**The Impact of Tai Chi Chuan Training on the Gait, Balance, Fear of Falling, Quality of Life, and Tremor in Four Women with Moderate Idiopathic Parkinson's Disease**

by

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## Dedication

This thesis is first and foremost dedicated to all those individuals afflicted by Ideopathic Parkinson's Disease in an effort to improve their quality and span of life. May a cure for this devastating disease soon be discovered and may God watch over all of you.

I also dedicate this work to my family and friends whose care and understanding have inspired me through out the duration of this project.

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**Abstract**

Tai Chi Chuan is an exercise that has been promoted to be beneficial to people suffering from idiopathic Parkinson's disease (IPD). The purpose of this study was to determine if Tai Chi Chuan training impacted the balance, fear of falling, gait, tremor, and quality of life in four women with moderate IPD. Four separate single subject A-B-A treatment with-drawl designs were employed with three-week pre and post intervention baseline measures (Phases A1 & A2) to establish disease trend and variability. The treatment phase (phase B) consisted of a 20 week community based Tai Chi Chuan training period with outcome measures every two weeks. Four female volunteer subjects, between the ages of 50-70 years, participated and were chosen to represent the following disease representations: tremor dominant in stage II, tremor dominant in stage III, bradykinetic dominant in stage II, and bradykinetic dominant in stage III. The initial interview included pre-intervention measures of the Unified Parkinson's Disease rating scale (UPDRS) and the Beck's Depression Inventory (BDI) plus practice session with the nine outcome measures of selected gait parameters, fear of falling, quality of life, tremor, and functional reach. Upon completion the UPDRS and BDI were reassessed. Data was analyzed using visual analysis, split middle technique, C-statistic, and inductive content analysis of subject log-books. No significant trend changes in outcomes measured for any subject were noted. There were significant level changes in some measures primarily due to the different phase length. Subjects two and three had non-significant Phase B improvements in all gait measures. Only subject three showed non-significant trends towards improvement in functional reach, perceived quality of life and fear of falling measures. The other three subjects showed inconclusive evidence of improvement in ability to reach forward. The subjective measures of the other three subjects showed a worsening or no change of perceived quality of life and fear of falling over the duration of the study. There was insufficient conclusive evidence that TCC training was beneficial for people with IPD although visual inspection of data indicated that people with shorter duration since diagnosis of IPD may benefit. Consistency and duration of training plus control over extraneous variables such as medication and humidity is advised for future research.

**List of Abbreviations**

| | |
|---|---|
| ADL | activities of daily living |
| BDI | Beck's Depression Inventory |
| BG | basal ganglia: paired structures |
| BOS | base of support |
| CABG | coronary artery bypass graft |
| COG | center of gravity |
| COMT | catechol – O - methyltransferase |
| EEG | electroencephalograph |
| FICSIT | Frailty and Injuries: Cooperative Studies of Intervention Techniques |
| FR | Functional Reach |
| GPe | globus pallidus external segment |
| GPi | globus pallidus internal segment |
| H&Y | Heohn and Yahr |
| IPD | Idiopathic Parkinson's disease |
| MAO-B | Monoamine oxidase B |
| MFES | Modified Falls Efficacy Scale |
| MMSE | Mini Mental State Exam |
| PIMS | Parkinson's Impact Measurement Scale |
| ROM | range of motion |
| RSL | right stride length |
| RST | right stride time |
| SL | stride length |
| SMA | supplementary motor area |
| SN | substantia nigra |
| SNpc | substantia nigra pars compacta |
| SNr | substantia nigra reticularus |
| SSD | single subject design |
| SST | single support time |
| ST | stride time |
| STN | subthalamic nucleus |
| S&E | Schwab and English |
| TCC | tai chi chuan |
| UPDRS | Unified Parkinson's Disease Rating Scale |
| WHO | World Health Organization |
| WS | walking speed |

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# CHAPTER 1

## INTRODUCTION

Idiopathic Parkinson's disease (IPD) is a progressive neurologic disorder resulting in four main movement dysfunctions: slowness of movement (bradykinesia), difficulty initiating movement (akinesia), stiffness (rigidity), and tremor (Marsden 1994). The movement problems associated with IPD lead to soft tissue changes that eventually cause postural deformity, decreased joint range (ROM), diminished endurance, reduced lung function and limitations in activities of daily living. The characteristic flexed posture of people with IPD alters body mechanics compromising balance and limiting walking performance. In addition, delayed initiation and implementation of the normal balance responses increases the likelihood of falls in people with IPD. Falls, a feature of IPD, are associated with injuries, such as hip fractures, leading to costly hospitalization and increased morbidity (Charlett *et. al.* 1997). Fear of falling may also lead to decreased activity and has been identified as the greatest fear in 25% of community dwelling elderly (Hill *et. al.* 1996). The neuromuscular manifestations of IPD lead to changes in physical abilities, safety, and quality of life.

Adequate balance control is critical to prevent falls in everyday activities like walking and reaching. The gait of people with IPD is characterized by reduced walking speed, stride length, and single support with increased cadence and double support time (Morris *et. al.* 1994a & 1994b, 1996a & 1996b). The shuffling gait pattern of people with IPD interferes with the ability to perform basic activities such as crossing the street safely at a signaled intersection. The ability to control dynamic balance is an essential part of walking and is compromised in IPD (Brown and Marsden 1998). The ability to control balance while reaching forward and not changing foot position (static balance) has been shown to decrease as IPD duration increases (Smithson *et. al.* 1998, Grill 1999). Further, the gait and balance abilities can vary greatly during the day due to the effects of long term medication that alter motor performance and often affect functional independence (Erikksson *et. al.* 1984).

Idiopathic Parkinson's disease (IPD) results from the death of dopaminergic cells, primarily in the substantia nigra, that decreases the output from the globus pallidus internal segment of the basal ganglia. The primary treatment for IPD is the administration of medication. Currently, available drugs are effective in controlling the IPD symptoms for approximately five years (Fahn 1996). Subsequently, the medications become unreliable and the person begins to experience wearing off, dyskinesias, "on-off" syndromes, and motor fluctuations. The term "on" refers to when the medication is working as expected and "off" refers to the reappearance of IPD symptoms (Erikksson *et. al.* 1984). The medication adequately controls the IPD symptoms for a number of years often resulting in referral for physiotherapy only once function is greatly impaired. By this time, posture and joint range of motion (ROM) has been adversely affected resulting in balance, gait, breathing and swallowing difficulties. Many of these delayed complications are irreversible due to permanent soft tissue and joint changes. Minimizing the joint and muscular complications through preventive exercises is likely to improve the quality of life, thereby allowing people with IPD to benefit from advances in the medical and surgical management of the disorder.

Community based exercise has been shown to improve balance, decrease falls, and increase lower extremity strength and flexibility in older, healthy females (Hubley-

Kozey, 1995a and 1995b, Turnbull *et. al.* 1991). Exercise programs specifically designed for people with IPD have been shown to be beneficial (Reuter *et. al.* 1999). Tai Chi Chuan (TCC), a community based Chinese exercise composed of a series of slow rhythmical movements, has been advocated for people with IPD as a method to improve mental and physical performance (Kutner *et. al.* 1997, Turnbull *et. al.* 1996, Wolf *et. al.* 1996, Jin 1989, Zhuo 1988, Zhou 1984).

Tai Chi Chuan involves movements usually included in physiotherapy programs for individuals with IPD such as; balance training, reciprocal limb motion, spinal rotation, deep breathing, rib-cage movement, strength training emphasizing the lower extremity, postural muscle training, and relaxation exercises (Reuter *et. al.* 1999). Because of the inclusion of the traditional physiotherapy elements, TCC has a potential role in the management of IPD particularly in the areas of improving balance, gait, and falling. Tai Chi Chuan has been shown to improve balance, strength and kinesthetic sense in healthy adults and reduce the fear of falling in the healthy elderly (Wolf *et. al.* 1997 and 1993, Jacobson *et. al.* 1997). However, these studies included only a few modified TCC forms and, as such, did not represent community-based TCC programs. In addition to the physical training in TCC, it is purported to have benefits to mental well being.

Training in TCC has been reported to decrease depression and improve quality of life in subjects with IPD (Waters and Walsh 1997). These results were encouraging but a high attrition rate prevented any statistical analysis. No systematic study of the use of this exercise approach has been conducted to support these claims or to identify which aspect (the cognitive, quality of life, and movement presentations) of IPD might benefit from TCC training. In addition to the physical benefits of exercise, perceived state of well-being can be enhanced by the inclusion of cognitive components into the exercise regime (Brown *et. al.* 1995, Blumenthal *et. al.* 1989, Wolf *et. al.* 1997). The inherent meditative and cognitive aspects in TCC training, as indicated by changes in the EEC readings of individuals performing meditation, should also improve the perceived state of well being and quality of life in people with IPD (Lee *et. al.* 1997).

In addition to improving balance control, which may improve quality of life, TCC classes may encourage people with IPD to participate in group-settings with healthy people thereby encouraging retention of social skills and contacts while improving the participant's perceptions of well being. The ability to participate in leisure activities has been reported as a major determinant of quality of life scores (Chrischilles *et. al.* 1998). The social component of TCC training may reduce isolation and improve motivation and compliance. Reinforcing the physical management of IPD within community-based programs enhances the philosophy of health promotion in IPD management in contrast to the more common "illness" paradigm. The perception of the inevitability of disability as a result of IPD can be reduced thus improving quality of life.

Previous research has indicated that TCC training may have a role in the enhancement of a wider social framework as well as improve the physical and mental well being of people with IPD (Waters and Walsh 1997, Wolf *et. al.* 1997 and 1993). However, there is a need to test these hypotheses on people at different stages and presentations of IPD to identify those who might benefit from such an intervention.

## Study Significance

The significance of this study was to determine the impact of a community-based TCC program with respect to the function and quality of life of four individuals with moderate (Hoehn and Yahr stage II and III) IPD. Early exercise intervention for people with IPD may help delay the onset of physical complications resulting from the pathological poverty of movement. By delaying these complications, people would be better able to function and maintain leisure activities, a major determinant of perceived quality of life. Participants in formalized exercise programs often do not continue unless the exercise is a sport with a strong social component. The cognitive component and social nature of the TCC exercises should encourage compliance with the regime. Since there is indication in the literature that daily TCC practice improves balance in well elderly, this exercise should also reduce the risk of falls, improve function and perceived quality of life for people with early stages IPD thereby easing financial health care costs.

## Problem

Tai Chi Chuan has been widely advocated and commonly performed as an inexpensive community-based leisure activity program that can improve the function and well-being of people with IPD. Theoretically, TCC training may delay the joint and muscular complications experienced due to the poverty of movement in people with IPD. However, the research to support these claims is inadequate.

## Purpose

The purpose of this study was to determine if community based TCC training influenced the quality of life, fear of falling, tremor, balance and specific gait characteristics of four women in stage II and III IPD.

## Objectives

The specific objectives of this study were:

1. To identify if TCC training improved the gait characteristics of speed (WS), stride length (SL), stride time (ST), single support time (SST), cadence and range of walking speeds in each of the four subjects with IPD.
2. To identify if TCC training improved balance in terms of increased ability to reach forward in each of the four subjects with IPD.
3. To identify if TCC training reduced the fear of falling and number of falls in each of the four subjects with IPD.
4. To identify if TCC increased the quality of life scores in each of the four subjects with IPD.
5. To identify if TCC training had any effect on tremor scores in each of the four subjects with IPD.

## Hypotheses

The following hypotheses were examined

1. There will be a positive trend in the WS, SL, SST, and range of walking speeds in four individuals with IPD who participate in 20 weeks of TCC training. The expected WS for free gait after TCC training in the four individuals with IPD will approximate the normal value of 0.8 -1 stat/s.
2. There will be a negative trend in the ST in the four individuals with IPD who participate in 20 weeks TCC training.
3. Cadence will approximate normal values (120 steps / min. for free WS) in the four individuals with IPD who participate in 20 weeks TCC training.

4. There will be an improvement in functional reach in four individuals with IPD who participate in 20 week TCC training.

5. There will be a subjective reduction in fear of falling and falls in four individuals with IPD who participate in 20 week TCC training.

6. There will be an improvement in quality of life scores in four individuals with IPD who participate in 20 week TCC training.

7. There will be some change in tremor during a writing task in four individuals with IPD who participate in 20 week TCC training.

# CHAPTER 2

# LITURATURE

## Incidence and Prevalence

Approximately eighty percent of people with Parkinson's disease suffer from IPD (Fahn 1995). The incidence of IPD in North America is roughly 20 per 100 000 people (Rajput and Birdi 1997, Marsden 1994, Mutch *et. al.* 1986, Rajput 1984) with no apparent gender or race differences (Rajput and Birdi 1997, Marsden 1994). There is some indication of geographic differences in incidence rate (Rajput and Birdi 1997) suggesting environment and / or genetics may play a role in disease development.

