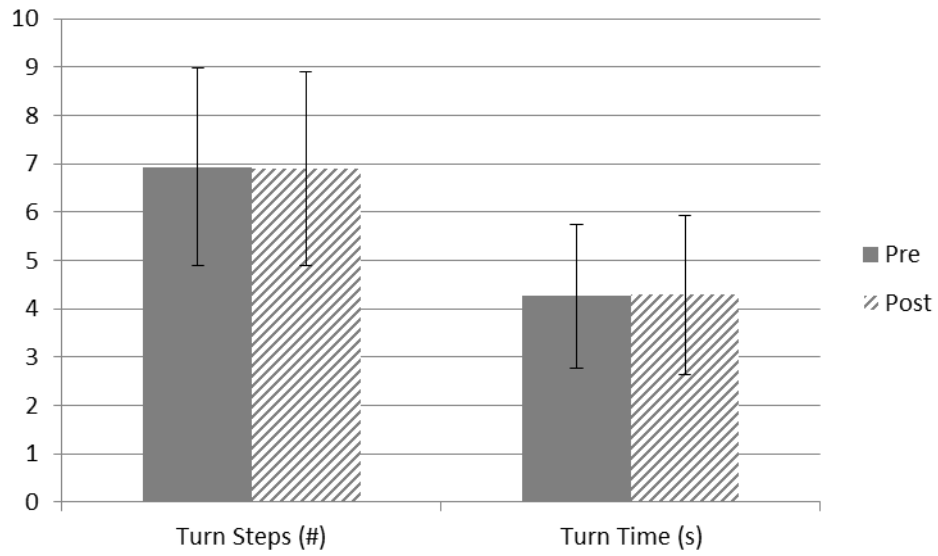




**Figure 1 (b):** Gait Performance. Average values with standard deviations of pre- and post-intervention measures of double support time (as percent gait cycle) are given. Significant difference in outcome measures as determined by post-hoc t-testing is indicated by an asterisk ( $p < 0.0125$ ).



**Figure 2: Gait Variability.** Average values with standard deviations of pre- and post-intervention coefficient of variation for stride time and stride length are given. A significant difference in outcome measures as determined by post-hoc t-testing is indicated by an asterisk ( $p < 0.0250$ ).



**Figure 3: Turn Performance.** Average values with standard deviations of pre- and post-intervention measures of turn performance are given. The total number of steps and total time to complete the turning task was measured.

Subject #	Age (yrs)	Gender	PD Duration (yrs)	H&Y	MMSE	Medication	Dosage (mg/day)
1	65	F	9	3	28	Carbidopa/Levodopa	50/200
						Rasagiline	0.5
2*	55	F	3	2	27	Carbidopa/Levodopa	125/500
						Rasagiline	1
3	77	F	1	1	30	Carbidopa/Levodopa	75/300
4	76	M	3	2.5	23	Carbidopa/Levodopa/Entacapone	125/500/800
5	67	F	4	3	30	---	---
6	59	M	1.5	2	30	Pramiprexole	1.5
						Rasagiline	1
7	69	M	3	3	27	Carbidopa/Levodopa	150/600
						Ropinirole	4
66.86 ± 8.13		---	3.5 ± 2.6	2.4 ± 0.8	27.9 ± 2.5		

**Table 1:** Characteristics of subjects. Summary data on bottom row represents mean (standard deviation).

\*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.

Subject #	Qigong Exercise			Other Exercise	
	Morning (% completed)	Evening (% completed)	Total (% completed)	Pre-Intervention (days/week)	Intervention (days/week)
1	69.05%	54.76%	61.90%	2.00	3.00
2	97.62%	97.62%	97.62%	4.00	2.33
3	94.29%	94.29%	94.29%	2.00	0.00
4	69.70%	66.67%	68.18%	3.00	0.60
5	95.24%	83.33%	89.29%	0.00	0.00
6	100.00%	100.00%	100.00%	7.00	7.00
7	74.36%	79.49%	76.92%	7.00	3.67
	85.75% ± 13.98%	82.31% ± 16.85%	84.03% ± 15.08%	3.57 ± 2.64	2.37 ± 2.51

**Table 2:** Exercise Compliance. Exercise compliance given as percentage of total sessions completed for morning, evening, and total sessions. Involvement in additional exercise is given with comparison to reported activity levels prior to intervention.

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>PDQ-39 Total</b>	35.86 ± 35.85	35.57 ± 31.19	0.9437
<i>Mobility</i>	9.29 ± 10.89	10.86 ± 11.74	0.3186
<i>ADL</i>	5.29 ± 4.11	4.71 ± 4.27	0.6314
<i>Emotional Well Being</i>	6.00 ± 6.27	6.57 ± 6.13	0.4362
<i>Stigma</i>	3.14 ± 4.78	1.86 ± 3.49	0.3802
<i>Social Support</i>	0.86 ± 2.27	1.57 ± 3.36	0.1824
<i>Cognitions</i>	4.29 ± 3.20	4.14 ± 2.73	0.8291
<i>Communications</i>	3.00 ± 4.24	2.29 ± 3.30	0.5265
<i>Bodily Discomfort</i>	4.00 ± 3.51	3.57 ± 2.70	0.6286

**Table 3:** Parkinson’s Disease Questionnaire (PDQ-39). Mean ± standard deviation for pre- and post-intervention testing are given, where higher scores indicate more severe complications. P-value is given from t-test with significance level at  $p < 0.05$ .

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>NMS-Quest Total</b>	48.43 ± 36.90	49.57 ± 41.48	0.8575
<i>Cardiovascular and Falls</i>	1.86 ± 2.54	1.43 ± 2.15	0.4072
<i>Sleep and Fatigue</i>	11.14 ± 12.16	11.00 ± 10.28	0.9725
<i>Mood and Cognition</i>	9.71 ± 12.20	13.00 ± 19.14	0.4809
<i>Perceptual Problems</i>	0.57 ± 0.79	0.14 ± 0.38	0.1996
<i>Attention and Memory</i>	5.43 ± 9.74	6.86 ± 7.86	0.6231
<i>GI Tract</i>	2.14 ± 1.86	2.86 ± 3.48	0.4888
<i>Urinary</i>	9.71 ± 13.07	6.00 ± 7.57	0.1842
<i>Sexual Function</i>	8.57 ± 10.18	2.43 ± 4.47	0.1243
<i>Miscellaneous</i>	2.71 ± 4.42	5.86 ± 6.12	0.2286

**Table 4:** Non-Motor Symptoms Questionnaire (NMSQuest). Mean ± standard deviation for pre- and post-intervention testing are given, where higher scores indicate more severe complications. P-value is given from t-test with significance level at  $p < 0.05$ .

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>PDSS-2 Total</b>	29.29 ± 15.74	16.29 ± 9.18	0.0733
<i>Motor Symptoms at Night</i>	<b>9.43 ± 6.63</b>	<b>3.71 ± 2.56</b>	<b>0.0494</b>
<i>PD Symptoms at Night</i>	7.14 ± 6.82	3.86 ± 4.60	0.2865
<i>Disturbed Sleep</i>	12.71 ± 4.31	8.71 ± 3.55	0.0634
<b>PFS-16 Total</b>	47.14 ± 17.12	54.14 ± 16.72	0.3006

**Table 5:** Revised Parkinson’s Disease Sleep Scale (PDSS-2) and Parkinson’s Fatigue Scale (PFS-16). Mean ± standard deviation for pre- and post-intervention testing are given, where higher scores indicate more severe complications. Bold entries indicate significant difference ( $p < 0.05$ ) in t-test.



	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>Velocity (m/s)</b>	<b>0.899 ± 0.258</b>	<b>0.977 ± 0.220</b>	<b>0.0104</b>
<b>Stride Length (m)</b>	1.083 ± 0.209	1.128 ± 0.163	0.0598
<b>Stride Time (s)</b>	<b>1.241 ± 0.152</b>	<b>1.175 ± 0.112</b>	<b>0.0001</b>
<b>Double Support (% GC)</b>	<b>28.52 ± 6.54</b>	<b>25.95 ± 4.87</b>	<b>0.0005</b>

**Table 6:** Gait Performance: Mean ± standard deviation is given for gait velocity, stride length, stride time, and double support time. Bold entries indicate significant changes from pre- to post-test when evaluated with post-hoc t-test ( $p < 0.0125$ ).

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>CV Stride Length</b>	5.141 ± 1.596	4.240 ± 1.768	0.1311
<b>CV Stride Time</b>	<b>4.520 ± 2.022</b>	<b>2.885 ± 1.060</b>	<b>0.0058</b>

**Table 7:** Gait Variability: Mean ± standard deviation is given for the coefficient of variation for stride length and stride time. Bold entries indicate significant changes from pre- to post-test when evaluated with post-hoc t-test ( $p < 0.0250$ ).

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>Turn Steps (# steps)</b>	6.93 ± 2.04	6.90 ± 2.01	0.8809
<b>Turn Time (s)</b>	4.26 ± 1.48	4.29 ± 1.65	0.7748

**Table 8:** Turn Performance: Mean ± standard deviation is given for the number of steps and total time taken to complete the turning task. No significant changes from pre- to post-test were seen when evaluated with post-hoc t-test ( $p < 0.0250$ ).

## CHAPTER FOUR: SUMMARY

### *Summary of Study*

The goal of this study was to investigate the impact of a Qigong exercise intervention on symptoms related to sleep quality, fatigue, and gait function in Parkinson's disease (PD). Subjects diagnosed with PD participated in a six-week Qigong exercise program. This included performance of the exercise routine twice daily over the course of the intervention, as well as weekly group exercise sessions. Subjects were assessed in sleep quality and fatigue using standard clinical assessments specific to PD. Gait function was tested using three-dimensional motion analysis during the performance of several gait tasks. The performance of these tasks was assessed in three main categories: overall gait function, gait variability, and turning. Parameters related to overall gait function included stride time, stride length, double support time, and gait velocity. Gait variability was assessed using the coefficient of variation of stride time and stride length. Turning performance was assessed by the total number of steps and total time taken to complete a full turn.