The North American prevalence of IPD is 300 per 100 000 people and increases exponentially beyond the age of 50 years making IPD predominantly a disease of the elderly (Rajput and Birdi 1997, Marsden 1994, Mutch *et. al.* 1986, Rajput 1984). The number of Canadians over the age of 85 has doubled between 1971 and 1991 thereby increasing the population at risk of developing IPD (Rajput and Birdi 1997). In Canada there is presently an estimated 100 000 people diagnosed with IPD (Parkinson Foundation of Canada 1988). With the current trend in Canadian health care toward community-based programs, and the aging population, the societal and health care costs associated with IPD are likely to increase. Since exercise has been shown to decrease the number of falls and improve the UPDRS scores in people with IPD, the recent increase in early onset IPD provides the impetus for early exercise intervention to help reduce the complications resulting from poverty of movement (Reuter *et. al.* 1999). Maintenance of optimal physical function is paramount to allow individuals with IPD to take advantage of advances in medical treatment of this disease.

## Cost

The social, economic, emotional, and health stresses of chronic disease such as IPD are great with the estimated cost of IPD medication alone as $5000 Canadian per person per year (Turnbull 1992). Additional costs incurred by the families of people with IPD include specialized transportation, home wheelchair adaptations, specialized food preparations, adaptive devices, and medical costs of fall related injuries. The estimated direct and indirect costs of IPD across Canada are several billion Canadian dollars per year although actual values are not available (Parkinson Foundation of Canada, 1988). Preventing or maintaining better posture, gait, and balance would help reduce the costs by reducing the number of falls, improving general mobility, and improving the quality of life. Exercise and increased mobility has been shown to improve life expectancy in people with IPD (Reuter *et. al.* 1999).

## Morbidity and Mortality

People with IPD have a 2-5 fold increased risk of mortality (Rajput 1984, Di Rocco *et. al.* 1996, Louis *et. al.* 1997 and 1996) and higher risks are associated with bradykinetic IPD and dementia (Louis *et. al.* 1997 and 1996). People with IPD often die as a result of complications developed due to lack of mobility. According to Di Rocco *et. al.* (1996), the leading causes of death in people with IPD older than 65 years are cardiovascular disease (21.7%) and pneumonia (16.5%). The reduction in movement increases the risk of cardiovascular disease plus the associated decreased rib cage motion, development of the forward flexed posture, and swallowing difficulties in people with IPD increases the risk of developing pneumonia. Gait and balance abnormalities seen with IPD can lead to falls and hip fracture, one of the top age-related morbidities (Hill *et.*

*al.* 1996). The causes of the IPD motor dysfunction that lead to morbidity are known to be related to the loss of dopaminergic cells in the Basal Ganglia (BG). However, the mechanism of cell death remains unclear.

## Etiology

The cause of IPD is not known. The traditional theory that IPD resulted from accelerated normal aging process is no longer considered valid since Fearnley and Lees (1991) showed that in IPD the neurons die in an opposite pattern and much faster rate than normal aging. There are several prominent theories are about the cause of IPD. Heredity (DeMichele *et. al.* 1996, Marsden 1994, Piccini *et. al.* 1999, Golbe 1999); environmental factors such as pesticide exposure, minor head trauma, non smoking, cell aptopsis (Burke 1998); viral damage, Lewy body formation (DeMichele *et. al.* 1996, Marsden 1994), and DNA mitochondrial mutations (Gu *et. al.* 1998) have been investigated. Despite the above studies, there are no definitive conclusions about the cause of IPD. It is possible that an acute event imposed on genetically predisposed cells results in disease development.

## Pathophysiology

The BG (caudate, putamen, globus pallidus and subthalamic nuclie, substantia nigra, and the dopaminergic neurons of the ventral tegmental area) are integral to normal motor and cognitive human functions, yet little is known of the exact function of these important structures. The BG have no direct output to the spinal cord and modulate movement through neural loops (Cohen 1999). The BG are essentially anatomically modeled as components of the basal ganglia-thalamo-cortical neural circuits (both the direct and indirect pathways) which serve the motor, visual-motor, and cognitive functions (Alexander *et. al.* 1990, Hoover and Strick 1993).

The direct pathway involves a circuit between the putamen (Put) and internal segment of the globus pallidus (GPi) and the substantia nigra pars compacta (SNpc). The direct pathway involves sequential inhibitory synapses in the GPi (and SNpc) and the thalamus that effectively release excitatory glutaminergic thalamo-cortical projections (Brown and Marsden 1998). See figure 1.

The indirect pathway leads from the Put to the external segment of the globus pallidus (GPe) and subsequently to the subthalamic nuclei (STN). From the STN the pathway procedes back to the Gpi, GPe and SNpc. The indirect route through the STN facilitates the GPi and SNpc suppressing the thalamo-cortical activity (Alexander *et. al.* 1990, Hoover and Strick 1993, Delong 1990). See figure 1.

Regardless of which pathway leads to the GPi and the SN, the neurons project to the thalamus and brainstem thereby indirectly influencing movement. The direct and indirect pathways are differentially affected by the dopaminergic projections from the SN (Brown and Marsden 1998) resulting in stimulation of the direct and inhibition of the indirect pathway. The opposing effects of the dopamine released from SNpc neurons are mediated by subsets of dopaminergic receptors at the GPe. The BG have many feedback loops resulting in complex interactions between different BG areas (Brown and Marsden 1998).

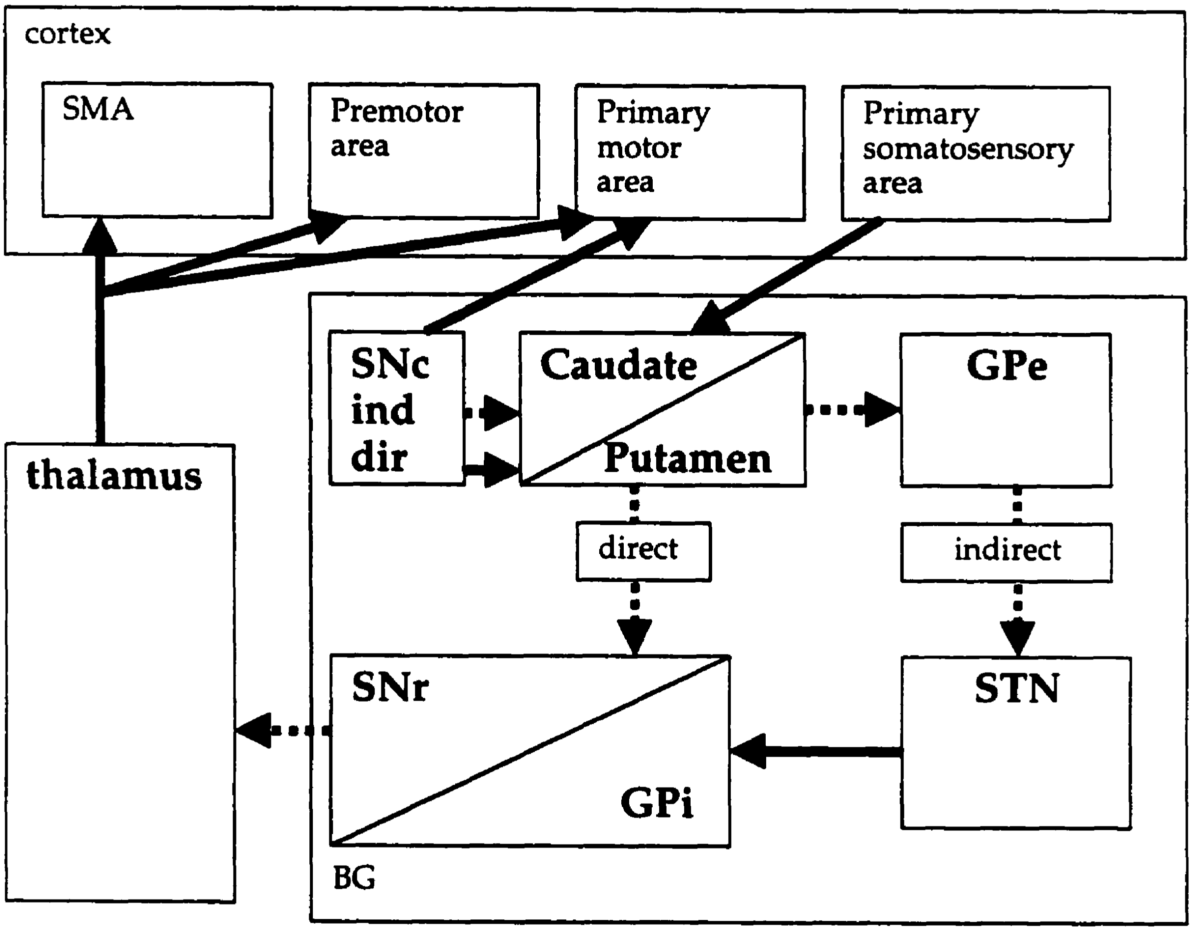


Figure 1. Graphic representation of the BG. Solid arrows represent stimulatory neural transmission and broken arrows represent inhibitory neurotransmission. SMA = supplementary motor area, GPe = globus pallidus external segment, GPi = Globus pallidus internal segment, SNc = substantia nigra pars compacta, SNr = substantia nigra, STN = subthalamic nucleus. Ind = SNc influence over indirect pathway. Dir = SNc influence over direct pathway.

The gradual death of dopaminergic neurons mainly located in the SNpc along with the development of extensive Lewy bodies throughout the brain lead to IPD (Marsden 1994, Braak *et. al.* 1995). The death of SNpc cells alters the GP output and influences thalamic output resulting in the cardinal signs of IPD (Braak *et. al.* 1995). All areas of the SNpc are not equally effected by cell death. The dopaminergic cells projecting to the mesencephalic central gray and the hypothalamic dopaminergic cells are often not affected by IPD (Agid *et. al.* 1993, Franceschi *et. al.* 1988, Matzuk and Saper 1985). Other extranigral areas, like the amygdala, Nucleus Basalis of Maynert, and Locus Cereleus, are affected in IPD (Braak *et. al.* 1995, Norback *et. al.* 1991). Since the BG are widely interconnected throughout the brain, other areas of the brain receive sub-normal activation due to the death of the dopaminergic neurons. The damaged BG do not provide the proper out-put to other cortical areas often leading to reorganization and atrophy due to lack of use (Daum *et. al.* 1995).

The essentially anatomical model does not adequately explain some clinical findings. Therapeutic inactivation of the GPi, by ablative surgery or stimulation, improves the symptoms and dyskinesias of people with IPD with little adverse affect on their movement. Severely akinetic people with IPD may quickly sidestep an oncoming car, flee a fire, or have normal speech and gait when sleep walking and talking. This paradoxical kinesia is not solely the result of heightened attention because the effects also occur during sleep (Brown and Marsden 1998).

## Theoretical Basis of BG function

Recent theories regarding the functions of the BG suggest that, similar to the mechanisms in the sensory system, they function to synchronize temporal and frequency dispergent neural discharges. By making the neural discharges coherent, the BG effectively group and preferentially select neural patterns that favor goal attainment (Brown and Marsden 1998, Singer 1993, Tatton *et. al.* 1984). The function of the BG is reflected in electroencphalograph (EEG) readings. With IPD, the basal ganglia dysfunction results in a predominance of slow "idling" cortical rhythms, and impairment of global EEG signal desynchoronization. This is associated with local high frequency gamma synchronization (Brown and Marsden 1998, Munk *et. al.* 1996, Wichmann *et. al.* 1994, Filion *et. al.* 1991, Neufeld *et. al.* 1994, Defebve *et. al.* 1994). The inability to attain the local high frequency gamma synchronization is reflected in motor unit discharges of 10 Hz, a frequency unsuited for strong and quick movement (Sem-Jacobsen *et. al.* 1956, Defrance *et. al.* 1988, Pfurtscheller *et. al.* 1993, Salenius *et. al.* 1996, Nini *et. al.* 1995). The return of the normal 50 Hz motor unit discharge and global desynchronization of the EEG is achieved with Ldopa administration (Yaar 1977). Desynchronization of EEG activity apparently enables local high frequency gamma synchronization of neural activity vital to motor processing (Munk *et. al.* 1996). Brown and Marsden (1998) base this assumption on the results of EEG animal and human research which indicated that BG lesions result in loss of normal EEG desynchronization. The motor impairment (akinesia) associated with the loss of EEG desynchronization is reversed with Ldopa administration (Munk *et. al.* 1996, Diekman 1968, Wichmann *et. al.* 1994, Filion *et. al.* 1991, Defebve *et. al.* 1994).