Following the six-week intervention, the Qigong exercise showed a positive impact on several PD symptoms. First, sleep quality appeared to be improved as a result of the exercise therapy. Subjects also displayed improvements in several aspects of gait. Overall gait performance showed a large benefit from the exercise. All outcome measures within this category showed improvement following the intervention. Stride length was increased and stride time was decreased to result in an increase in gait velocity. Additionally, time spent in double support was reduced. Gait variability showed significant improvement as well. Stride time

variability was the most significantly impacted, showing reduced variability in the post-intervention testing. Finally, neither turning performance nor fatigue appeared to benefit from the exercise as no significant change occurred in either of these parameters.

### *Conclusions and Recommendations*

This study found improvements in several PD features as a result of a six-week Qigong exercise intervention. This specific exercise therapy appears to have a positive influence on sleep quality and several aspects of gait in people with PD. Specifically, gait velocity, stride time, stride time variability, and double support time were all significantly improved following completion of the intervention. Stride length also appeared to improve, though not significantly. These findings suggest that this specific therapy may provide additional benefit to PD patients beyond those experienced with standard medical treatment. This exercise was shown to be easy to learn and generally well accepted by those participating. It requires no additional equipment and is relatively short in duration, lasting only 15 to 20 minutes per session. These features along with the potential benefits make this a viable option to further improving the management of PD and its related symptoms. Further study is required to provide more statistical power to support these observations as well as more clearly define the extent of the benefits related to this exercise. Future studies may consider alternative options for assessing features of PD related to quality of life and non-motor symptoms. Additionally, it may be possible to take a more simplified and direct approach to evaluating gait performance in future work.

### *Limitations*

This study has several limitations. First, a small sample size was used to evaluate the measured variables in this study. Although several significant changes were found following the intervention, these should be looked at with caution due to the limited number of subjects tested. Second, this study used a pre-test post-test design without a control group. Although the observed changes may be a result of the intervention, this design makes it difficult to test for other variables that could influence results. One example is a testing effect. Though the gait tasks were designed with the intentions of reducing this effect, familiarity with the tasks being performed as well as the testing environment could contribute to some changes in performance. Further, it is difficult to determine what specific aspect of the intervention may have contributed to the observed changes. It could be possible that a single aspect, such as the social interaction, movement, or breathing focus, may be largely responsible for the results. Finally, selection bias could be an issue. The subjects participating in this study had a high interest in being involved in a structured exercise program. Because of this, there may be a placebo effect resulting from high expectations of the therapy and related outcomes. Alternatively, this particular subject group may not be representative of the PD population in general.

### *Further Study*

The purpose of this study was to explore the potential impact of Qigong on PD symptoms relating to sleep, fatigue, and gait. Important changes were discovered in several aspects of sleep quality and gait performance. Further study is needed to confirm the observations from this small sample of patients. Additionally, future studies may be able to incorporate a simplified and more

focused approach to gait analysis. Evaluation of the current results suggests that it should be possible to adequately assess gait performance through simple gait testing while off of medication. Additional considerations may be to complete testing while the patients are on and off of their medications. This may provide a more complete picture of the extent of benefits gained from this exercise therapy.

## **APPENDIX A: STUDY PROTOCOL**



**Phone Screening Script**  
**Study of freezing of gait and mild exercise in Parkinson's disease**

Subject identification number \_\_\_\_\_

Date \_\_\_ / \_\_\_ / \_\_\_

Subject name \_\_\_\_\_

1. Is the individual available for a telephone interview?      YES      NO

If YES, proceed with telephone script

If NO, answer the following:

Subject is not available for telephone interview because;

1. Unable to reach - number of times attempted \_\_\_\_\_
2. Subject is busy / not at home (specify the time to call again) \_\_\_\_\_

2. Are you able to participate in a study which requires the practice of mild, daily exercise and about 11 visits for assessment and group exercise sessions?

YES - move on to question #3

NO - thank them for their time and let them know they are not eligible for this study at this time

3. Have you been diagnosed with primary (or idiopathic) Parkinson's disease?

YES – move on to question #4

NO - thank them for their time and let them know they are not eligible for this study at this time

4. Are you between the ages of 40 and 89?

YES – move on to question #5

NO – thank them for their time and let them know they are not eligible for this study at this time

5. Are you physically independent and able to walk a distance of about 25 feet unassisted?

YES – move on to question #6

NO – thank them for their time and let them know they are not eligible for this study at this time

6. Treatment

a) Are you currently taking medication for Parkinson's disease? If so, what are you taking?      Y      N      Medication: \_\_\_\_\_

b) Are you aware of any intentions of changing your medication or dosages over the next four months? Y      N

c) Does your treatment include Deep Brain Stimulation (DBS)?      Y      N

(part A – YES; part B and C – NO) – move on to question #7

NO – thank them for their time and let them know they are not eligible for this study at this time

7. Have you been diagnosed with any other medical problems (neurological, orthopedic, etc) that interfere with your ability to walk and/or follow instructions?

YES – thank them for their time and let them know they are not eligible for this study at this time

NO – move on to question #8

8. Do you experience freezing of gait, or the feeling that your feet are glued to the floor? If yes, does this occur only during the "ON" state of your medication?

YES – move on to question #9

YES – **only occurs during "ON" state** – thank them for their time and let them know they are not eligible for this study at this time

NO – move on to question #9

9. Can you be contacted for participation in the study within two weeks?

YES - move on to question #10

NO – When will you be available for the study \_\_\_\_\_

10. What is the phone # to contact you? \_\_\_\_\_

## CONSENT FORM

### FOG and mild exercise in PD

**INTRODUCTION:** As a person between the ages of 40-89 who has been diagnosed with Parkinson's disease (PD), you are being invited to participate in a pilot study to explore the effect of a mild exercise that may affect your sleep quality, fatigue, overall quality of life, and occurrence of freezing of gait (FOG). The research will be conducted at Center on Aging at the University of Kansas Medical Center with Wen Liu, Ph.D., as the Principal Investigator. Some aspects of the study may be conducted by scientific colleagues, research associates and students, working under the supervision of Dr. Liu. Approximately 24 subjects will be enrolled at KUMC.

*You do not have to participate in this research study. Before you make a decision to participate, you should read the rest of this form. The main purpose of research is to benefit future patients and society in general. You may receive personal benefit from participating in this study, but you should understand that the primary purpose of research is to create new knowledge.*

**BACKGROUND:** Sleep disturbance, gait and balance problem, and freeze of gait are common in PD patients. Previous studies indicated that some mild exercises may improve sleep quality, fatigue, and overall quality of life. Clinical trial studies are needed to test whether or not a mild exercise can help people with PD, specifically those who experience FOG.

**PURPOSE:** The purpose of this study is to understand the effect of a mild exercise on sleep quality, fatigue, quality of life and the occurrence and severity of FOG episodes in PD patients.

#### **PROCEDURES:**

Your participation in this study will involve a total of 11 visits over about 19 weeks to Center on Aging at The University of Kansas Medical Center (KUMC).

Prior to this consent, we have contacted your doctor with a consent form and obtained a permission to include you in our research study.

In the first week, you will come to the Center on Aging at KUMC on two days for evaluation sessions. At the baseline evaluation, you will be asked to provide your demographic data and medical history. This information may include use of alcohol, caffeine, and tobacco; level of education; occupation (or last occupation if retired); usual activity level; socio-demographics; and additional health conditions in addition to PD. In addition, you will be given questionnaires to assess your sleep quality, fatigue, cognitive ability, and overall quality of life. These evaluations will occur on one day. On a second day, gait testing will be used to assess your performance of several walking tasks. To measure your movements during these walking tasks, reflective, non-invasive markers will be placed on your legs and pelvis to be recorded by specialized cameras that record only the markers. Each visit may last one and a half hours.

In a following week, you will visit the Center on Aging on two different days for two group training sessions. During these training sessions, you will learn a mild exercise (qigong) from an experienced instructor. Each training session may last about one hour.

In the following six weeks, you will be asked to practice twice the mild exercise every day at home and maintain a diary on your daily exercise. In the diary, which will be provided by the research team, you will record your daily fatigue, sleep quality, FOG episodes, and exercise sessions. During this period, you will also be asked to come to the Center on Aging once per week for a group exercise session. During the weekly group exercise sessions, you will have the opportunity to ask any questions related to the exercise and PD/FOG in general. The instructor will help you to improve your performance in the exercise. Each group exercise sessions may last about one hour.

At the end of the six-week intervention period, you will come once to the Center on Aging on two days for the same evaluations as in the first week. In three months after your first visit, you will come back to the Center on Aging on one day for a repeated follow-up evaluation using the questionnaires only. There will be no gait testing at the three-month evaluation.

**RISKS:** Possible risks for your participation in this study are the following:

- You may feel slight muscle fatigue during or after the exercise in stance posture. The feeling of fatigue will go away after a brief rest. You may choose a sitting posture in performing the exercise if you have difficulty in stance posture.
- You may feel slightly frustrated if you have a difficulty in learning accurate body movements. You will be told to focus on your practice and not to worry about the accuracy of your movements.
- During gait evaluations, there is a risk of experiencing FOG or a loss of balance while performing the walking tasks. A member of the research team will follow closely behind to assist you in the event of a loss of balance.
- You may feel uncomfortable answering some of the questions in the surveys. If a question makes you feel uncomfortable you may skip that question or stop your participation at any time.