## Application to information processing

Information processing studies of "selective stimulus attention" indicate that coherent and synchronized neural discharges are likely more effective when convergence occurs during the later stages of information processing allowing certain channels of activity to be favored over others (Tiitinen *et. al.* 1993). This theory has been supported by research in sequential task behavior in people with IPD where cueing subjects for sequential tasks was most effective during the later stage of the first motor task (Beneke 1987a and 1987b, Tatton *et. al.* 1984, Schwab *et. al.* 1954). The faulty output of the BG results in reduced SMA activity leading to deficeint gait initiation that can be overcome by electrical stimulation of the SMA early in a movement (Cunnington *et. al.* 1996, Cohen 1999, Defebve *et. al.* 1994, Tatton *et. al.* 1984).

Concurrent task interference occurs to a greater degree in people with IPD possibly due to inability to inhibit unwanted neural discharges and lack of boosting of the desired neural discharges (Morris *et. al.* 1996b and 1994b). This effect is shown in the slowing of movement during concurrent tasks in people with IPD compared to healthy individuals (Schwab *et. al.* 1954, Tatton *et. al.* 1984, Beneke *et. al.* 1987a, 1987b and 1986, Morris *et. al.* 1994, Kritikos *et. al.* 1995, Brooks 1996). The BG likely alter the "gain" of motor sequences, facilitate correct input – output matching, and generate the necessary internal cues required to maintain movement sequences like gait (Tatton *et. al.* 1984, Morris *et. al.* 1994a and 1994b, Brown and Marsden 1999). Appropriate BG output to the SMA is thought to be responsible for providing internal cues for maintenance of repetitive movement (Jahanshahi *et. al.* 1995). Neural imaging studies support this view showing that the SMA, lentiform nucleus, anterior cingulate, and dorsolateral prefrontal cortex were less active in people with IPD than controls (Brooks 1996, Jahanshahi *et. al.* 1995).

Brown and Marsden (1998) suggest that although the brainstem reticular activating system has some influence on degree of cortical EEG dysynchronisation, the highly somatotropically organized BG are principally responsible for the desynchronous activity in the executive forebrain. The BG may facilitate neural discharge coherence, represented by the gamma band, by subconscious goal directed selection of relevant neural discharges among the plethora of activities happening at any time.

Without the ability to focus the input of certain channels in the BG the motor processing takes longer leading to bradykinesia. This is made more pronounced when two or more actions occur at one time (dual processing). Movement may become over-inclusive, constrained, leading to co-contaction and dystonia (Brown and Masden 1998). Neural signal processes are further stretched when multiple tasks are processed at one time. With dual-tasks, motor performance is adversely affected by outcome conflict, interference, and cross talk (Allport 1980, Navon and Miller 1987). Outcome conflict refers to the mismatching of input to output. Marsden and Brown (1998) suggest that input – output matching is the primary function of the BG. Interference refers to competition for the same codes during information flow that leads to confusion of individual codes during processing. Inhibition of parallel response tendencies which threaten the stability of actions (limiting interference) are essential to allow normal motor responses (Neuman 1987). Cross-talk may also occur between two processes involved in dual tasks leading to confusion in motor output (Navon and Miller 1987). Performance limits are determined by the ability to limit or control interference, outcome conflict, or cross talk (Detweiler and Schneider 1991). Dual tasks increase risk of erroneous decisions due to competing instructions about which regions contribute to each response.

The monitoring of task oriented goals happens at different levels of processing. Local structures modulate ongoing processes in elementary input-output structures that compete for admission to the next processing stage in the flow from stimulus to response. Central structures coordinate regions in a more modular way than local structures. Brown and Marsden (1998) suggest the BG are employed to prevent chaos between regions and direct attention to the task. The role of the BG in a well-learned task is unclear.

Learning a new task sometimes requires new cooperation between brain areas (modules) and a communication must be organized (Navon and Miller 1987). Attention establishes this communication and promotes cooperation (Navon and Miller 1987). The BG likely helps promote wanted and inhibit unwanted neural pathways. Brown & Marsden (1998) suggest that BG help bind input to output in the executive forebrain through supporting the attentional mechanism. In the BG, the subconscious neural selectivity of patterns effectively focuses attention and links voluntary effort, sensory input, and development and implementation of motor programs. The ability of the BG to facilitate convergence during stages of processing in the forebrain is lost in people with IPD (Brown and Marsden 1998). Brown and Marsden (1998) suggest that BG are involved in subconscious or automatic focussing of neural discharges meant to take over from conscious attention once pathways and communication between brain areas has been facilitated. This would explain reduction in movement size with repeated actions.

The deranged output of the BG affect the direct and indirect pathways. Over-activity of the GPi in IPD produced with L-dopa treatment increases the thalamo-cortical activity effectively releasing the motor areas of the cortex from the slow rhythms and restoring the normal motor unit discharge rate (Brown and Masden 1998). Inhibition of the output of the STN with L-dopa or deactivation of the STN removes excitation of GPi and SN, and also restores the normal motor unit discharge (Brown and Marsden 1998). Excessive inhibition of GPi through excessive dopaminergic stimulation, or combined loss of STN function in the presence of relatively intact inhibition of GPi by the direct pathway, may lead to dyskinesias by excessive gamma synchronisation (Brown and Marsden 1998). The gamma synchronisation of the BG becomes exaggerated and less discriminating with over-stimulation of the BG by L-dopa. The resulting movements become brisk but unrelated elements of motor activity also become coherent, synchronous and are processed together leading to L-dopa induced dyskinesias (Brown and Marsden 1998). Dyskinesias are indistinguishable from Huntington's chorea, characterized by progressive EEG voltage decrease that may reflect desynchronization of neural discharges rather than cell loss (Brown and Marsden1998, Thompson *et. al.* 1994).

The paradox of IPD is that the symptoms are not overcome with volition but at times of increased arousal (fright) the symptoms may disappear, or at times of decreased arousal (sleep) the symptoms also disappear. At normal arousal levels there is interference with the motor output. At times of stress or sleep alternate pathways may be employed. In acutely alert situations the increased activation of the reticular activating system achieves de-synchronization and overcomes the BG deficit leading to paradoxical kinesia (Brown and Marsden 1998).

The BG likely coordinate and alter gain of competing neural discharges to allow motor response by spatial and temporal summation of neural discharges through local synchonous neural activity in the gamma band (Brown and Marsden 1998). This is adversely affected with IPD leading to the classic motor dysfunctions seen in this disease.

## Medical and Surgical Management

Medication is the primary method of managing IPD. The commonly used drugs are: dopamine replacement Levodopa (L-dopa) plus decarboxylase inhibitors (carbidopa), monoamine oxidase B (MAO-B) inhibitor (Eldyprenol or Selegeline), ergot structure dopamine agonists, new non-ergoline agonists, tremor reducing anticholinergics, and Catech-O-methyltransferase (COMT) inhibitors which prevent dopamine breakdown within the brain (Pletscher and DaPrada 1993).

L-dopa is a dopamine precursor which is able to cross the blood brain barrier where it is converted to dopamine, stored and released close to available striatal dopaminergic cells stimulating the D1, D2, and D3 receptors (Morris 1992, Pletscher and DaPrada 1993). The decarboxylase inhibitors increase the ability for L-dopa to cross the blood-brain-barrier and increase available L-dopa levels within the brain. L-dopa has been shown to improve akinesia, rigidity, and tremor in people with IPD and decrease mortality rates by 6 to 12 years (Quinn 1990).

After several years of L-dopa treatment abnormal motor responses and fluctuations begin to occur leading to "on / off" dystonias, dyskinesias (onset, end of dose, and peak dose), and end of dose deterioration (Marconi *et. al.* 1994). The "on" phase is when the medication is working as intended, resulting in the reduction of Parkinson's symptoms. The "off" phase is when those symptoms recur, resulting in panic, anxiety, depression, pain, bradykinesia, gastrointestinal and motor problems. Variations in rate and extent of gastric emptying, ineffective intestinal absorption, variable extracellular metabolism of L-dopa and competition from other large amino acids to cross blood brain barrier may affect the "on/off" times (Quinn 1990). In a study by Di Rocco *et. al.* (1996), 41% of IPD subjects developed on/off syndrome. People with IPD have more difficulty controlling their physical symptoms once these "on/off" periods begin. Basic activities like shopping for groceries are often timed with the medication to ensure motor freezing or dyskinesias do not occur while attempting tasks outside the home. The choreic nature of the dyskinesias, the unexpected freezing, and the unpredictable motor performance can destabilize the person's balance and lead to falls.

The surgeries currently available (pallidotomies, subthalamic lesions, tissue transplant, and deep brain stimulation) are not curative in nature and do not alter existing joint and postural complications. Therefore, if the individual with IPD is to take advantage of the medical and surgical advances they must maintain joint range and postural muscle alignment through exercise.

## Cardinal Signs

There are four main signs of IPD: tremor, rigidity, akinesia, bradikinesia and postural instability. At least three are present in every case of IPD. All the cardinal signs are caused by changes in the output of the basal ganglia but different mechanisms and neural adaptations lead to different expressions of each sign in different individuals.

### Tremor

Tremor is rhythmic muscular oscillations of about 4 hertz (Hz) and occurs in about 2/3 of all people with IPD (Spieker *et. al.* 1995). Tremor dominant IPD shows more damage medially than laterally in the SNpc (Jellinger 1995). Tremor worsens with rest indicating that the thalamus may be up-regulating it's normal output to accommodate for the decrease BG output (Brown and Marsden 1998). Brown and Marsden (1998) suggest that when volitional movement is initiated the tremor wanes due to asynchronous firing of the neurons in the gamma band. As the disease progresses the tremor is often present throughout the movement adversely affecting function such as signing cheques and drinking a cup of hot coffee. Tremor as an initial sign of IPD seems to indicate a better prognosis than if rigidity or bradykinesia are initial symptoms (Rajput *et. al.* 1997, Hershey *et. al.* 1991). The reason for this trend is unclear.

Tremor is often treated with medication or deep brain stimulation. Dopamine (L-Dopa), anticholenergics, antihistamines, and MAO-B inhibitors have been suggested to be effective for tremor reduction (Spieker *et. al.* 1995). Deep brain stimulation may reduce tremor but has no effect on gait parameters with IPD (Caparros-Lefebvre 1993, Defebre *et. al.* 1996).

## Rigidity

Rigidity can be defined as resistance to passive movement of a limb in either direction unlike spasticity which is velocity dependent and unidirectional (Delwaide *et. al.* 1986). Both the flexor and extensor muscle groups are equally affected with rigidity. Sometimes the tremor is superimposed on the rigidity creating a "cogwheel" type of rigidity. Rigidity causes more resting muscle tone which increases with mental concentration, voluntary movements of the rigid limb, and voluntary or passive movement of the contra-lateral limb (Delwaide *et. al.* 1986). Rigidity is highly variable and affected by L-dopa administration which makes clinical assessment difficult (Schwab 1954, Obyle *et. al.* 1996). Rigidity results from alteration in the excitability of motor neurons through abnormal central descending influences and is reduced with the administration of L-dopa therapy.

Post mortem studies on people with IPD disease characterized by rigidity have shown more destruction in the ventrolateral than the medial portion of the SNpc leading to decreased striatum stimulation, consequently inhibiting the thalamo-cortical projection loop (Forno 1996). Changes in the output from the BG indirectly influences spinal cord neurons, via the reticulospinal tract, and the SMA (Rothwell *et. al.* 1983, Berardelli *et. al.* 1983, Gonce and Delwaide 1984, Tatton *et. al.* 1984, Delwaide *et. al.* 1986, Narabayashi 1996, Tasker *et. al.* 1996, Dogali *et. al.* 1996). When the reticulospinal tract is stimulated, both the flexor and extensor muscles are facilitated as well as collaterals affecting limb coordination (Delwaide *et. al.* 1986). The mechanism of rigidity is thought to be different from akinesia.

## Akinesia

Akinesia is the inability to initiate movement possibly due to deficiencies creating internal cues (Stelmach and Phillips 1992, Stelmach *et. al.* 1986, Brown and Marsden 1998). Hallet and Khoshbin (1980) showed that the time after the onset of muscle activity to movement was the same with IPD and control regardless of bradykinesia. This agrees with a study by Stelmach *et. al.* (1989b and 1989c) which showed that people with IPD had delays in initiating force production (twice as long as controls) solely due to the premotor reaction times indicating that people with IPD have difficulty initiating movement. Akinesia is seen in damage or deficient input to the SMA, the main output from the BG (Cohen 1999)

## Bradykinesia

Bradykinesia is the slowing of movement characterized by jerky, asymmetric acceleration-deceleration profiles during ballistic movements (Marsden 1994). Although reliance on external cues rather than internal feedback mechanism usually produces this type of movement in IPD the mechanism appears to be central (Stelmach and Phillips 1992). A study by Delwaide *et. al.* (1986) showed that lesions of the pallido-tegmental projection decreased bradykinesia where as lesions of the pallido-thalamo-cortical tract had no effect on bradykinesia suggesting that the tegmental tract is involved in bradykinesia. Also, unlike akinesia, bradykinesia, responds well to dopamine replacement therapies (Stelmach and Phillips 1992). Bradykinesia may be due to deficient SMA activation secondary to decreased pallidal output or faulty ability to switch from one task to another within an ongoing movement (Stelmach and Phillips 1992, Stelmach *et. al.* 1986). Brown and Marsden (1999) suggest that in IPD there is an the inability to focus the input of certain channels in the BG resulting in increased motor processing time which manifests as bradykinesia. Dual processing, two or more actions occuring at one time, highlights the deficits and results in over-inclusive, constrained movement ultimately leading to muscular co-contraction and dystonia (Brown and Masden 1998). This slowing of movement can affect the person's balance reactions.

People with IPD also appear to have more "noisy" output from the motor system and an inability to produce smooth muscular force. This noise seems to be due to abnormal reciprocal inhibition (increased antagonistic muscular activity during movement) possibly due to reticular formation stimulation. Results from a study by Stelmach *et. al.* (1989c) showed that people with IPD took longer to generate peak force and showed less variability in force production indicating that people with IPD may be trading speed for accuracy (Stelmach *et. al.* 1989c). Bradykinetic dominant IPD occurs when the bradikinesia is the dominant symptom of the IPD and generally has a worse prognosis than tremor dominant IPD (Rajput *et. al.* 1993, Hersy *et. al.* 1991).

## Postural instabilty

As IPD progresses, individuals have increasing difficulty maintaining their balance and tend to fall (Wszolek and Koller 1999). Postural instability refers to the difficulty maintaining balance.

### Balance

Balance is a complex behavior involving the visual, vestibular, and proprioceptive systems plus associated muscular responses (Morris *et. al.* 1994a and 1994b). Different muscular strategies are combined in different magnitudes to maintain balance allowing quick balance responses (Horak and Nasher 1986). The BG deficits may affect the ability of the person with IPD to select neural discharges to achieve the balance reactions. People with IPD have been shown to use hip strategies to maintain balance more often indicating a defect in critical muscle programming (Deitz *et. al.* 1988). The normal aging deficiencies in the timing and sequencing of muscle activity as well as in the functional coordination of their postural reflexes and voluntary sway add to the balance difficulties experienced by people with IPD (Stelmach *et. al.* 1989a, 1989b, and 1989c). Balance reactions can be assessed in a variety of ways: quiet standing balance, anticipatory postural reactions, and dynamic balance (as in gait).

In quiet stance, disordered axial movements are common in IPD and respond poorly to L-dopa (Bloem *et. al.* 1996). There is indication from the literature that when "on" medication, the ankle musculature (gastrocnemius and tibialis anterior muscle) postural responses are comparable to healthy individuals (Bloem *et. al.* 1996). Despite similar muscular activation, individuals with IPD appear to have a larger posterior displacement the body center of gravity (COG), as calculated from force platform and anthropometric data (Bloem *et. al.* 1996). During the "off" phase of medication, the posterior ankle musculature predominates and the COG moves farther posterior (Bloem *et. al.* 1996). Bloem *et. al.* (1996) suggested that the late automatic and voluntary corrections contributed greatly to the postural sway. Dopaminergic medication fails to improve balance because medication only partially corrects early postural muscular responses and appears not to have any effect on later responses (Bloem *et. al.* 1996). The lack of medication effect on later postural reactions indicates that nondopaminergic lesions play a role in the pathophysiology of the abnormal postural responses seen in IPD and that balance difficulties are not affected by treatment in most people with IPD, increasing the risk of falls (Bloem *et. al.* 1996).

The tendency for a greater posterior displacement of COG adds to the phenomenon of retropulsion, the difficulty regaining balance when a posterior perturbation is applied. Studies have indicated that people with IPD had worse backward than forward balance (Dietz *et. al.* 1988). The deficiency in anterior / posterior balance may be compensated for with increased medio-lateral sway (Mitchell *et. al.* 1995). Mitchell *et. al.* (1995) found that people with IPD exhibited larger medio-lateral sway during quiet stance than did the controls.

Thalamic stimulation has been shown to improve some balance tasks (quiet stance, step initiation, and equilibrium responses to surface displacements) but had no improvement in gait (Burleigh-Jacobs 1993). The balance difficulties people with IPD experience affect their ability to perform functional tasks like reaching and walking.

Improving functional balance is key to decrease the number of falls in the people with IPD. Any balance deficits are magnified when a person is in motion.

Anticipatory postural adjustments occur immediately prior to, and in the opposite direction of, any volitional movement in preparation for the destabilizing effects of the limb-motion (Burliegh *et. al.* 1994, Hirschfeld and Forssberg 1991, Stelmach *et. al.* 1989a, Traub *et. al.* 1980). Anticipatory postural adjustments, which are thought to depend more on higher central nervous system levels than quiet standing balance, are often assessed using gait initiation (Burleigh *et. al.* 1994, Hirschfeld and Forssberg 1991). Gait initiation requires that anticipatory postural adjustments occur prior to the voluntary movement and has been found to be affected in IPD (Burleigh-Jacobs *et. al.* 1997, Burleigh *et. al.* 1994). Burleigh-Jacobs *et. al.* (1997) showed that force production and timing during gait initiation were smaller for individuals with IPD when not on medication, possibly reflecting dopaminergic pathway involvement in gait initiation. The slow initiation of movement can apparently become faster with the practiced use of advanced information (Worrington and Stelmach 1990). The duration of the improvements is presently unknown. Morris *et. al.* (1996a and 1996b) found that individuals with IPD can maintain newly learned motor information one day later only when reminded or cued. Conversely, Worrington and Stelmach (1990) showed that people with IPD can learn new motor patterns but at a slower rate than controls. Perhaps the inability to spontaneously recall the new walking pattern in the Morris *et. al.* (1996a) study did not reflect an inability to learn but a lack of sufficient practice.

## Other Signs

Since the BG are widely interconnected with many areas of the brain, other signs may manifest with the development of IPD. Some other difficulties that occur with IPD are problems with gait, depression, memory and learning, and fear of falling.

### Gait

Walking can be divided into alternating stance and swing phases. This deceptively simple movement sequence requires phasic activity of the impaired neuromuscular system in IPD. The typical IPD shuffling gait is characterized by adoption of flexed posture, muscular co-contraction, freezing, involuntary acceleration, decreased lower extremity ROM, step length, stride time, single support phase, and push off (Morris *et. al.* 1994b, Knuttson *et. al.* 1972, Forssberg *et. al.* 1984). Stride time (ST) is the elapsed time between ipsi-lateral heel strikes and single support phase is the time when only one foot is in contact with ground (often expressed as a percentage of stride time). The gait deficits are correctable by L-dopa medication and, unlike balance, do not appear to be affected by thalamic stimulation (Defebre *et. al.* 1996, Burleigh-Jacobs *et. al.* 1993, Forssberg 1984).

The BG in people with IPD do not provide adequate output for maintenance of gait sequence (Morris *et. al.* 1994a, 1994b, 1996a and 1996b, Brown and Marsden 1998, Tatton *et. al.* 1984). The IPD gait becomes more pronounced with the performance of concurrent motor activities (McIntosh *et. al.* 1997, Benecke 1987a, 1987b, and 1986, Schwab *et. al.* 1954). External cues (auditory or visual) are often used in physiotherapy to help generate longer stride lengths because the cues improve the ability to shift to the next task and reduce the hesitation between movements (Weiss *et. al.* 1997, Kritikos *et.*

*al.* 1995). Morris *et. al.* (1996a and 1996b) found that individuals with IPD had deficiencies in maintaining increased stride length (SL, distance along line of progression between ipsi-lateral heel strikes) learned one day prior. When reminded, people with IPD could walk with the newly learned SL; However, if they were not watched or cued, they tended to revert to the shuffling gait pattern (Morris *et. al.* 1996a and 1996b). This suggests that the addition of external cues can partially overcome the deficits in BG output.

Gait spatiotemporal kinematics (free walking speed, stride length, double support time, stride to stride variability) are sensitive measures of treatment effectiveness (Hausdorff *et. al.* 1998, Viereggi *et. al.* 1997, Weller *et. al.* 1993, Blin *et. al.* 1991, Bowes *et. al.* 1992, Pederson 1991). Although variability of SL and WS increase as IPD and L-dopa cycle progress (time between medication ingestions), these gait parameters correlate well ($r>0.50$) with scales of bradykinesia (MacKay-Lyons 1998, Viereggi *et. al.* 1997, Montgomery and Reynolds 1990). Temporal gait parameters are more reliable but are not as sensitive to treatment effects as spatial measures (Blin *et. al.* 1991, MacKay-Lyons 1998). MacKay-Lyons (1998) demonstrated that subjects in stage III or higher exhibited temporal parameters similar to healthy controls, however, the SL and WS tended to be more variable (MacKay-Lyons 1998). The normal WS (0.8 - 1 stat/s) is reduced in IPD primarily due to shortened SL. Cadence (normal values 120 steps/min) is increased in people with IPD in an attempt to compensate for the shorter SL (Morris *et. al.* 1996a). The ability to vary walking speed may also become impaired as the disease progresses. The risk of falls increases in people with IPD because their ability to adjust gait parameters to avoid obstacles and adapt to different situations becomes impaired.

The ability to achieve functional tasks like crossing the road at a traffic light is also diminished. Normal aging causes muscle activation to be less tightly coupled and less stereotypically organized (Stelmach *et. al.* 1989a). The combined effect of aging and IPD can severely affect the person's ability to walk. Motor performance may also be adversely affected by changes in mood.

## Depression

Depression is an altered mood with a loss of interest in pleasurable activities such as food, sex, work, friends, hobbies, or entertainment accompanied by weight loss/gain, fatigue, agitation, insomnia / hypersomnia, and recurrent thoughts of suicide (Fisk and Doble 1992, Thomas 1993). Depression has been found to be a very common (51%) mood disorder associated with IPD (Fisk and Doble 1992, Sato *et. al.* 1989) and could be the result of underlying neuropathology and/or a reaction to the physical, social, and cognitive disabilities resulting from IPD (Winfield *et. al.* 1996). The frontal lobe mood deficits seen in IPD can be explained by reduced input to the cortex secondary to the cell loss in the BG and do not necessarily directly reflect the functions of the BG (Daum *et. al.* 1995). Depression is difficult to assess in IPD due to the mask face, flat affect, and other symptoms of IPD (Fisk and Doble 1992). Hersey *et. al.* (1991) stated that depression was positively correlated to motor dysfunction and could have a drastic effect on the outcome of treatment in terms of compliance and motivation.

Exercise has been shown to help reduce depression in non-pathological populations (Brown *et. al.* 1995, Moses *et. al.* 1989, Blumenthal *et. al.* 1989). Brown *et. al.* (1995) concluded that exercise which included cognitive elements (as with TCC) were more effective than exercise programs lacking the cognitive component in promoting psychological benefits ($p<0.05$). Although depression can affect the person's performance, it is not the sole determining factor.

## Memory Impairments and Learning

Performance of motor tasks and information processing is partially dependent on an intact memory system. People with IPD appear to have increased memory deficits, especially in coding, as the disease progresses (Fisk and Doble 1992). Post mortem studies have shown that people with IPD have smaller hippocampi, one of the main memory centers in the brain, than people without IPD (Lisanby *et. al.* 1993). Therefore, information needs to be provided in a well-organized fashion to allow retrieval (El-Awar *et. al.* 1987). Normal coding of memories is possible with IPD if no cognitive strategies are required. A study by Daum *et. al.* (1995) indicated that people with IPD had deficits on tasks which required self directed cognitive operations but motor and perception were normal, therefore, information should be presented in order to ensure retrieval. Worrigton and Stelmach (1990) found that people with IPD could use advanced information to initiate movement but this required practice, suggesting faulty short-term memory and coding retrieval of information due to BG dysfunction. This theory is supported by results from a study by El-Awar *et. al.* (1987) indicated that people with IPD have greater difficulty with initial learning. However, they seem to retain the newly learned information as well as controls one-hour later. Although the memory tests used by El-Awar *et. al.* (1987) were word-pairing tests, these results could have an implication in terms of motor learning. Morris *et. al.* 1996a and 1996b, supported the ability of people with IPD to learn and access motor memories. However, the subjects could not recall the newly learned information the next day unless they were prompted. Therefore, people with IPD can store memories but do not code or are unable to access this stored information. People with IPD may benefit from the use of cues to help them retrieve memory and facilitate learning (Brown and Marsden 1998). As IPD progresses, these memory difficulties increase and lead to greater difficulty with motor skill acquisition.