**NEW FINDINGS STATEMENT:**

You will be informed if any significant new findings developed during the course of this study that may affect your willingness to participate in this study.

**BENEFITS:** You may benefit from your participation in this study as the mild exercise may improve your fatigue, sleep quality, and FOG occurrence. It is hoped that information gathered in this study will contribute to current scientific knowledge of the exercise on PD and FOG.

**ALTERNATIVES:** The alternative to participating in this study is not participating. You may freely choose not to participate and this will have no negative impact on your ability to get appropriate care at the University of Kansas Medical Center. You may also withdraw from the study at any time without any negative impact on your clinical care. You may practice the qigong exercise without being in this study.

**COSTS:** There are no costs for participating in this study.

**PAYMENTS:** You will not be paid for participating in the study.



**IN THE EVENT OF INJURY:** If you have a serious side effect or other problems during this study, you should immediately contact Dr. Liu at phone (913) 588-4565. If it is after 5:00 pm, a holiday, or a weekend, you should call (913) 526-2250. A member of the research team will decide what type of treatment, if any, is best for you at that time.

If you have a bodily injury as a result of participating in this study, care will be provided for you at the usual charge. Claims will be submitted to your health insurance policy, your government program, or other third party, but you will be billed for the costs of that care to the extent insurance does not cover them. Payment for lost wages, disability or discomfort is not routinely available. You do not give up any of your legal rights by signing this form.

**INSTITUTIONAL DISCLAIMER STATEMENT:** If you think you have been harmed as a result of participating in research at the University of Kansas Medical Center (KUMC), you should contact the Director, Human Research Protection Program, Mail Stop #1032, University of Kansas Medical Center, 3901 Rainbow Blvd., Kansas City, KS 66160. Under certain conditions, Kansas state law or the Kansas Tort Claims Act may allow for payment to persons who are injured in research at KUMC.

**CONFIDENTIALITY AND PRIVACY AUTHORIZATION:**

Efforts will be made to keep your personal information confidential. Researchers cannot guarantee absolute confidentiality. If the results of this study are published or presented in public, information that identifies you will be removed.

The privacy of your health information is protected by a federal law known as the Health Insurance Portability and Accountability Act (HIPAA). By signing this consent form, you are giving permission (“authorization”) for KUMC to use and share your health information for the purposes of this research study. If you decide not to sign the form, you cannot be in the study.

To do this research, we need to collect health information that identifies you. We will collect information from activities described in the PROCEDURES section of this form and from your medical record.

Your study-related health information will be used by Dr. Liu, members of the research team, medical record departments, the KUMC Human Subjects Committee and other committees and offices that review and monitor research, if a regulatory review takes place.

All study information that is sent outside the Neuromuscular Research Laboratory will have your name and other identifying characteristics removed, so that your identity will not be known. Because identifiers will be removed, your health information will not be re-disclosed by outside persons or groups and will not lose its federal privacy protection.

Your permission to use and disclose your health information remains in effect until the study is complete and the results are analyzed. After that time, information that personally identifies you will be removed from the study records.

**QUESTIONS:** Before you sign this form, Dr. Liu or other members of the study team should answer all your questions. You can talk to the researchers if you have any more questions, suggestions, concerns or complaints after signing this form. If you have any question about your

rights as a research subject, or if you want to talk with someone who is not involved in the study, you may call the Human Subjects Committee at (913) 588-1240. You may also write the Human Subjects Committee at Mail Stop #1032, University of Kansas Medical Center, 3901 Rainbow Blvd., Kansas City, KS 66160.

**SUBJECT RIGHTS AND WITHDRAWAL FROM STUDY:** Your participation in this study is voluntary and that the choice not to participate or to quit at any time can be made without penalty or loss of benefits. Not participating or quitting will have no effect upon the medical care or treatment you receive now or in the future at the University of Kansas Medical Center. The entire study may be discontinued for any reason without your consent by the investigator conducting the study.

You have a right to change your mind about allowing the research team to have access to your health information. If you want to cancel permission to use your health information, you should send a written request to Dr. Liu. The mailing address is Wen Liu PhD, Department of Physical Therapy & Rehabilitation Science, 3901 Rainbow, Kansas City, KS 66160. If you cancel permission to use your health information, you will be withdrawn from the study. The research team will stop collecting any additional information about you. The research team may use and share information that was gathered before they received your cancellation.

**CONSENT:** Dr. Liu or his associates have given you information about this research study. They have explained what will be done and how long it will take. They explained any inconvenience, discomfort or risks that may be experienced during this study.

I freely and voluntarily consent to participate in this research study. I have read and understand the information in this form and have had an opportunity to ask questions and have them answered. I will be given a signed copy of the consent form to keep for my records.

Research Subject:

\_\_\_\_\_

Type/Print Subject's name

\_\_\_\_\_

Date

\_\_\_\_\_

Subject's signature

Person obtaining consent:

\_\_\_\_\_

Type/Print Name of Person Obtaining Consent

\_\_\_\_\_

Date

\_\_\_\_\_

Signature of Person Obtaining Consent



5. **With regard to your current or most recent job activity, what kind of work do (did) you do? (Job Title)**

---

(For example: registered nurse, personnel manager, supervisor of order department, gasoline engine assembler, grinder operator, etc.)

6. **Do you smoke cigarettes?**

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If yes, how many packs per day? \_\_\_\_\_

7. **Do you drink alcohol?**

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If yes, how many drinks? \_\_\_\_\_ /day      \_\_\_\_\_ /week      \_\_\_\_\_ /month

8. **How much caffeine do you consume in an average day?**

Coffee, # ounces \_\_\_\_\_

Tea, # ounces \_\_\_\_\_

Caffeinated soda, # ounces \_\_\_\_\_

9. **Do you exercise regularly?**

\_\_\_\_\_ YES      \_\_\_\_\_ NO

How often (1x/day; 3x/week, etc) \_\_\_\_\_

What type of exercise? \_\_\_\_\_

10. **Outside of exercise, how would you rate your daily activity level?**

\_\_\_\_\_ High activity      \_\_\_\_\_ Low activity

\_\_\_\_\_ Moderate activity      \_\_\_\_\_ Little or no activity

11. **How long have you had Parkinson's disease?**

Time since onset of symptoms \_\_\_\_\_

Time since diagnosis \_\_\_\_\_



**12. Do you have any other chronic health conditions? (check all that apply)**


**If yes, give details**

Heart Disease	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
Diabetes	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
Depression/Anxiety	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
Cancer (list type)	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
Alcohol/Drug Abuse	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____
	<input type="checkbox"/>	NO	<input type="checkbox"/>	YES	_____

## Mini-Mental State Examination (MMSE)

Patient's Name: \_\_\_\_\_ Date: \_\_\_\_\_

**Instructions:** Ask the questions in the order listed. Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: _____
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.) 
30		TOTAL

(Adapted from Rovner & Folstein, 1987)

## **Instructions for administration and scoring of the MMSE**

### **Orientation (10 points):**

- Ask for the date. Then specifically ask for parts omitted (e.g., "Can you also tell me what season it is?"). One point for each correct answer.
- Ask in turn, "Can you tell me the name of this hospital (town, county, etc.)?" One point for each correct answer.

### **Registration (3 points):**

- Say the names of three unrelated objects clearly and slowly, allowing approximately one second for each. After you have said all three, ask the patient to repeat them. The number of objects the patient names correctly upon the first repetition determines the score (0-3). If the patient does not repeat all three objects the first time, continue saying the names until the patient is able to repeat all three items, up to six trials. Record the number of trials it takes for the patient to learn the words. If the patient does not eventually learn all three, recall cannot be meaningfully tested.
- After completing this task, tell the patient, "Try to remember the words, as I will ask for them in a little while."

### **Attention and Calculation (5 points):**

- Ask the patient to begin with 100 and count backward by sevens. Stop after five subtractions (93, 86, 79, 72, 65). Score the total number of correct answers.
- If the patient cannot or will not perform the subtraction task, ask the patient to spell the word "world" backwards. The score is the number of letters in correct order (e.g., dlrow=5, dlorw=3).

### **Recall (3 points):**

- Ask the patient if he or she can recall the three words you previously asked him or her to remember. Score the total number of correct answers (0-3).

### **Language and Praxis (9 points):**

- Naming: Show the patient a wrist watch and ask the patient what it is. Repeat with a pencil. Score one point for each correct naming (0-2).
- Repetition: Ask the patient to repeat the sentence after you ("No ifs, ands, or buts."). Allow only one trial. Score 0 or 1.
- 3-Stage Command: Give the patient a piece of blank paper and say, "Take this paper in your right hand, fold it in half, and put it on the floor." Score one point for each part of the command correctly executed.
- Reading: On a blank piece of paper print the sentence, "Close your eyes," in letters large enough for the patient to see clearly. Ask the patient to read the sentence and do what it says. Score one point only if the patient actually closes his or her eyes. This is not a test of memory, so you may prompt the patient to "do what it says" after the patient reads the sentence.
- Writing: Give the patient a blank piece of paper and ask him or her to write a sentence for you. Do not dictate a sentence; it should be written spontaneously. The sentence must contain a subject and a verb and make sense. Correct grammar and punctuation are not necessary.
- Copying: Show the patient the picture of two intersecting pentagons and ask the patient to copy the figure exactly as it is. All ten angles must be present and two must intersect to score one point. Ignore tremor and rotation.

(Folstein, Folstein & McHugh, 1975)

## **Frontal Assessment Battery**

### **Purpose**

The FAB is a brief tool that can be used at the bedside or in a clinic setting to assist in discriminating between dementias with a frontal dysexecutive phenotype and Dementia of Alzheimer's Type (DAT). The FAB has validity in distinguishing Fronto-temporal type dementia from DAT in mildly demented patients (MMSE > 24). Total score is from a maximum of 18, higher scores indicating better performance.