In healthy individuals a well-learned task requires less attention to perform the task. However, walking is a very well learned task that deteriorates in IPD. People with IPD have difficulty achieving and maintaining the automatic stage of skill acquisition (Fisk and Doble 1992). The normal rate of skill breakdown with time is accelerated in IPD, due to the effects of SN cell death, therefore more frequent feedback of motor performance is suggested for people with IPD.

## Fear of Falling

Falls represent a large percentage of morbidity in elderly people. Fear of falling may also lead to decreased activity and has been identified as the greatest fear in 25% of community dwelling elderly (Hill *et. al.* 1996). People who have identified that they are afraid of falling often have increased center of pressure excursions as measured by force platform measures (Maki *et. al.* 1991). There is an inconsistent correlation between other balance measures and the fear of falling possibly due to the practice of defining fear of falling as a dichotomous variable (Maki *et. al.* 1991). In reality, fear of falling ranges from no fear to extremely high levels of anxiety. People with IPD tend to decrease activity after diagnosis and as the disease progresses (Spirduso 1983), which may be partially due to the fear of falling created from poor balance abilities. If an individual is fearful of falling they may alter their activities to reduce the chance of falls, possibly resulting in a reduction in the number of falls. Alternatively, if a person falls frequently they may be familiar with the sensation and not fear of the act of falling. Although associated, fear of falling, balance abilities and number of falls appear not to be directly related.

## Assessment

### Measurement of Disease Stages

The most widely used assessment for disease staging is the Hoehn and Yahr (H&Y) scale that classifies the IPD progression into five categories (Hoehn and Yarh, 1967). In Stage I, the symptoms are well controlled with medication. In stage II and III, people experience difficulties with movement and balance, especially during the "off" phase, but are usually able to walk and function within the community with minimal assistance. In Stage III postural instability is prominent. People in stage IV and V experience major postural deformities, great variability in motor performance level, and are severely limited in function. All stages of H&Y scale correlate well with the Unified Parkinson's Disease Rating Scale (van Hilten *et. al.* 1994, Martines-Martin *et. al.* 1994, Richards *et. al.* 1994). At later stages, medical management becomes increasingly difficult and is unable to correct any permanent postural or joint changes. Minimizing the joint and muscular complications through preventive measures may improve the quality of life and allow people with IPD to benefit from advances in the medical and surgical management of the disorder.

Other scales have attempted to quantify the disease and give an overall picture of the person: Webster scale, Schwab and English scale, Columbia University Rating scale, Duke university scale, and Unified Parkinson's disease Rating Scale (UPDRS) to name a few (Fahn *et. al.* 1988, Yarh *et. al.* 1969, Webster 1968). Although these scales were developed for different purposes, many of them do not assess the subject in both the "on" and "off" phases. The most common scale used today is the UPDRS since it includes two other scales (H&Y and Schwab & England) and measurements of motor function in both the "on" and "off" stages. This tool includes tests representing only the disability level of IPD motor assessment as defined by the World Health Organization (WHO): impairment, disability, and handicap. As such, this test alone does not adequately represent the disease state and impact. Quality of life questionnaires are suggested to address the handicap issues. Neural imaging techniques may be used to quantify the impairment of neural function. Completion of the historical section of the UPDRS requires no cognitive impairment because dementia adversely affects the reliability of this section. For this reason a dementia-screening test is suggested when assessing IPD with the UPDRS. Overall the UPDRS is a reliable and valid tool to represent the disability associated with IPD (reliability & validity between r=0.76-0.96, van Hilten *et. al.* 1994, Geminiani *et. al.* 1991).

## Measurement of Motor Abilities

Measurement of motor abilities may be performed at the level of the impairment, disability, or handicap. No one measure adequately reflects all aspects of functional movement. For this reason a battery of tests is often used. There have been many attempts to quantify IPD but the variable nature of motor performance makes quantification of the cardinal signs as well as motor abilities very difficult.

### Tremor

The tremor associated with IPD is extremely variable and can change drastically from one moment to the next. As such, the meaningfulness of quantitative assessment is questionable and only represents the severity of tremor at a single point in time. Attempts have been made to represent total daily tremor activity using accelerometers but the rotational component is not adequately represented and other activities occur at frequencies close to that of the resting tremor confounding results. Accelerometers and other technical devices are complex, costly, and the information gained is of questionable value since tremor rarely impacts function to the same degree as the other signs of IPD (Janovic *et. al.* 1996).

Inexpensive clinical scales are less complex but are subject to similar validity and reliability issues as highly technical measures (Fahn *et. al.* 1988). The Fahn tremor scale is a common clinical measure of tremor, takes 20 minutes to complete, and assesses tremor at a single point in time in both resting state and functional activities (Fahn *et. al.* 1988). No reliability studies were found related to this scale. A quantifiable component of the Fahn tremor scale is the drawing of spirals and lines which is designed to mimic the activity of writing (see Figure 4, page 68). The number of times the guidelines are touched equals the score given. Pilot work indicated that this portion of the Fahn score was not significantly different and correlated well with the overall Fahn tremor score for the dominant hand only ($r = .93$, $p>0.05$, see Appendix A for study results). The common practice of writing with the dominant hand explains these results. Since the entire scale is time consuming and the results of the drawing task represent the overall score, this portion of the Fahn scale may be used to give a snap shot picture of the tremor.

**Gait**

Certain gait characteristics adequately represent bradykinesia, which can not be functionally discriminated from rigidity, in people with IPD (Viereggi *et. al.* 1997, Montgomery and Reynolds 1990). The spatiotemporal parameters of free WS represent other measures of bradykinesia and have been shown to be reliable and valid indicators of medication effects on motor function (Hausdorff *et. al.* 1998, Weller *et. al.* 1993, Blin *et. al.* 1991, MacKay-Lyons 1998, Viereggi *et. al.* 1997, Montgomery and Reynolds 1990). Instrumented walkways and gait analysis systems have been used for many years to provide precise on line data collection of gait parameters. Gait spatiotemporal parameters also assess the ability to control dynamic balance, a necessary component of fall prevention and functional abilities.

**Balance**

Balance is often measured using force platforms, however, functional balance tests best represent a person's daily activities which require balance control. The ability to reach without falling is necessary in everyday tasks and has been shown to be a reliable and valid measurement of balance for people with IPD (Light *et. al.* 1996, Weiner *et. al.* 1993 and 1992, Duncan *et. al.* 1992 and 1990). Smithson *et. al.* (1998) found that individuals who tended to fall were in stage III or greater while non-fallers were in stage II or less.

Functional reach (FR) is a simple clinical measure that has been utilized in previous studies of balance and shown to give valid, sensitive (r=0.97) and reliable measures of forward balance ability (intrarater reliability r=0.98, interrater reliability ICC=0.98, test retest reliability r=0.92, Cole *et. al.* 1995). The subject stands with feet together, arm flexed to 90 degrees, and the change in fingertip position, as measured by a meter stick, as the subject reaches forward is determined. Since the feet are not moved during this task, FR can be considered a measure of static balance. Functional reach is highly predictive of falls in the elderly (Cole *et. al.* 1995). Only 30% of the subjects used to validate the FR were diagnosed with IPD. Smithson *et. al.* (1998) found that FR was reliable at peak medication for subjects in stage II and III IPD. However, presence of dyskinesias was not stated for the sample. A case study by Grill (1999) indicated that the FR declined as IPD progressed. The FR has been shown to correlate well with other balance measures: force platform measures (PPMC r=0.71), gait speed (r=0.71) and ability to stand on one leg (r=0.64, Cole *et. al.* 1995). Pilot work with FR indicated that this test is fairly reliable within one and one and a half-hour post medication (< 5% error) and severity of dykinesias, often present during peak dose, might confound results (see Appendix B for study results).

## Measurement of Psychological Factors

Objective motor scores may not completely represent the impact that IPD has on a person's mood, safety, and quality of life. The chronic nature of IPD combined with financial and social impact can cause psychological stress leading to depression that occurs in 51 % of people with IPD (Fisk and Doble 1992, Sato *et. al.* 1989, Winfield *et. al.* 1996).

### Depression

There are many methods to assess depression. The Beck's Depression Inventory (BDI) has been used clinically and modified over the years to assess level of depression (Beck *et. al.* 1961). Although this scale has not been specifically designed for people with IPD, people with IPD were represented in the samples used to validate the scale (Beck *et. al.* 1961). The internal consistency, rater reliability, and validity of the BDI is high compared to depth of depression ratings (r = 0.86, rho = 0.93, r = 0.86, p<0.001

respectively). The BDI is able to discriminate significantly ($p < 0.000$) between depression categories, with the exception of the more severe ratings, and shows good sensitivity to change (85% agreement, Beck *et. al.* 1961). Fatigue, one question on the BDI, is a prominent factor for people with IPD and is a function of the pathology and not solely an indicator of the level of depression.

**Dementia**

Dementia may affect a person's ability to accurately complete the subjective portion of the UPDRS. The Mini Mental State Exam (MMSE) is a widely used screening method of assessing cognitive mental status. Orientation, attention, immediate and short-term memory, language, spatial ability, and the ability to follow simple commands are assessed using the MMSE. A maximum score of 30 may be achieved and the MMSE takes less than 10 minutes to administer. The scores of the MMSE classify impairment into three categories; 24-30 = no impairment, 18-23 = mild impairment, 0-17 = severe. Age and educational level may influence scores on MMSE (Crum *et. al.* 1993). The MMSE is associated with other dementia scales, computerized tomography (CT) scan and positron emission tomography (PET) scan results (DeKosky *et. al.* 1990, Zillmer *et. al.* 1990, Fillenbaum *et. al.* 1987, Horton *et. al.* 1987, Tsai 1979). The MMSE alone is not intended to diagnose any disorder but has sufficient sensitivity (87%) to be used as a screening tool (Morris *et. al.* 1989, Davous *et. al.* 1987, Stern *et. al.* 1987, Thal *et. al.* 1986). Other psychological issues may influence performance of assessments.

**Fear of Falling**

Fear of falling has been identified as a major issue when dealing with older populations and several scales have been developed to quantify the fear. The Falls

Efficacy Scale (FES), Activity Specific Balance Confidence Scale, and Modified Falls Efficacy Scale (MFES) are three tools that have been developed (Hill *et. al.* 1996, Powell and Myers 1995). The MFES has been shown to be valid, retest reliable (ICC .93), differentiates between healthy and elderly with balance issues ($p<0.05$), and includes elements of the Tinetti and FES scales. The sensitivity of this scale has not been investigated. The MFES is a simple, quick, easy-to-administer clinical evaluation of variables that affect the balance of older people and measures 14 common activities performed by community dwelling elderly, including some outdoor activities. A Likert type scale for each of the 14 items is used with numerical values assigned giving a minimum value of 0 representing severe fear of falling and the maximum value of 140 representing total confidence in balance abilities.

**Quality of Life**

Quality of life measures are important to ensure that the more subtle impacts of chronic diseases are represented and quantified (Calne *et. al.* 1996). Often people experience changes in their life prior to detectable changes in other measurement tools (Fitzpatrick *et. al.* 1997). Generic measurements of quality of life, like the Sickness Impact Profile, may not adequately represent the impact IPD has on the person's life. Three IPD specific quality of life measures are available today: Parkinson's Disease Quality of Life Scale, Parkinson's Disease Questionnaire 39, Parkinson's Impact Measurement Scale (Lyons *et. al.* 1997, deBoer *et. al.* 1996, Calne *et. al.* 1996, Jenkinson *et. al.* 1995, Peto *et. al.* 1994). Of these specific scales, the Parkinson's Impact Measurement Scale (PIMS) has been the most fully validated scale and weights different areas according to the perceived importance in the person's life (Calne *et. al.* 1996). The

PIMS has been shown to have good interrater reliability, internal consistency, sensitivity to disease level, and construct validity of "on" versus "off" scores (r=0.72, r=0.90, r = 0.72, p<0.0001 respectively, Calne *et. al.* 1996). The patient's subjective assessment of how IPD impacts their emotional, social, leisure, safety, family, sexual, work, travel and community well-being are indicated with the PIMS (Calne *et. al.* 1996). As such this measure may adequately represent the impact IPD has on a person's life as the disease progresses.