### **1. Similarities (conceptualization)**

"In what way are they alike?"

- A banana and an orange

(In the event of total failure: "they are not alike" or partial failure: "both have peel," help the patient by saying: "both a banana and an orange are fruit"; but credit 0 for the item; do not help the patient for the two following items)

- A table and a chair
- A tulip, a rose and a daisy

**Score** (only category responses [fruits, furniture, flowers] are considered correct)

Three correct: 3      Two correct: 2      One correct: 1      None correct: 0

### **2. Lexical fluency (mental flexibility)**

"Say as many words as you can beginning with the letter 'S,' any words except surnames or proper nouns."

If the patient gives no response during the first 5 seconds, say: "for instance, snake." If the patient pauses 10 seconds, stimulate him by saying: "any word beginning with the letter 'S.' The time allowed is 60 seconds.

**Score** (word repetitions or variations [shoe, shoemaker], surnames, or proper nouns are not counted as correct responses)

> 9 words: 3      6-9 words: 2      3-5 words: 1      < 3 words: 0

### **3. Motor series "Luria" test (programming)**

"Look carefully at what I'm doing."

The examiner, seated in front of the patient, performs alone three times with his left hand the series of "fist-edge-palm."

"Now, with your right hand do the same series, first with me, then alone."

The examiner performs the series three times with the patient, then says to him/her:

"Now, do it on your own."

### **Score**

- Patient performs six correct consecutive series alone: 3
- Patient performs at least three correct consecutive series alone: 2
- Patient fails alone, but performs three correct consecutive series with the examiner: 1
- Patient cannot perform three correct consecutive series even with the examiner: 0

### **4. Conflicting instructions (sensitivity to interference)**

"Tap twice when I tap once."

To ensure that the patient has understood the instruction, a series of 3 trials is run: 1-1-1.

"Tap once when I tap twice."

To ensure that the patient has understood the instruction, a series of 3 trials is run: 2-2-2.

The examiner then performs the following series: 1-1-2-1-2-2-2-1-1-2.

**Score**                      No errors: 3                      1 -2 errors: 2                      > 2 errors: 1  
Patient taps like the examiner at least four consecutive times: 0

#### **5. Go-No Go (inhibitory control)**

"Tap once when I tap once."

To ensure that the patient has understood the instruction, a series of 3 trials is run: 1-1-1.

"Do not tap when I tap twice."

To ensure that the patient has understood the instruction, a series of 3 trials is run: 2-2-2.

The examiner then performs the following series: 1-1-2-1-2-2-2-1-1-2.

**Score**                      No errors: 3                      1 -2 errors: 2                      > 2 errors: 1  
Patient taps like the examiner at least four consecutive times: 0

#### **6. Prehension behaviour (environmental autonomy)**

"Do not take my hands."

The examiner is seated in front of the patient. Place the patient's hands palm up on his knees. Without saying anything or looking at the patient, the examiner brings his own hands close to the patient's hands and touches the palms of both the patient's hands, to see if he will spontaneously take them. If the patient takes the examiner's hands, try again after asking the patient: "Now, do not take my hands."

#### **Score**

Patient does not take the examiner's hands: 3  
Patient hesitates and asks what he/she has to do: 2  
Patient takes the hands without hesitation: 1  
Patient takes the examiner's hand even after he/she has been told not to do so: 0

#### **Interpreting results**

A cut off score of 12 on the FAB has a sensitivity of 77% and specificity of 87% in differentiating between frontal dysexecutive type dementias and DAT

#### **References**

Dubois, B. ; Litvan, I.; The FAB: A frontal assessment battery at bedside. *Neurology*. 55(11): 1621-1626, 2000.

Slachevsky, A; Dubois, B. Frontal Assessment Battery and Differential Diagnosis of Frontotemporal Dementia and Alzheimer Disease. *Archives of Neurology*. 61(7): 1104-1107, 2004.



## Trail Making Test (TMT) Parts A & B

### Instructions:

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The patient should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Time the patient as he or she connects the "trail." If the patient makes an error, point it out immediately and allow the patient to correct it. Errors affect the patient's score only in that the correction of errors is included in the completion time for the task. It is unnecessary to continue the test if the patient has not completed both parts after five minutes have elapsed.

- Step 1: Give the patient a copy of the Trail Making Test Part A worksheet and a pen or pencil.
- Step 2: Demonstrate the test to the patient using the sample sheet (Trail Making Part A – *SAMPLE*).
- Step 3: Time the patient as he or she follows the "trail" made by the numbers on the test.
- Step 4: Record the time.
- Step 5: Repeat the procedure for Trail Making Test Part B.

### Scoring:

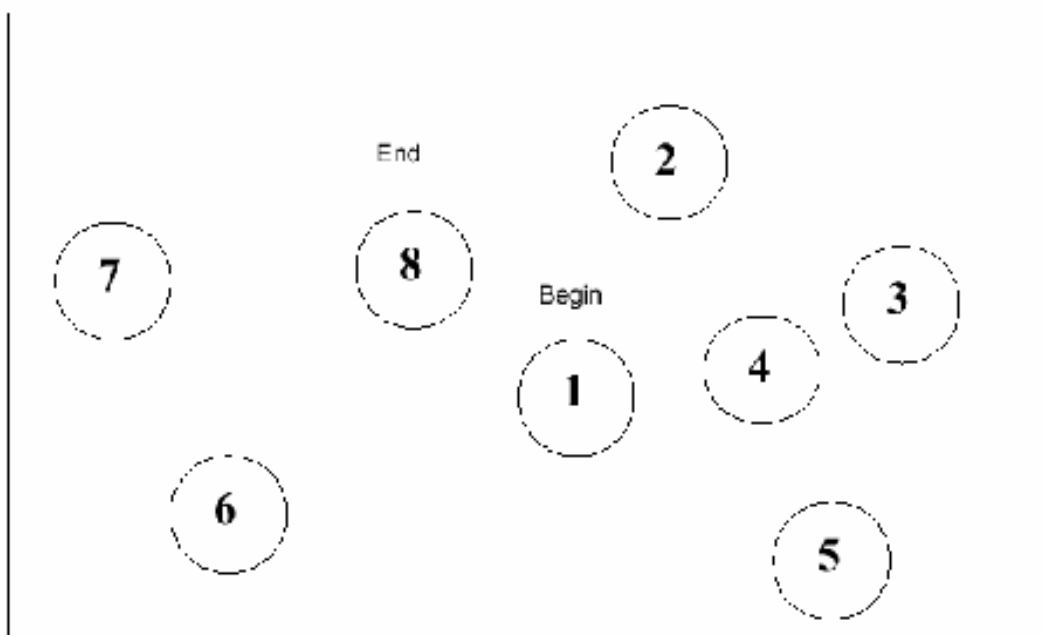
Results for both TMT A and B are reported as the number of seconds required to complete the task; therefore, higher scores reveal greater impairment.

	Average	Deficient	Rule of Thumb
Trail A	29 seconds	> 78 seconds	Most in 90 seconds
Trail B	75 seconds	> 273 seconds	Most in 3 minutes

### Sources:

- Corrigan JD, Hinkeldey MS. Relationships between parts A and B of the Trail Making Test. *J Clin Psychol.* 1987;43(4):402-409.
- Gaudino EA, Geisler MW, Squires NK. Construct validity in the Trail Making Test: what makes Part B harder? *J Clin Exp Neuropsychol.* 1995;17(4):529-535.
- Lezak MD, Howieson DB, Loring DW. *Neuropsychological Assessment.* 4th ed. New York: Oxford University Press; 2004.
- Reitan RM. Validity of the Trail Making test as an indicator of organic brain damage. *Percept Mot Skills.* 1958;8:271-276.

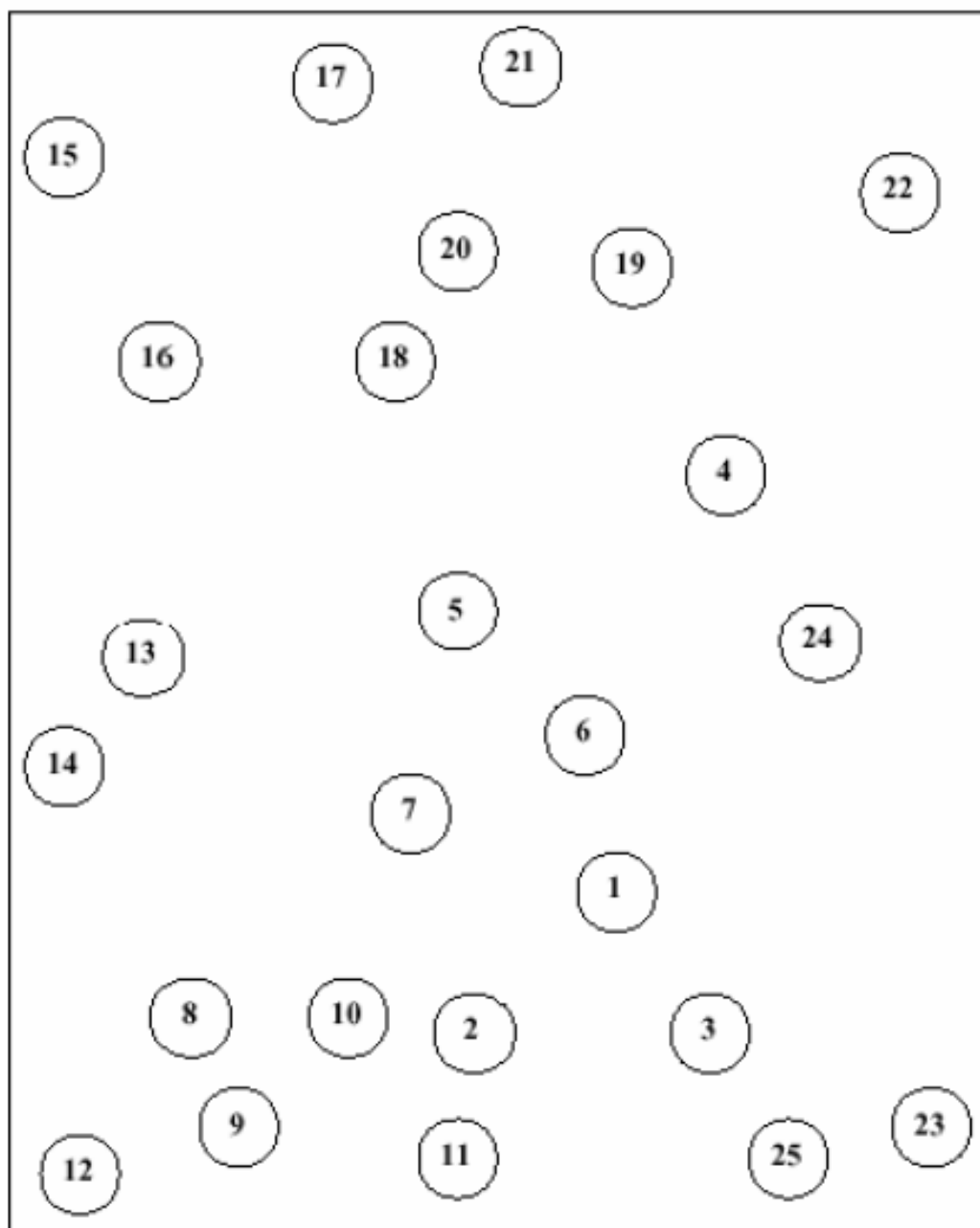
**Trail Making Test Part A – SAMPLE**



## Trail Making Test Part A

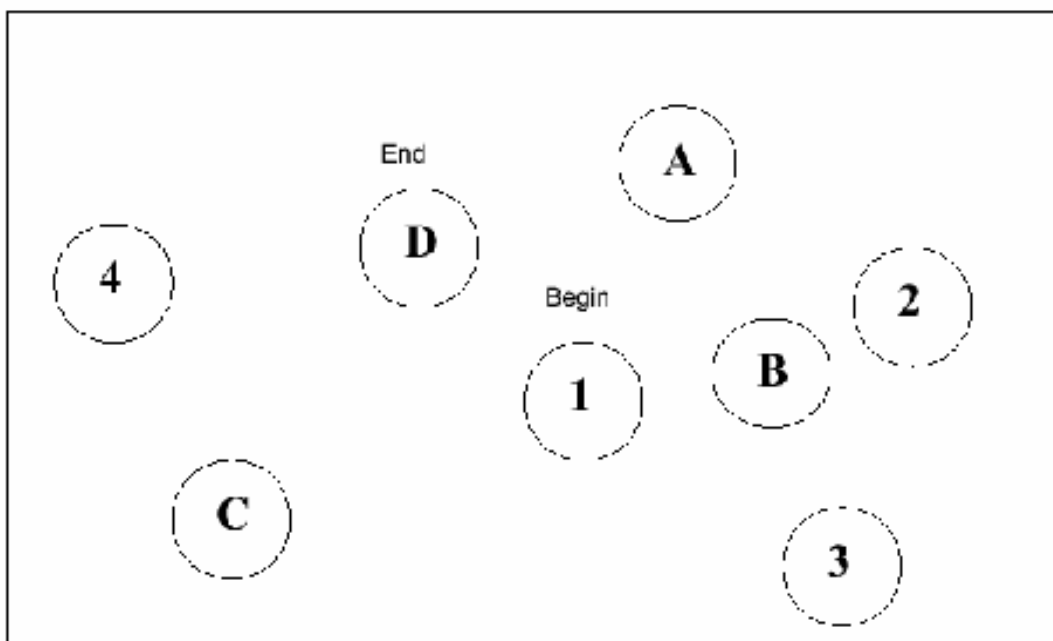
Patient's Name: \_\_\_\_\_

Date: \_\_\_\_\_





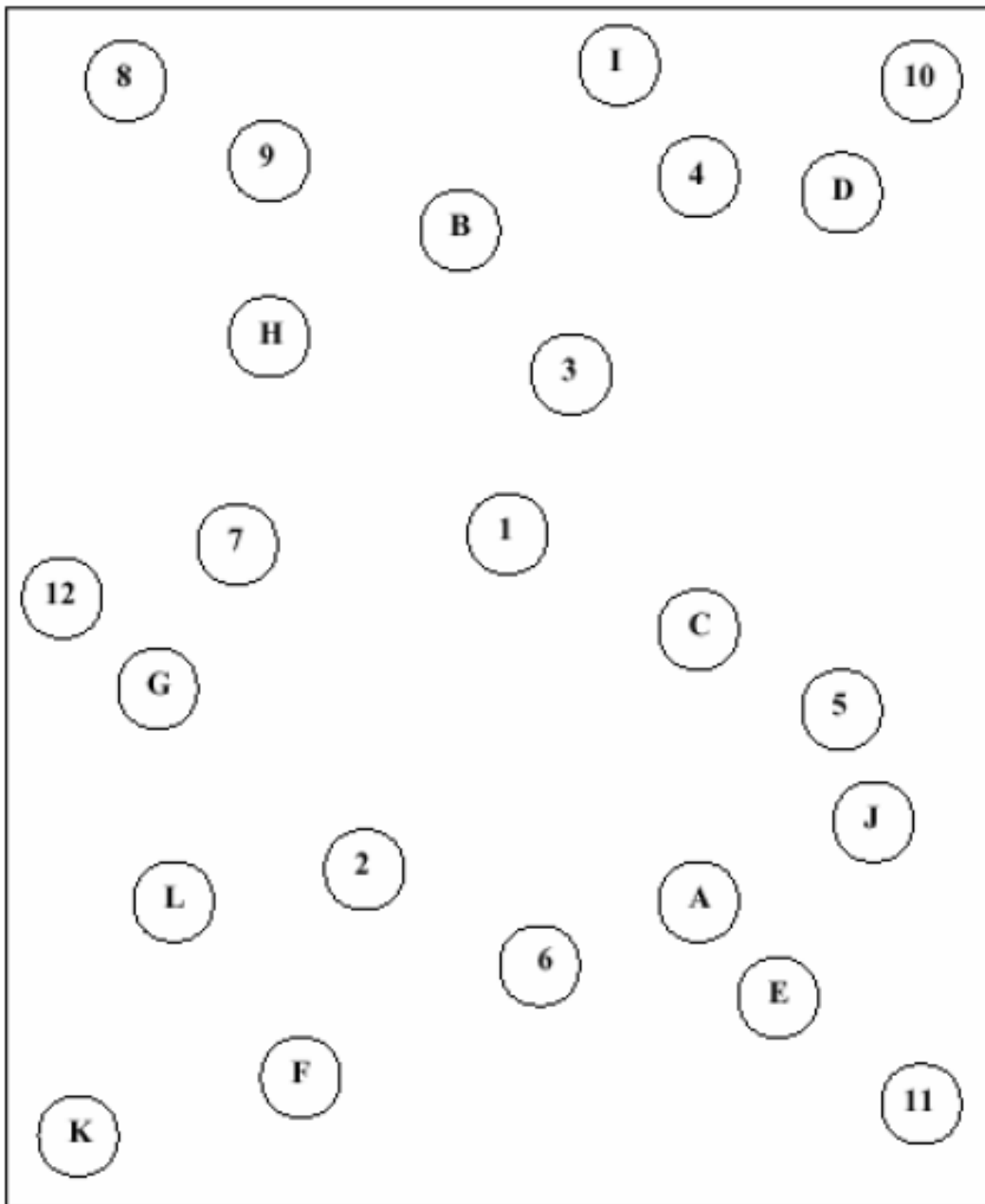
**Trail Making Test Part B – *SAMPLE***



## Trail Making Test Part B

Patient's Name: \_\_\_\_\_

Date: \_\_\_\_\_



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Department of Neurology

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Meds On

Patient Name \_\_\_\_\_

Med. Rec. No. \_\_\_\_\_

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 in 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.
- 9 - Information Missing

2. Thought Disorder.....

- 0 - None
- 1 - Frequent dreaming.
- 2 - "Bizarre" hallucinations with insight retained.
- 3 - Unusual to frequent hallucinations or delusions; without insight; could interfere with daily activities.
- 4 - Persistent hallucinations, delusions, or florid psychosis. Not able to care for self.
- 9 - Information Missing

3. Depression.....

- 0 - Not present
- 1 - Periods of sadness or grief 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.
- 9 - Information Missing

4. Motivation / Initiative.....

- 0 - Normal
- 1 - Less assertive than usual; more passive.
- 2 - Loss of initiative or disinterest in elective (non-routine) activities.
- 3 - Loss of initiative to disinterest in day-to-day (routine) activities.
- 4 - Motivated, complete loss of motivation.
- 9 - Information Missing

5. Total Mentation Score.....

II. ACTIVITIES OF DAILY LIVING

6. 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.
- 9 - Information Missing

Date \_\_\_\_\_

UPDRS

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7. Salivation .....