## Clinical Progression of the Disease

Parkinson's disease usually progresses through several stages. The first stage occurs with unilateral symptoms that are manageable with medication (Marsden 1994). As the disease progresses, the poverty of movement causes changes in soft tissue, bones, and joints resulting in permanent loss of motion. The symptoms eventually become bilateral with the cardinal signs becoming more noticeable as time passes (Hoehn and Yahr 1967, Marsden 1994). Shaking hands often make writing and pouring hot liquids difficult. Movements become slowed and laborious leading to swallowing and speech problems along with prolonged time spent in the flexed position (Marsden 1994). As a result, posture becomes affected leading to the characteristic flexed forward position that further aggravates swallowing difficulties. Drooling begins due to gravity, inability to swallow, loss of facial muscle control, and the flexed forward posture (Marsden 1994). Reduced ribcage motion and fixed forward posture leads to reduction in lung capacities and increased risk of developing pneumonia. Balance reactions become increasingly affected leading to an inability to stand and eventual confinement to a wheelchair (Hoehn and Yahr 1967, Marsden 1994).

Current medical treatment focuses on medication. However, after long-term medication use motor side effects begin which may lead to falls. The success of available surgeries (pallidotomies, subthalamic lesions, tissue transplantation, and deep brain stimulation) depends on the prior maintenance of joint range of motion and posture through exercise to prevent the permanent soft tissue and joint changes. No matter how successful the brain surgery, it will not change any permanent soft tissue and joint changes. Preventative exercise should will help delay or prevent joint and soft tissue changes that occur due to the poverty of movement and should allow people with IPD to take advantage of surgical and medical advances in the future.

**Exercise and IPD**

Exercise has been shown to reduce the number of falls in the elderly and people with IPD (Providence *et. al.* 1995, Wolf *et. al.* 1993, Tse and Bailey 1992, Kuroda *et. al.* 1992). There is a tendency of people with IPD to reduce physical activities after diagnosis and as the disease progresses (Fertl *et. al.* 1993). Exercise programs available within the community may help deter the complications associated with reduced motion and activity (Spiduro 1983). Changes in certain neurotransmitter levels (noradrenalin, dopamine, serotonin) have been shown with structured exercise programs in normal and depressed individuals (Ebert *et. al.* 1972). There is indication that increased levels of dopamine occur after moderate exercise (<5 METS, ACSM1995) and can be maintained if exercise is performed every 24 hours (Spiduro 1983). Conversely, intense exercise (>5 METS, ACSM 1995) has no overall effect on dopamine levels (Bortz *et. al.* 1981).

Regular exercise has been shown to assist in maintaining the cardiorespiratory fitness of individuals with IPD (Kuroda *et. al.* 1992). However, the exact effect of physical activity on the progression and complications of the disease are largely unknown (Fertle *et. al.* 1993). Regular exercise programs specifically designed for people with IPD have been shown by Reuter *et. al.* (1999) to temporarily improve some of the signs and symptoms of the disease.

There are only a few studies that report on the effects of physical activity on early stage IPD. Kuroda *et. al.* (1992) studied a large number of people with IPD over an average of 4 years and found that the people with IPD who exercised had lower mortality rate. The results indicated that physical activity is one factor that can influence survival rate in IPD. Group assignment was not randomized in the Kuroda *et. al.* (1992) study leading to possible bias and weakening the validity of the conclusions. Other researchers have indicated that physical activity may decrease the risk of developing IPD (Sasco *et. al.* 1992).

Controversy exists over the effects of exercise on motor performance in people with IPD. Although the results of earlier studies indicate no improvements in motor function of people with IPD after exercise training (Gibbard *et. al.* 1981), there are several well designed recent studies that indicate exercise may impact motor performance in people with IPD (Comella *et. al.* 1994, Reuter *et. al.* 1999, Formissano 1992, Palmer *et. al.* 1986).

The results from a randomized single blind cross over study by Comella *et. al.* (1994), indicated that after a four-week intensive exercise program, significant improvements were seen in the motor and ADL sections of the UPDRS scores. However, the improvements returned to baseline after 6 months when no further training was received. Other researchers have found maintenance of exercise induced improved motor performance for longer than 4 months with a program including mobilization (passive and active) and stretching exercises (Reuter *et. al.* 1999, Formissano *et. al.* 1992, Palmer *et. al.* 1986). Improved gait, tremor, and coordination have been reported with a 12-week karate training compared to a special stretching program (Palmer *et. al.* 1986). Karate is a martial art derived from similar sources as TCC. The reported ability of individuals with IPD to maintain exercise gains after the program ends is supported by later research (Reuter *et. al.* 1999, Morris *et. al.* 1994a, 1996a, and 1996b).

Reuter *et. al.* (1999) reported maintenance of significant improvements in UPDRS, Columbia University Rating Scale, and basic motor test scores six weeks after a 14 week water and land exercise program for 16 independent ambulatory subjects in H&Y stages II to IV of IPD. The subjects participated twice a week in an exercise program that included step initiation, standing balance, and rotation, all components of traditional TCC. Short-term post exercise improvements were reported in seven of the eight subjects who experienced dyskinesias. No significant change in cognitive functioning occurred during the study. However, mood and subjective well being improved with exercise training. The timing of the motor testing relative to medication ingestion was not reported. Subject selection methods were not identified so selection bias may have occurred. The fact that subjects in stage IV H&Y could stand and walk on their own suggests problems with the assessment procedures used for the Reuter *et. al.* (1999) study. Usually the balance of individuals in stage IV is impaired to the point that independent ambulation is no longer possible due to increased risk of falls. Even though there were unresolved methodological issues with the Reuter *et. al.* (1999) study, there is evidence that exercise which includes step initiation, rotation, and balance activities may improve the motor capabilities of individuals between stage II and IV IPD.

The research indicates that the key components of exercise programs specifically designed for people with IPD are stretching, step initiation, balance, and rotation (Comella *et. al.* 1994, Reuter *et. al.* 1999, Formissano 1992). The results of other studies indicates that community based programs using martial arts may be as effective as exercise programs specifically designed for individuals with IPD (Palmer *et. al.* 1986).

**Tai Chi Chuan**

Tai Chi Chuan is an oriental martial art exercise that has been promoted by people with IPD as beneficial in maintaining mobility and mental health. The sequence consists of 108 movements performed slowly and rhythmically. Tai Chi Chuan has been practiced in the Orient for many centuries as a method of maintaining physical health, mental health and longevity. Written documentation in 1881 traces the origins of TCC back to Wang Chung-Yeuh (See Table 1, page 44). All other TCC forms can be traced to Wang Chung-Yeuh. Today there are four main styles: Yang, Chen, Wu, and Taoist. Each has slightly different motions and involve different muscle groups. The Yang style has both a short (42 movements) form and a long (108 movements) form. More cardiovascular training effects were seen in people who trained the full 108 movements versus the shortened form (Brown *et. al.* 1989, Zhou *et. al.* 1988 and 1984, Han *et. al.* 1975).

The basic features of the TCC 108 movements are circular, slow (equal to the rhythm of the heartbeat), continuous, and balanced movements with alternating muscular contraction and relaxation (Wu 1992). Great attention is paid to developing awareness of balance reactions and proprioception. These alternating movements allow encouragement of appropriate muscle coordination and are believed to improve postural muscular endurance and strength.

Table 1. Documented lineage of TCC.

| Wang Chung-Yueh | | | | |
|---|---|---|---|---|
| Chiang Fa | | | | |
| **Chen Yu pun** | **Chen Yu-hung** | **Chen Chang-Hsing** | | |
| Chen Ching-Ping | Chen Por-Sang<br>Chen Chung-Sang<br>Chen Che-Sang | Yang Lu-Chan | | Chen Goung-Yun |
| Wu Yu-Seong | Chen Pin-San | Wu Yu-Seong<br>Yang Pan-Hou<br>Yang Chien-Hou | | Chen Yen-Se<br>Chen Yen-Se |
| Yang Pan-Hou<br>Lee I-Yu | Chen Chuen-Yueh<br>Chen Tze-Ming | Yang Sou-Hou<br>Yang Cheng-Fu<br>Hsu Yu-saug | Chuan Yuck | Chen Fa-Kor |
| Hao Wei-Jin | | Chen Wai-Ming | Wu Chien Chuan | Chen Jan-Pei<br>Chen Jan-Shin<br>Chen Jan-Kwai |
| Hou Yao-Yu<br>Sun Lu-Tang | | | Wu Kung Yi<br>Wu Kung Cho<br>Wu Ying Hua<br>Ma Yue Liang | |
| | | | Wu Tah Kwei<br>Wu Tah Chi<br>Wu Yan Hsai<br>Kwok Hsiao Jong<br>Wu Tah Sin | |
| Hou Shao Yu | | | Wu Kwon Yu<br>Wu Hsiao Fung | |
| | | | Wu Chung Him<br>Wu Chung Wai<br>Linda MacLaggan | |

The movements need to be practiced correctly to prevent injury. The most common problems are: standing with knees flexed beyond toes (so that a vertical line from the knee would be anterior to the toes), a chin forward posture, improper hip alignment in standing postures, and medial/lateral knee movement over the stationary foot when moving the hip (Chu 1991). Daily practice of these errors over years can lead to the development of chronic irreversible damage (Chu 1991). The movements of TCC should be relaxed and pain-free and instruction from a knowledgeable instructor is essential to prevent injury.

Wolf *et. al.* 1997 and 1993 studied the effects of TCC training on the balance of elderly individuals. The TCC exercise performed in the Wolf *et. al.* (1997) study included a few modified TCC forms, which does not represent how this discipline is taught in the community. This is a key element since participation in community based TCC classes encourages social interaction between participants. There is indication in the literature that TCC has some benefits to people's cardiovascular and respiratory fitness, strength, proprioception, balance, and quality of life (Lai 1993, Brown 1989, Jin 1989 and 1992, Waters and Walsh 1997, Xu *et. al.* 1986, Kutner *et. al.* 1997, Tse and Bailey 1992, Providence *et. al.* 1995, Wolf *et. al.* 1993, 1996, 1997, Jacobsen *et. al.* 1997, Forrest *et. al.* 1997).

Tai Chi Chuan has been shown to have cardiovascular and respiratory benefits for elderly and young healthy individuals. Subjects who received TCC training had significantly greater oxygen uptake ($VO_2$), oxygen pulse ($O_2$) and work rate compared to sedentary middle aged (50-64) individuals (Lai 1993). Comparison between other exercise forms is not possible from these study results because there was no exercise control and no random selection. An earlier crossover design study by Brown (1989) found TCC significantly improved ventilatory responses compared to the cycle ergomerty group. The age of subjects was not reported. More recent randomized control studies have provided evidence that TCC training is as effective as moderate aerobic exercise in reducing blood pressure for 62 healthy elderly (Younge *et. al.* 1999).

Tai Chi Chuan not only has an effect on physical but also mental well-being; by reducing tension, anxiety, anger and depression (Jin 1989 and 1992, Brown *et. al.* 1995, Waters and Walsh 1997). Other exercises may have similar benefits, but Brown *et. al.* (1995) found that exercises with strong cognitive components, as in TCC, are more effective in addressing psychological issues. While there is some indication that TCC training helps reduce depression and improve perceived quality of life, the studies performed to date used small sample sizes or had methodological flaws which weaken the conclusions (Waters and Walsh 1997, Xu *et. al.* 1986).

A study performed in China by Xu *et. al.* (1986) compared senior and young males. The findings indicated that the hormonal levels (particularly testosterone) in the TCC group were comparable with the young healthy group and significantly higher than the age matched non TCC training controls. Xu *et. al.* (1986) suggested that the hormonal normalizing effect of TCC training could help counter age related disorders and maintain emotional well being. This study did not include an alternate exercise group and therefore any form of exercise may have similar hormonal normalizing effects. A larger study by Kutner *et. al.* (1997) studied 200 healthy elderly (average age 76 years, 81% female) and compared TCC, balance training and education once a week for 15 weeks. In the TCC group, there was significant improvement in measures of physical activity, ADL, as well as quality of life and perceived well being. Unfortunately equal training time was not achieved between groups and the validity of the assessment scales was not discussed. Waters and Walsh (1997) studied 25 people (average age 66 years) with IPD and mild depression. After 10 weeks of TCC training there was a non-significant improvement in subjective quality of life and average decrease in depression by 70%. Only 10 subjects completed the study and the reasons for non-compliance were not discussed. These studies suggest that TCC may benefit the perceived state of well being of practitioners.

Other attempts to quantify the "meditative" effects of TCC did not show positive results (Jin 1992 and 1989). The use of plasma levels of cortisol as the outcome measure in these studies may not have been a valid representation of meditative effects. Also, males were over represented in the samples.