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

8. Swallowing .....

- 0 - Normal
- 1 - Rare choking.
- 2 - Occasional choking.
- 3 - Requires soft food.
- 4 - Requires NG tube or gastrostomy feeding.
- 9 - Information Missing

9. 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 - Information Missing

10. Cutting food and handling utensils .....

- 0 - Normal
- 1 - Somewhat slow and clumsy; no help needed.
- 2 - Use cut user 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.
- 9 - Information Missing

11. Dressing .....

- 0 - Normal
- 1 - Somewhat slow; no help needed.
- 2 - Occasional assistance with buttoning, getting arms in sleeves.
- 3 - Considerable help required, but can do some things alone.
- 4 - Helpless.
- 9 - Information Missing

12. Hygiene .....

- 0 - Normal
- 1 - Somewhat slow; no help needed.
- 2 - Needs help to shave or bathe, or very slow in hygiene care.
- 3 - Requires assistance for washing, brushing teeth, combing hair, going to bathroom.
- 4 - Fully cathect or other mechanical aids.
- 9 - Information Missing

13. Turning in bed and adjusting bed clothes .....

- 0 - Normal
- 1 - Somewhat slow and clumsy; no help needed.
- 2 - Can turn alone or adjust sheets, but with great difficulty.
- 3 - Can turn, but not turn or adjust sheets alone.
- 4 - Helpless.
- 9 - Information Missing

Date \_\_\_\_\_

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**14. 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.
- 9 - Information missing

**15. Freezing when walking**.....

- 0 - None
- 1 - Rare freezing when walking; may have start-hesitation.
- 2 - Occasional freezing when walking.
- 3 - Frequent freezing. Occasionally falls from freezing.
- 4 - Frequent falls from freezing.
- 9 - Information missing

**16. 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.
- 9 - Information missing

**17. Tremor**..... R \_\_\_\_\_

- 0 - Absent
- 1 - Slight and infrequently present.
- 2 - Moderate; bothersome to patient.
- 3 - Severe; interferes with many activities.
- 4 - Marked; interferes with most activities.
- 9 - Information missing

L \_\_\_\_\_

**18. 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.
- 9 - Information missing

**19. Total Activities of Daily Living Score**.....

Date \_\_\_\_\_

**UPDRS**

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III. MOTOR EXAMINATION

20. Speech \_\_\_\_\_

- 0 - Normal
- 1 - Slight loss of expiratory, diction and/or volume
- 2 - Moderate, stressed and understandable; moderately impaired
- 3 - Marked impairment, difficult to understand
- 4 - Unintelligible
- 9 - Information missing

21. 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 - Marked of fixed furrow with severe or complete loss of facial expression; lips parted by inch or more
- 9 - Information missing

22. Tremor at rest \_\_\_\_\_

- 0 - Absent
- 1 - Slight and infrequently present
- 2 - 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
- 9 - Information missing

JAW \_\_\_\_\_  
 RU \_\_\_\_\_  
 LU \_\_\_\_\_  
 RI \_\_\_\_\_  
 LI \_\_\_\_\_

23. Action of postural tremor of hands \_\_\_\_\_

- 0 - Absent
- 1 - Slight and infrequent
- 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
- 9 - Information missing

R \_\_\_\_\_  
 L \_\_\_\_\_

24. 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 induced
- 4 - Severe, range of motion achieved with difficulty
- 9 - Information missing

NECK \_\_\_\_\_  
 RU \_\_\_\_\_  
 LU \_\_\_\_\_  
 RI \_\_\_\_\_  
 LI \_\_\_\_\_

25. Finger taps \_\_\_\_\_

- 0 - Normal (8-12/5 sec)
- 1 - Mild slowing and/or reduction in amplitude (11-14/5 sec)
- 2 - Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement. (7-10/5 sec)
- 3 - Severely impaired. Frequent hesitation in initiating movement or arrests in ongoing movement. (4-6/5 sec)
- 4 - Can barely raise index finger. (6-2/5 sec)
- 9 - Information missing

R \_\_\_\_\_  
 L \_\_\_\_\_

26. Hand movements \_\_\_\_\_

Patient opens and closes hands in rapid succession with widest amplitude possible, each hand separately.

- 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 movement or arrests in ongoing movement
- 4 - Can barely perform the task
- 9 - Information missing

R \_\_\_\_\_  
 L \_\_\_\_\_

Date \_\_\_\_\_

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**27. Rapid alternating movements of hands**..... R \_\_\_\_\_

*Perforating/impairment movements of hands, vertically or horizontally, with as large an amplitude as possible, both hands simultaneously*

- 0 - Normal
- 1 - Mild slowing and/or reduction in amplitude.
- 2 - Moderately impaired. Delays and early fatiguing. May have occasional arrests in movement.
- 3 - Severely impaired. Frequent hesitation in initiating movement or arrests in ongoing movement.
- 4 - Can barely perform the task.
- 9 - Information Missing

L \_\_\_\_\_

**28. Leg agility with knee bent**..... R \_\_\_\_\_

*Patient sits feet on ground in rapid succession, picking up water foot. Amplitude should be about 3 inches*

- 0 - Normal
- 1 - Mild slowing and/or reduction in amplitude.
- 2 - Moderately impaired. Delays and early fatiguing.
- 3 - Severely impaired. Frequent hesitation in initiating movement or arrests in ongoing movement.
- 4 - Can barely perform the task.
- 9 - Information Missing

L \_\_\_\_\_

**29. Arising from chair**..... \_\_\_\_\_

- 0 - Normal
- 1 - Slow, or may need more than one attempt
- 2 - Pushes self up from arms of seat.
- 3 - Needs to get back and may have to try more than one time, but can get up without help.
- 4 - Unable to arise without help.
- 9 - Information Missing

**30. 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 slumped to one side
- 3 - Severely stooped posture with kyphosis, can be moderately leaning to one side
- 4 - Marked flexion with extreme abnormality of posture.
- 9 - Information Missing

**32. Gait**..... \_\_\_\_\_

- 0 - Normal
- 1 - Walks slowly, may shuffle with short steps but no fixation or propulsion
- 2 - Walks with difficulty, but requires little or no assistance, may have some fixation about steps, or propulsion
- 3 - Severe disturbance of gait, requiring assistance.
- 4 - Cannot walk at all, even with assistance.
- 9 - Information Missing

**33. Postural stability**..... \_\_\_\_\_

*Response to sudden posterior displacement produced by pull on shoulders while patient erect with eyes open and feet slightly apart. Patient is prepared*

- 0 - Normal
- 1 - Re-equilibrates, but recovers unaided

Date \_\_\_\_\_

**UPDRS**

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- 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.
- 9 = Information Missing

**34. Body bradykinesia and hypokinesia**.....

*Counting slowness, hesitancy, decreased arm swing, small amplitude, and poverty of movement in general.*

- 0 = None
- 1 = Minimal slowness, giving movement a deliberate character; could be normal for some persons.
- 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.
- 9 = Information Missing

**35. Total Motor Exam Score**.....

**TOTAL Unified Parkinson's Disease Rating Scale (UPDRS) Score**.....

**IV. COMPLICATIONS OF THERAPY**

**A. Dyskinesias**

**36. 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.
- 9 = Information Missing

**37. Disability**.....

*How disabling are the dyskinesias?*

- 0 = Not disabling
- 1 = Mildly disabling
- 2 = Moderately disabling
- 3 = Severely disabling
- 4 = Completely disabling
- 9 = Information Missing

**38. Painful dyskinesias**.....

*How painful are the dyskinesias?*

- 0 = No painful dyskinesias
- 1 = Slight
- 2 = Moderate
- 3 = Severe
- 4 = Marked
- 9 = Information Missing

**39. Presence of early morning dystonia**.....

- 0 = No
- 1 = Yes
- 9 = Information Missing

**B. Clinical fluctuations**

**40. Are any "off" periods predictable as to timing after a dose of medication?**.....

- 0 = No
- 1 = Yes

Date \_\_\_\_\_

**UPDRS**

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ENDING LINE

University of Kansas Medical Center  
 5901 Rainbow Boulevard - Kansas City, KS 66160  
 Department of Neurology

Patient Name \_\_\_\_\_

Med. Rec. No. \_\_\_\_\_

Meds Off

Meds On

9 = Information Missing

41. Are any "off" periods unpredictable as to timing after a dose of medication? .....

- 0 = No
- 1 = Yes
- 9 = Information Missing

42. Do any of the "off" periods come on suddenly, e.g. over a few seconds? .....

- 0 = No
- 1 = Yes
- 9 = Information Missing

43. What proportion of the waking day is the patient "off" on the average? .....

- 0 = None
- 1 = 1% - 25% of day.
- 2 = 26% - 50% of day.
- 3 = 51% - 75% of day.
- 4 = 76% - 100% of day.
- 9 = Information Missing

**C. Other complications**

44. Does the patient have anorexia, nausea, or vomiting? .....

- 0 = No
- 1 = Yes
- 9 = Information Missing

45. Does the patient have any sleep disturbances, e.g. insomnia or hypersomnolence? .....

- 0 = No
- 1 = Yes
- 9 = Information Missing

46. Does the patient have symptomatic orthostasis? .....

- 0 = No
- 1 = Yes
- 9 = Information Missing

V. Hoehn and Yahr Staging ..... H&Y \_\_\_\_\_

VI. Schwab and England staging ..... Rater \_\_\_\_\_

Date \_\_\_\_\_

**UPDRS**

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**Impressions**

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**Plan**

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**Return to clinic**

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**Signature**

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Date \_\_\_\_\_

**UPDRS**

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# PDQ-39 QUESTIONNAIRE

**Please complete the following**

*Please tick one box for each question*

***Due to having Parkinson's disease, how often during the last month have you....***

		Never	Occasionally	Sometimes	Often	Always or cannot do at all
1	Had difficulty doing the leisure activities which you would like to do?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Had difficulty looking after your home, e.g. DIY, housework, cooking?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Had difficulty carrying bags of shopping?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	Had problems walking half a mile?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	Had problems walking 100 yards?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	Had problems getting around the house as easily as you would like?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	Had difficulty getting around in public?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	Needed someone else to accompany you when you went out?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	Felt frightened or worried about falling over in public?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	Been confined to the house more than you would like?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	Had difficulty washing yourself?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	Had difficulty dressing yourself?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13	Had problems doing up your shoe laces?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