Tai Chi Chuan has been shown to improve exercise compliance in males. Lan *et. al.* (1998) studied 27 males post coronary artery bypass surgery (CABG) in phase III rehabilitation found significantly better compliance in the TCC group compared with an individual walking program. The difference in compliance may have been due to the social support and structure the TCC group exercise program provided. These results are consistent with a study by Channler *et. al.* (1995) that found TCC significantly improved the compliance with 125 males three weeks post discharge from hospital post acute myocardial infarct. Subjects were divided into TCC, aerobic, and support groups that met twice a week for eight weeks. Both of these studies included only male subjects and the effects of TCC training on compliance of female cardiac patients has not been investigated. Compliance with exercise programs in male cardiac patients increased their strength, functional capacity, and prevented muscular weakness that may lead to poor balance and falls.

There is evidence in the literature that TCC training can decrease the number and fear of falls in healthy and frail elderly (Wolf *et. al.* 1996, Providence *et. al.* 1995, Tse & Bailey 1992). A non randomized study by Tse & Bailey (1992) which studied 18 healthy elderly, comparing TCC practitioners with non practitioners on five measures of balance, indicated that the TCC group had less falls and better balance than the non TCC group. Tse & Bailey (1992) suggested that TCC enhances the number of motor responses available for postural adjustments. The lack of randomization weakens the study conclusions since the TCC subjects may have been more active, which could have been the source of improved balance. Even with the methodological flaws, this study is important since it laid the groundwork for further investigation.

Providence *et. al.* (1995) were involved in the Atlanta Frailty and Injuries: Cooperative Studies of Intervention Techniques study of nursing home and community elderly. Tai Chi Chuan training significantly reduced the number of falls and improved strength, range of motion, and coordination. Direct comparison across treatments was not possible due to different duration and frequency of treatments. Subsequent studies by Wolf *et. al.* (1996) on 200 healthy elderly found that TCC training delayed onset of falls by 46% compared with computerized balance training or education groups. Interestingly, the computerized training group was the only group that showed decreased postural sway in quiet stance after intervention. In the TCC group the postural sway increased, particularly in the mediolateral direction, although the number of falls decreased. Wolf *et. al.* (1996) suggested that TCC emphasized total body movement with a gradual decrease in the base of support, thereby encouraging greater total body displacement. The increase sway may reflect an integration of sensory and motor function rather than impaired cognitive processing or increased endurance. Wolf *et. al.* (1996) concluded that TCC likely reduced the number of falls by increasing, rather than decreasing, postural sway in quiet standing. If a person is afraid of falling they may hold themselves rigidly in an effort to decrease possible destabilizing forces. As confidence increases, sway may also increase. The results of the Wolf *et. al.* (1996) study also indicated that fear of falling decreased. Living alone was associated with increased fear of falling. Wolf *et. al.* (1997) performed a similar study with 72 inactive healthy elderly. There were statistical improvements in the number of falls and fear of falling, without improvements in postural sway. Therefore, there are indications in the literature that TCC training helps improve the fear of falling and number of falls in the elderly.

Fewer studies are available on the effects of TCC training on younger individuals. Jacobsen *et. al.* (1997) studied 24 healthy young people ranging in age from 20 to 45 years and found significant improvements in knee extensor strength, lateral postural sway in quiet standing (as measured by a balance platform), and shoulder proprioception at 60 degrees but not at 30 or 45 degrees. This study lacked an alternate exercise comparison group. Results from published research indicated that elderly and young may react differently to TCC training but both groups improve balance, the younger by reducing anteriorposterior postural sway and the elderly by increasing mediolateral sway (Jacobsen *et. al.* 1997, Wolf *et. al.* 1997, Wolf *et. al.* 1996, Providence *et. al.* 1995).

Other research indicates that TCC training may improve balance by altering the muscular recruitment patterns of individuals (Forrest *et. al.* 1997). Forrest *et. al.* (1997) studied the effects of TCC training on the electromyographic (EMG) readings of postural adjustments of eight healthy individuals, average age 37 years. Significant reductions in the EMG responses for anticipatory postural reactions were found after TCC training; suggesting better utilization of elastic joint components through the flexed knee posture. This may be a component of reduced EMG readings, however, it seems more likely that the flexed knee allowed for one more degree of freedom of movement in the lower extremity. When the knee is straight the leg acts a rigid lever requiring the generation of larger ankle and hip joint moments to maintain postural integrity. Once the knee is flexed, there are more possible muscular responses to the postural perturbation. Training TCC may improve the sensory motor responses to anticipated postural responses allowing a more efficient motor program to be implemented.

## Tai Chi Chuan training effects on IPD

### How TCC Might Alter BG Function

The meditative aspect of TCC, called Qi Gong, has been shown to alter the EEG patterns and is different from sleep or wakefulness (Lee *et. al.* 1997). TCC may help promote attentional resources in the BG by the meditative effects altering the reticular formation output. Alternatively, daily practice of TCC (learning) may promote development of new neural pathways, new motor programs, or improve the efficiency of existing programs allowing faster reactions and / or greater number of options for people with IPD to choose from when responding to postural perturbations. This may impact the cardinal signs of IPD.

### Theoretical Effects of TCC Training on Symptoms of IPD

In the literature reviewed, only one article was located that specifically studied TCC training effects on IPD (Waters and Walsh 1997). The compliance was poor with a drop out rate of 35% leading to a small sample size and a lack of conclusive statistics.

The only factor tested was the level of depression that improved in 7 of the 10 individuals who completed the study (Waters and Walsh 1997). No comparison group was studied.

Although there was no other identified research that specifically studied IPD and TCC training, TCC involves, in a nonspecific manner, many of the exercises traditionally included in a physical therapy program for people with IPD (Reuter *et. al.* 1999). Tai Chi Chuan training includes the following physiotherapy components: posture, balance, lower-extremity strength, spinal rotation, alternating movements which mimic walking, concentrated attention, deep breathing, ROM, weight bearing, as well as a social component which may help improve compliance. Other exercise programs that have included these aspects have been shown to reduce the UPDRS and Columbia University Rating Scale scores as well as improvements in dyskinesias and motor scores (Reuter *et. al.* 1999). Physiologic changes that occur with regular exercise improve function and perceived well being.

Tai Chi Chuan is a moderate exercise that may help normalize dopamine levels in people with IPD. Dopamine levels have been shown to increase through daily moderate activity and, conversely, strenuous exercise has no impact on dopamine levels (Spiduro 1983, ACSM 1995). Maintenance of youthful hormonal levels were found in a Chinese study of elderly males who trained TCC (Xu 1986). The daily practice of TCC may similarly help normalize neurotransmitter levels in H&Y stages II and III IPD (Spiduro 1983, ACSM 1995). Once a critical number of neurons have been destroyed by IPD, it is unlikely that TCC will be able to improve neurotransmitter function. Other physiological benefits of exercise are likely to occur with TCC training.

As with other forms of exercise, TCC has been shown to improve cardiovascular and ventilatory responses (Lai *et. al.* 1993 and 1995). Since the leading causes of death in IPD are cardiovascular disease and pneumonia, improvements in the ventilatory and cardiovascular system of people with IPD would be beneficial. Ventilation may also be improved through reduced rigidity in the musculature of the ribcage.

Trunk rotation has long been used by clinicians to temporarily reduce IPD rigidity, therefore, TCC should have a similar effect (McNiven 1986, Irwin-Carruthers 1971). Also, according to Delwaide *et. al.* (1986), rigidity increases with mental stress. There is indication in the literature that the meditative component of TCC reduces mental stress and stress is a factor known to increase rigidity (Kutner *et. al.* 1997, Delwaide *et. al.* 1986). Improvements in trunk rotation may help improve balance by allowing less rigid motion.

Tai Chi Chuan has been shown by previous research to improve balance, reduce number of falls and fear of falling in healthy and frail elderly as well as healthy middle aged subjects (Wolf *et. al.* 1997 and 1996, Providence *et. al.* 1995). Similar improvements in the common age related balance parameters should occur in people with IPD. The size of improvements would be smaller and take longer to achieve based on the other factors that affect the balance reactions in people with IPD.

Continual practice of anticipatory postural adjustments combined with postural reactions during the movements occurs with TCC training and should improve these abilities in IPD. Tai Chi Chuan is performed at the pace of the heart beat (about 78 beats per minute at rest and increases to about 120 beats per minute with TCC) and musical cues used for enhancing movement in people with IPD. Therefore, the rhythm of TCC should assist with the switching abilities in Parkinson's. The slow movements of TCC allow time to create a smooth transition from one movement to the next, making TCC an achievable skill for people in H&Y stages II and III IPD. Success in performance leads a person to strive for higher standard where as failure often decreases performance (Gentile 1987, Fitts and Posner 1967). The positive feedback of successful completion of TCC movements should help improve self-esteem and sense of well being. Previous research supports the assumption that people with IPD can learn new motor skills (Morris *et. al.* 1996b, Daum *et. al.* 1995).

Tai Chi Chuan is presented in a pre-sequenced manner to assist the defective coding and retrieval of information experienced by people with IPD (El-Awar *et. al.* 1987, Daum *et. al.* 1995). People with IPD have been shown to be able to learn; however, require more practice (Morris *et. al.* 1996b, Daum *et. al.* 1995). The meditative component of TCC allows for mental rehearsal of newly learned information, a process shown to enhance learning and performance (Gentile 1987, Fitts and Posner 1967). The daily performance of TCC provides practice at retrieving memory in an enjoyable manner. Daily performance of the TCC is suggested and compliance is important to gain maximal benefits.

Compliance to exercise programs is notoriously poor even for able populations and is closely tied with motivation (Tan 1972, Chu 1991). A study by Crook *et. al.* 1998, stated that fifty percent of healthy individuals who started group aerobic exercise programs stopped with-in the first six months. Motivation to continue with exercise is improved if the person has a feeling of control of the situation (Fisk and Doble 1992). Since TCC should help IPD symptoms, improve the quality of life, and is self-directed, it should provide motivation to continue with the exercises. There are indications from previous research that TCC training tends to have better compliance than other forms of aerobic exercise in males (Channler *et. al.* 1995, Lan *et. al.* 1998). Studies with longer TCC exercise duration (>10 weeks) report attrition rates of 35% which, although lower than other group exercise programs, would affect the statistical inferences of certain research designs (Waters and Walsh 1997). The rising popularity of eastern medicine, TCC, and the mysticism surrounding the Chinese exercise should improve compliance.

## Summary

Current medical treatment focuses on medication, however, after long-term medication use motor side effects begin which may lead to costly falls. The success of available surgeries and medical advances depends on the prior maintenance of joint ROM and posture through exercise so that the permanent soft tissue and joint changes do not occur. The development of the characteristic forward flexed posture of people with IPD leads to reduced lung capacity, adoption of the head forward posture, and alterations in the neck muscle biomechanics. These changes combined with slowed muscular response leads to drooling and swallowing difficulties, increasing the risk of aspiration pneumonia. Preventative exercise will help delay or prevent the joint and soft tissue changes that occur due to the poverty of movement and allow people with IPD to take advantage of future surgical and medical advances. People with stage II or III IPD may be able to prevent or delay the onset of complications due to the poverty of movement inherent in the disease through exercise.

There is evidence in the literature that TCC training improves balance in the well elderly but it remains to be seen if similar improvements occur with IPD. Some improvements in the levels of depression with TCC training in people with IPD have been noted, however, there is no conclusive evidence in the literature (Waters and Walsh 1997). Tai Chi Chuan exercise involves movements utilized in traditional physiotherapy programs for the people with IPD and as such may be a cost-effective addition to traditional physiotherapy programs that may improve compliance.

Community based exercise programs can improve compliance and help maintain socialization while moving rehabilitation from the "illness" paradigm to a "wellness" paradigm. Tai Chi Chuan is an inexpensive, accessible, and achievable exercise program for people in the early stages of IPD that includes many of the exercises inherent in traditional IPD physiotherapy programs. Tai Chi Chuan has not been investigated as an exercise program for people with moderate IPD. This study will help determine if TCC has beneficial effects in people with moderate IPD.

# CHAPTER 3

# MATERIAL AND METHODS

## Subjects

### Subject selection

Six female volunteers, mean age 54 years (range 51-61years), were recruited from the Halifax area through the local chapter of the Parkinson's Foundation of Canada, local neurologists, and by poster advertising. Four subjects were purposefully selected to most closely represent the following disease presentations: One stage II tremor dominant, one stage III tremor dominant, one stage II bradykinetic dominant, and one stage III bradykinetic dominant. Only people in stages II and III IPD with no contraindications to moderate exercise (equal to fast walking, 4 metabolic equivalents, as defined by American College of Sports Medicine 1995) were included to ensure safety and to decrease the intra-subject variability in measurements. One volunteer did not meet the preset selection criteria. One stage II bradykinetic volunteer reported a high likelihood of being transferred to another city and, as a result, was not selected for the study.