***Please check that you have ticked one box for each question before going on to the next page***

**Due to having Parkinson's disease, how often during the last month have you....**

**Please tick one box for each question**

		Never	Occasionally	Sometimes	Often	Always or cannot do at all
14	Had problems writing clearly?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15	Had difficulty cutting up your food?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16	Had difficulty holding a drink without spilling it?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17	Felt depressed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18	Felt isolated and lonely?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19	Felt weepy or tearful?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20	Felt angry or bitter?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21	Felt anxious?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22	Felt worried about your future?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23	Felt you had to conceal your Parkinson's from people?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24	Avoided situations which involve eating or drinking in public?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25	Felt embarrassed in public due to having Parkinson's disease?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26	Felt worried by other people's reaction to you?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27	Had problems with your close personal relationships?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28	Lacked support in the ways you need from your spouse or partner? <i>If you do not have a spouse or partner tick here</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29	Lacked support in the ways you need from your family or close friends?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Please check that you have ticked one box for each question before going on to the next page**

***Due to having Parkinson's disease, how often during the last month have you....***

***Please tick one box for each question***

	<b>Never</b>	<b>Occasionally</b>	<b>Sometimes</b>	<b>Often</b>	<b>Always</b>	
30	Unexpectedly fallen asleep during the day?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31	Had problems with your concentration, e.g. when reading or watching TV?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32	Felt your memory was bad?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33	Had distressing dreams or hallucinations?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34	Had difficulty with your speech?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
35	Felt unable to communicate with people properly?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36	Felt ignored by people?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37	Had painful muscle cramps or spasms?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38	Had aches and pains in your joints or body?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
39	Felt unpleasantly hot or cold?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

***Please check that you have ticked one box for each question before going on to the next page***

***Thank you for completing the PDQ 39 questionnaire***

## Non-Motor Symptom assessment scale for Parkinson's disease

Name Initial: \_\_\_\_\_

Date: \_\_\_\_\_

Symptoms assessed over the **last month**. Each symptom scored with respect to:

Severity: 0 = None,

1 = Mild: symptoms present but causes little distress or disturbance to patient;

2 = Moderate: some distress or disturbance to patient;

3 = Severe: major source of distress or disturbance to patient.

Frequency: 1 = Rarely (<1/wk);

2 = Often (1/wk);

3 = Frequent (several times per week);

4 = Very Frequent (daily or all the time).

(Bracketed text in questions within the scale is included as an explanatory aid).

	Severity	Frequency
<b>Domain 1: Cardiovascular including falls</b>		
1. Did you experience light-headedness, dizziness, weakness on standing from sitting or lying position?	[ ]	[ ]
2. Did you fall because of fainting or blacking out?	[ ]	[ ]
<b>Domain 2: Sleep/fatigue</b>		
3. Did you doze off or fall asleep unintentionally during daytime activities? (For example, during conversation, during mealtimes, or while watching television or reading).	[ ]	[ ]
4. Did fatigue (tiredness) or lack of energy (not slowness) limit your daytime activities?	[ ]	[ ]
5. Did you have difficulties falling or staying asleep?	[ ]	[ ]
6. Did you experience an urge to move the legs or Restlessness in legs that improves with movement when he/she is sitting or lying down inactive?	[ ]	[ ]
<b>Domain 3: Mood/cognition</b>		
7. Has you lost interest in his/her surroundings?	[ ]	[ ]
8. Has you lost interest in doing things or lack motivation to start new activities?	[ ]	[ ]
9. Did you feel nervous, worried or frightened for no apparent reason?	[ ]	[ ]
10. Did you seem sad or depressed or has he/she reported such feelings?	[ ]	[ ]
11. Did you have flat moods without the normal "highs" and "lows"?	[ ]	[ ]
12. Did you have difficulty in experiencing pleasure from their usual activities or report that they lack pleasure?	[ ]	[ ]
<b>Domain 4: Perceptual problems/hallucinations</b>		
13. Did you indicate that he/she sees things that are not there?	[ ]	[ ]

	Severity	Frequency
14. Did you have beliefs that you know are not true? (For example, about being harmed, being robbed or being unfaithful)	[ ]	[ ]
15. Did you experience double vision? (2 separate real objects and not blurred vision)	[ ]	[ ]
<b>Domain 5: Attention/memory</b>		
16. Did you have problems sustaining concentration during activities? (For example, reading or having a conversation)	[ ]	[ ]
17. Did you forget things that he/she has been told a short time ago or events that happened in the last few days?	[ ]	[ ]
18. Did you forget to do things? (For example, take tablets or turn off domestic appliances?)	[ ]	[ ]
<b>Domain 6: Gastrointestinal tract</b>		
19. Did you dribble saliva during the day?	[ ]	[ ]
20. Did you have difficulty swallowing?	[ ]	[ ]
21. Did you suffer from constipation? (Bowel action less than three times weekly)	[ ]	[ ]
<b>Domain 7: Urinary</b>		
22. Did you have difficulty holding urine? (Urgency)	[ ]	[ ]
23. Did you have to void within 2 hours of last voiding? (Frequency)	[ ]	[ ]
24. Did you have to get up regularly at night to pass urine? (Nocturia)	[ ]	[ ]
<b>Domain 8: Sexual function</b>		
25. Did you have altered interest in sex? (Very much increased or decreased, please underline)	[ ]	[ ]
26. Did you have problems having sex?	[ ]	[ ]
<b>Domain 9: Miscellaneous</b>		
27. Did you suffer from pain not explained by other known conditions? (Is it related to intake of drugs and is it relieved by antiparkinson drugs?)	[ ]	[ ]
28. Did you have a change in ability to taste or smell?	[ ]	[ ]
29. Did you have a recent change in weight (not related to dieting)?	[ ]	[ ]
30. Did you experience excessive sweating (not related to hot weather)?	[ ]	[ ]

**TOTAL SCORE:**

Developed by the International Parkinson's Disease Non-Motor Group.  
Contacts: ray.chaudhuri@uhl.nhs.uk or alison.forbes@uhl.nhs.uk

## Parkinson's Disease Sleep Scale (PDSS-2)

Name Initial: \_\_\_\_\_

Date: \_\_\_\_\_

Please rate the severity of the following based on your experiences during the past week (7 days). Please make a cross in the answer box.

	Very often (6 to 7 days a week)	Often (4 to 5 days a week)	Sometimes (2 to 3 days a week)	Occasionally (1 day a week)	Never
1. Overall, did you sleep well during the last week?	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4
2. Did you have difficulty falling asleep each night?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
3. Did you have difficulty staying asleep?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
4. Did you have restlessness of legs or arms at night causing disruption of sleep?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
5. Was your sleep disturbed due to an urge to move your legs or arms?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
6. Did you suffer from distressing dreams at night?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
7. Did you suffer from distressing hallucinations at night (seeing or hearing things that you are told do not exist)?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
8. Did you get up at night to pass urine?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
9. Did you feel uncomfortable at night because you were unable to turn around in bed or move due to immobility?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
10. Did you feel pain in your arms or legs which woke you up from sleep at night?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
11. Did you have muscle cramps in your arms or legs which woke you up whilst sleep at night?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
12. Did you wake early in the morning with painful posturing of arms or legs?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
13. On waking, did you experience tremor?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
14. Did you feel tired and sleepy after waking in the morning?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0
15. Did you wake up at night due to snoring or difficulties with breathing?	<input type="checkbox"/> 4	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0



Parkinson Fatigue Scale (From Brown et al.)

Name initial: \_\_\_\_\_ Date: \_\_\_\_\_ ID: \_\_\_\_\_

1. I have to rest during the day.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
2. My life is restricted by fatigue.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
3. I get tired more quickly than other people I know.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
4. Fatigue is one of my three worst symptoms.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
5. I feel completely exhausted.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
6. Fatigue makes me reluctant to socialize.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
7. Because of fatigue it takes me longer to get things done.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
8. I have a feeling of "heaviness."  
*strongly disagree disagree do not agree or disagree agree strongly agree*
9. If I was not so tired I could do more things.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
10. Everything I do is an effort.  
*strongly disagree disagree do not agree or disagree agree strongly agree*

11. I lack energy for much of the time.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
12. I feel totally drained.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
13. Fatigue makes it difficult for me to cope with everyday activities.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
14. I feel tired even when I have not done anything.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
15. Because of fatigue I do less in my day than I would like.  
*strongly disagree disagree do not agree or disagree agree strongly agree*
16. I get so tired I want to lie down wherever I am.  
*strongly disagree disagree do not agree or disagree agree strongly agree*

## Exercise Diary

**Time period:**

**Name initial:**

Date	Qigong this morning	Qigong last night	Other exercise yesterday > 0.5 hour	Sleep quality last night (1-5)	Fatigue level yesterday (0-10)
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		
	Yes / No	Yes / No	Yes / No		
	morning pain daily pain		Important events:		

**Sleep quality:** 1 (very restless) ---- 5 (very sound)

**Fatigue level:** 0 (no fatigue) ---- 10 (maximum fatigue)

**Pain level:** 0 (no pain) ---- 10 (extremely painful)

## **APPENDIX B: ADDITIONAL DATA**

**Early Cue**

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>Stride Time (s)</b>	<b>1.24 ± 0.15</b>	<b>1.18 ± 0.12</b>	<b>0.0000</b>
<b>Stride Length (m)</b>	<b>1.07 ± 0.24</b>	<b>1.14 ± 0.19</b>	<b>0.0033</b>
<b>Double Support (%)</b>	<b>28.84 ± 7.04</b>	<b>25.64 ± 5.23</b>	<b>0.0000</b>
<b>Velocity (m/s)</b>	<b>0.89 ± 0.27</b>	<b>0.99 ± 0.24</b>	<b>0.0004</b>

(a)

**Late Cue**

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>Stride Time (s)</b>	<b>1.23 ± 0.15</b>	<b>1.18 ± 0.11</b>	<b>0.0000</b>
<b>Stride Length (m)</b>	1.05 ± 0.25	1.10 ± 0.19	0.0316
<b>Double Support (%)</b>	<b>29.58 ± 8.41</b>	<b>26.79 ± 5.34</b>	<b>0.0008</b>
<b>Velocity (m/s)</b>	<b>0.88 ± 0.28</b>	<b>0.95 ± 0.23</b>	<b>0.0027</b>

(b)

**Table B1:** Gait performance in cueing conditions. Mean ± standard deviation is given for pre- and post-intervention testing in early (a) and late (b) cue conditions. P-values from post-hoc t-tests are given. Bold entries indicate significant difference ( $p < 0.0125$ ).

**Early Cue**

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>CV Stride Time</b>	<b>5.46 ± 1.90</b>	<b>2.95 ± 1.44</b>	<b>0.0213</b>
<b>CV Stride Length</b>	10.04 ± 7.27	5.95 ± 7.30	0.0726

(a)

**Early Cue**

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>CV Stride Time</b>	4.55 ± 2.66	3.21 ± 1.47	0.1023
<b>CV Stride Length</b>	9.43 ± 9.58	6.54 ± 6.15	0.1306

(b)

**Table B2:** Gait variability in cueing conditions. Mean ± standard deviation is given for pre- and post-intervention testing in early (a) and late (b) cue conditions. P-values from post-hoc t-tests are given. Bold entries indicate significant difference ( $p < 0.0250$ ).

**Early Cue**

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>Turn Steps (#)</b>	6.90 ± 2.14	6.95 ± 1.99	0.9048
<b>Turn Time (s)</b>	4.25 ± 1.41	4.27 ± 1.58	0.9434

(a)

**Late Cue**

	<b>Pre</b>	<b>Post</b>	<b>p-value</b>
<b>Turn Steps (#)</b>	7.05 ± 2.18	6.76 ± 1.87	0.5209
<b>Turn Time (s)</b>	4.44 ± 1.57	4.15 ± 1.75	0.4492

(b)

**Table B3:** Turn performance in cueing conditions. Mean ± standard deviation is given for pre- and post-intervention testing in early (a) and late (b) cue conditions. P-values from post-hoc t-tests are given. Bold entries indicate significant difference ( $p < 0.0250$ ).

	Subj 1		Subj 2*		Subj 3		Subj 4		Subj 5		Subj 6		Subj 7	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
<b>Mobility</b>	10	7	3	10	2	2	0	3	25	31	1	0	24	23
<b>ADL</b>	4	4	7	12	1	0	2	2	7	6	3	1	13	8
<b>Emotional well being</b>	11	8	3	5	2	3	0	2	8	8	1	1	17	19
<b>Stigma</b>	0	0	2	4	0	0	0	0	9	0	0	0	11	9
<b>Social Support</b>	0	2	0	0	0	0	0	0	0	0	0	0	6	9
<b>Cognitions</b>	6	7	2	3	3	3	0	2	5	2	4	3	10	9
<b>Communication</b>	3	4	0	0	0	1	0	0	9	2	0	0	9	9
<b>Bodily Discomfort</b>	5	4	4	3	3	0	0	1	10	7	0	3	6	7
<b>Total</b>	39	36	21	37	11	9	2	10	73	56	9	8	96	93

**Table B4:** Individual Responses to Parkinson’s Disease Questionnaire (PDQ-39). Scores for each subsection are given with higher scores indicating more severe complications. \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.



	Subj 1		Subj 2*		Subj 3		Subj 4		Subj 5		Subj 6		Subj 7	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
<b>Cardiovascular</b>	1	1	5	2	0	0	1	0	0	0	0	1	6	6
<b>Sleep/Fatigue</b>	10	15	6	9	2	1	0	3	36	16	8	3	16	30
<b>Mood/Cognition</b>	32	40	0	2	4	1	0	2	15	2	0	2	17	42
<b>Perceptual Problems/ Hallucinations</b>	2	0	0	0	1	0	0	0	0	0	0	0	1	1
<b>Attention/Memory</b>	27	16	0	3	1	1	1	3	0	0	3	5	6	20
<b>GI Tract</b>	2	3	2	2	2	0	0	0	5	4	0	1	4	10
<b>Urinary</b>	0	0	2	2	18	16	1	2	36	18	6	2	5	2
<b>Sexual Function</b>	0	0	0	0	0	0	12	1	20	12	4	4	24	0
<b>Miscellaneous</b>	3	5	12	12	0	0	0	0	4	2	0	6	0	16
<b>Total</b>	77	80	27	32	28	19	15	11	116	54	21	24	79	127

**Table B5:** Individual Responses to Non-Motor Symptoms Questionnaire (NMS Quest). Scores for each subsection and the total are included with higher scores indicating more severe complications. \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.

	Subj 1		Subj 2*		Subj 3		Subj 4		Subj 5		Subj 6		Subj 7	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
<b>Motor Symptoms at Night</b>	7	3	14	4	6	1	20	3	13	8	0	1	6	6
<b>PD Symptoms at Night</b>	3	3	4	1	3	1	20	1	11	7	0	1	9	13
<b>Disturbed Sleep</b>	8	6	15	5	6	6	16	11	18	8	13	10	13	15
<b>Total</b>	18	12	33	10	15	8	56	15	42	23	13	12	28	34

**Table B6:** Individual Responses to Revised Parkinson’s Disease Sleep Scale (PDSS-2). Scores for each subsection and the total are included with higher scores indicating more severe complications. \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.

	Subj 1		Subj 2*		Subj 3		Subj 4		Subj 5		Subj 6		Subj 7	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
<b>PFS Total</b>	55	63	46	63	31	20	19	57	66	64	49	45	64	67

**Table B7:** Individual Responses to Parkinson’s Fatigue Scale (PFS). Scores for each subsection and the total are included with higher scores indicating more severe complications. \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.

Subj #	Gait Velocity (m/s)		Stride Length (m)	
	Pre	Post	Pre	Post
1	1.121 ± 0.064	1.131 ± 0.067	1.187 ± 0.050	1.193 ± 0.040
2*	0.703 ± 0.068	0.794 ± 0.047	0.991 ± 0.047	1.021 ± 0.040
3	0.803 ± 0.090	0.891 ± 0.059	1.082 ± 0.067	1.136 ± 0.044
4	0.905 ± 0.093	0.778 ± 0.076	1.114 ± 0.070	1.003 ± 0.077
5	0.602 ± 0.023	0.860 ± 0.058	0.801 ± 0.039	0.996 ± 0.061
6	1.435 ± 0.136	1.460 ± 0.078	1.573 ± 0.074	1.525 ± 0.051
7	1.034 ± 0.104	1.121 ± 0.071	1.097 ± 0.079	1.189 ± 0.050

(a-b)

Subj #	Stride Time (s)		Double Support (% gait cycle)	
	Pre	Post	Pre	Post
1	1.060 ± 0.024	1.056 ± 0.032	21.908 ± 1.528	22.293 ± 1.463
2*	1.417 ± 0.080	1.288 ± 0.041	32.390 ± 2.134	27.809 ± 1.321
3	1.356 ± 0.079	1.277 ± 0.050	34.213 ± 2.337	30.360 ± 3.051
4	1.238 ± 0.090	1.293 ± 0.052	30.219 ± 4.710	33.156 ± 2.330
5	1.332 ± 0.046	1.158 ± 0.019	34.644 ± 2.183	24.656 ± 1.615
6	1.101 ± 0.059	1.046 ± 0.024	20.691 ± 1.589	21.562 ± 1.100
7	1.065 ± 0.038	1.062 ± 0.026	19.965 ± 1.692	20.114 ± 1.186

(c-d)

**Table B8:** Individual Gait Performance: Mean ± standard deviation is given for (a) gait velocity, (b) stride length, (c) stride time, and (d) double support time. \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.

Subj #	CV Stride Time		CV Stride Length	
	Pre	Post	Pre	Post
1	2.263	2.999	4.248	3.365
2*	5.666	3.173	4.700	3.936
3	5.853	3.885	6.182	3.876
4	7.261	3.986	6.300	7.649
5	3.443	1.641	4.909	6.149
6	5.329	2.317	4.686	3.312
7	3.557	2.436	7.229	4.240

**Table B9:** Individual Gait Variability: Coefficient of variation is given for stride time and stride length (CV = 100\*(standard deviation / mean)). \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.

Subj #	Turn Steps (# steps)		Turn Time (s)	
	Pre	Post	Pre	Post
1	5.167 ± 0.408	5.167 ± 0.408	2.947 ± 0.169	2.949 ± 0.238
2*	6.500 ± 0.837	6.667 ± 0.816	4.879 ± 0.478	4.988 ± 0.392
3	4.667 ± 0.516	5.167 ± 1.472	3.358 ± 0.279	3.976 ± 1.532
4	8.667 ± 1.211	8.667 ± 1.211	6.193 ± 1.175	6.246 ± 1.521
5	8.667 ± 1.966	9.167 ± 2.041	5.950 ± 1.053	5.890 ± 1.387
6	5.500 ± 0.548	5.333 ± 0.816	2.763 ± 0.537	2.632 ± 0.484
7	9.333 ± 0.816	8.167 ± 1.329	3.746 ± 0.660	3.382 ± 0.590

**Table B10:** Individual Turn Performance: Mean ± standard deviation is given for total number of steps and total time taken to complete turning task. \*Subject 2 reduced Carbidopa/Levodopa medication from 125/500 mg/day to 75/300 mg/day during the course of the intervention.