### Specifics for Each Subject

**Subject 1 History**

Specific details about subject 1 are shown in Table 2 (page 58). Subject 1 was an employed female who reported her employers suggested retirement since her productivity had declined. She stated that she hoped the group class would help her with exercise compliance and assist her to move more easily. She had heard that TCC helped people with IPD.

**Subject 2 History**

Specific details regarding subject 2 are presented in Table 3 (page 58). Subject 2 was a female who could walk alone but was more comfortable with standby assistance. She stopped driving and retired once she was diagnosed with IPD. She reported participation in a TCC class several years before. She expressed hope that the class would improve her balance, lower extremity strength, posture and sense of well-being.

**Subject 3 History**

Subject 3 specific details are presented in Table 4 (page 59). She reported having little knowledge regarding TCC and hoped that the TCC class would improve her knowledge about herself, Parkinson's, and TCC, as well as improve her posture and sense of well being.

**Subject 4 History**

Specific details regarding subject 4 are presented in Table 5 (page 59). Subject 4 had participated in TCC classes more than one year ago and reported she did not know what she expected to gain from training TCC. She expressed hope that TCC would benefit her by improving her balance and memory. She stated that she was "relieved" when she got diagnosed with IPD because she "did not have cancer."

Table 2. Subject 1 personal and disease characteristics

| Age | Ht (m) | Wt (Kg) | Dominant hand | Regular Exercise | BDI score | MMSE score |
|---|---|---|---|---|---|---|
| 61 | 1.6 | 54 | Right | Physiotherapy home exercises | 9 | 27/30 |

| Stage | UPDRS | Symptom dominant side | Duration since diagnosis | IPD Medications | Type IPD |
|---|---|---|---|---|---|
| 2 on<br>2 off | **Subj:**19<br>**Motor**<br>On:34<br>Off:43<br>**Sdeffect:**8<br>**Dysk:** 18<br>**SE**(ADL).<br>On:80%<br>Off:50%<br>**H&Y:**<br>On: 2<br>Off: 2.5 | Left | 12 years | CR Sinemet ™100/25mg tid<br>Ranitidine HCl 150mg bid<br>Amantadine HCl 100mg tid<br>Ropinirole HCl 4mg tid<br>Novotriamzide 50mg bid<br>Selegiline HCl 5mg bid | Dyskinetic tremor |

Table 3. Subject 2 personal and disease characteristics

| Age | Ht (m) | Wt (Kg) | Dominant hand | Regular Exercise | BDI score | MMSE score |
|---|---|---|---|---|---|---|
| 52 | 1.56 | 57 | Left | Physiotherapy home exercises & IPD pool class | 9 | 29/30 |

| Stage | UPDRS | Symptom dominant side | Duration since diagnosis | IPD Medications | Type IPD |
|---|---|---|---|---|---|
| 2.5 on<br>2.5 off | **Subj:** 27<br>**Motor:**<br>On:12<br>Off:26<br>**Sdeffect:**9<br>**Dysk:**16<br>**SE**(ADL)<br>On:70%<br>Off:70%<br>**H&Y**<br>On: 3<br>Off: 3 | Right | 10 years | CR Sinemet™100/25mg tid<br>Ropinirole HCl 0.75mg tid<br>Gabapentin 400mg tid<br>Amitriptyline 50mg<br>Novotriamzide 50mg bid<br>Selegiline HCl 5mg bid | Dyskinetic bradykinetic |

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Table 4. Subject 3 personal and disease characteristics

| Age | Ht (m) | Wt (Kg) | Dominant hand | employed | Regular Exercise | BDI score | MMSE score |
|---|---|---|---|---|---|---|---|
| 52 | 1.65 | 59 | Right | Yes | Low impact aerobics, Light weights, Golf Skiing, Bowling | 1 | 30/30 |

| Stage | UPDRS | Symptom dominant side | Duration since diagnosis | IPD Medications | Type IPD |
|---|---|---|---|---|---|
| 2 on<br>3 off | **Subj:** 16<br>**Motor:**<br>On:13<br>Off:21<br>**Sdeffect:**4<br>**Dysk:** 0<br>**SE**(ADL)<br>On:90%<br>Off:90%<br>**H&Y**<br>On:2.5<br>Off:3 | Left | 2 months | Sinemet™ 100/25 tid | tremor |

Table 5. Subject 4 personal and disease characteristics.

| Age | Ht (m) | Wt (kg) | Dominant hand | employed | Regular Exercise | BDI score | MMSE score |
|---|---|---|---|---|---|---|---|
| 51 | 1.58 | 68 | Left | Yes | None | 9 | 30/30 |

| Stage | UPDRS | Symptom dominant side | Duration since diagnosis | Medications | Type IPD |
|---|---|---|---|---|---|
| 2 on<br>2 off | **Subj:** 21<br>**Motor**<br>On:11<br>Off:20<br>**Sdeffect:**4<br>**Dysk:**0<br>**SE**(ADL)<br>On:90%<br>Off:80%<br>**H&Y**<br>On:2<br>Off:2 | Left | 1 year | Ropinirole HCl | bradykinetic |

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A TCC class size of ten participants was required for effective TCC teaching to maintain adequate group dynamics. Other class participants were recruited from a similar age group through posters at community centers and sports complexes.

## Inclusion criteria

1. Previously diagnosed by a neurologist as having IPD.
2. Assessed by a neurologist as being in stage II or stage III of Hoehn and Yahr scale IPD when "off" medication.
3. Able to ambulate 50 meters unassisted.
4. Between the ages of 50-70 years.
5. Stable on medication for at least 3 months

## Exclusion criteria

1. Cognitive impairments as defined as a score less than 23/30 on the Mini Mental State Exam (MMSE).
2. Significant heart disease (angina, myocardial infarct, coronary artery bypass, congestive heart failure, severe valvar disease, valve surgery, heart transplant, cardiomyopathy, pacemaker, or left bundle branch block). Confirmed through a letter to physician.
3. Major orthopedic problems (moderate to severe knee or hip osteoarthritis, low back pain). Confirmed through a letter to physician.
4. A pulmonary or systemic embolism within the past 12 months. Confirmed through a letter to physician.
5. Medications, other than Parkinson's medication, which might affect balance. Confirmed through a letter to physician.

6. Uncontrolled hypertension. Confirmed through a letter to physician.
7. Legally Blind
8. Tai Chi Chuan training within the past three months

## Design

Four systematic replications of a single subject A-B-A treatment withdrawal designs were concurrently performed over the 26 week study duration. The single subject design (SSD) allowed a thorough investigation of how TCC training might affect individuals differently based on IPD presentations. In a clinical physiotherapy situation, individual patients are treated and may not be adequately represented by group normative values. The SSD allows a comprehensive analysis of each subject's personal and disease characteristics to be considered when assessing the impact of TCC training on that person's life. Repeated objective measures allow assessment of performance stability over time and association of changes with the intervention (Dattillo 1986). Each subject acted as his / her own control eliminating confounding factors introduced with matching different individuals. The baseline variability and trend of disease progression for each subject was established prior to the intervention. The repeated measurements allowed statistical determination of trends even with the inherent disease variability.

Threats to internal validity were reduced by systematic replication of the SSD using people with different IPD presentations. The SSD research technique is well suited to clinical research and provides useful trend information regarding intervention procedures (Tripoli 1994, Barlow and Hersen 1984, Wollery and Harris 1982). Although the generalizability of a SSD is limited, multiple SSD using the same treatment protocol allows for increased external validity. Statistical inferences can be made from SSD data when at least eight values are gathered per phase (Barlow and Hersen 1984). As with other long-term exercise programs, TCC classes have some attrition and the SSD is less affected by attrition than other research designs (Tripoli 1994, Barlow and Hersen 1984). Unpublished TCC studies with longer exercise duration report attrition rates of approximately 35% (Waters and Walsh 1997). The population of IPD in Nova Scotia is geographically dispersed making travel difficult and limiting subject recruitment. The expected effect size was small and the between subject variability of IPD was great. Replication of SSD allows analysis of treatment effect in situations with large between-individual variability (Barlow and Hersen 1984). For these reasons the SSD was the most appropriate design for this research.

Ethical approval for this study was obtained from the Faculty of Health Professions and Faculty of Graduate Studies. See appendix C.

## Procedure

### Initial interview and assessment session

There was an interview and assessment session before and after the study. A standardized questionnaire using open-ended questions was used to determine motivational factors, expectations, and previous exercise experience of subjects (see appendix D). Differences in motivation and experience could have produced different training results and were recorded. At the initial interview session, the subjects met the testers, TCC instructor, and safety personnel. The subjects completed an informed consent form including permission to contact their physicians to determine if there were any medical reasons why the person should not attend training (see appendix E). The subjects had an opportunity to ask any questions and participate in sessions designed to familiarize the subjects with the outcome measures. This was designed to improve the reliability of outcome measures by reducing the stress of new situations during the actual data collection period, and improve communication throughout the study. Stress has been identified as a factor in symptom exacerbation. Each subject was administered a screening questionnaire to ensure all inclusion and exclusion criteria were met. Written permission was gained to contact each subject's family physician with a health questionnaire to identify any other exclusionary health issues (see Appendix F).

The initial assessments included the Beck's Depression Inventory (BDI) and UPDRS (both "on" and "off"). The MMSE was also administered to screen for cognitive impairment in order to ensure valid completion of the subjective portion of the UPDRS. A copy of the MMSE is found in Appendix G. The initial videotaped "on" and "off" UPDRS measurements were rated by an experienced assessor. The "off" phase was defined for this study as the time of medication ingestion. The "on" phase was defined as between one to two hours post medication, a time considered to have the highest plasma levels of L-dopa. Therefore, subjects were asked to arrive 30 minutes prior to medication ingestion and the UPDRS "off" was assessed. The subjects then took their medication and were re-tested one hour later ("on" phase). The videos were then sent to a neurologist for determination of the H&Y stage of each individual. The BDI and UPDRS were administered both pre and post intervention using the same protocol to document level or change in depression and disease severity. Copies of the BDI and UPDRS forms are shown in Appendices H and I respectively. Learning and fatigue effects were controlled for through the inclusion of a practice session prior to baseline measures and multiple baseline measures. Subjects were accompanied by safety personnel to reduce the risk of falls on all measures of gait and balance. All assistants were asked to sign a confidentiality form.

## Outcome Measurements

During the repeated measures data collection (A-B-A phases), the order of motor tests (gait, FR, and partial Fahn tremor scale) was randomized using a random number chart for each testing session to control for fatigue and medication effects over the half hour motor test time. Movement testing occurred one-hour post medication ingestion, a time considered to be subject's optimal functioning level, as has been used in many other studies (Erikksson *et. al.* 1984). The diurnal and medication induced symptom variability are great, therefore, measurements were taken at the same interval post medication and when possible at the same time of day in an attempt to control for medication effects.

Selected temporal and spatial gait parameters were measured using an electronic grid walkway that had on-line data collection and analysis (Crouse *et. al.* 1987). This walkway has been used in many other studies of normal and pathological gait (Turnbull and Wall 1985, Wall and Turnbull 1986, Wall *et. al.* 1991, Turnbull *et. al.* 1995). The walkway has a series of mats 10 meters long and data collection occurs in the middle 7.2 meters (see Figure 2, page 66). Each of the nine central mats had an electrical grid embedded in the surface. The "dummy" mats at each end of the transduced portion of the walkway allowed the subject to obtain a constant walking speed prior to data collection. The timing and distance errors associated with the walkway were 3 ms and 0.9 cm. respectively. The subject had self-adhesive conducting tape placed on the soles of their shoes to complete the electrical circuit on the portion of grid in contact with the tape. This allowed measurement of the duration and location of each foot to floor contact. The data collection, processing, and storage were performed automatically by an Apple IIE microcomputer. The spatiotemporal gait parameters were calculated using a computer program that included an algorithm to detect and eliminate toe scuffs. The parameters measured and calculated by the electronic walkway system were WS, RSL, RST, and SST. The WS was expressed in statures / second (stat/s), a method of standardizing walking speed for height differences (Greive and Gear 1966, Wall and Turnbull 1986). The range of walking speed and cadence were calculated using the walkway data. Cadence was calculated from the ST data as follows:

$$\left[\frac{1}{(SL/2)}\right] \times 60 = \text{cadence in steps / minute}$$

The subjects were given standardized instructions of "walk at your ____ speed, safely, the length of the walkway and begin when I say go. Ready, set, go." At the statement "go" the walkway data collection was begun. Subjects walked at their self-selected speeds in the following order: free, slow, slow, free, fast, fast. The average of the two walks at each speed were used in order to improve reliability of measures. Improvement in gait parameters were considered to represent improvements in dynamic balance.

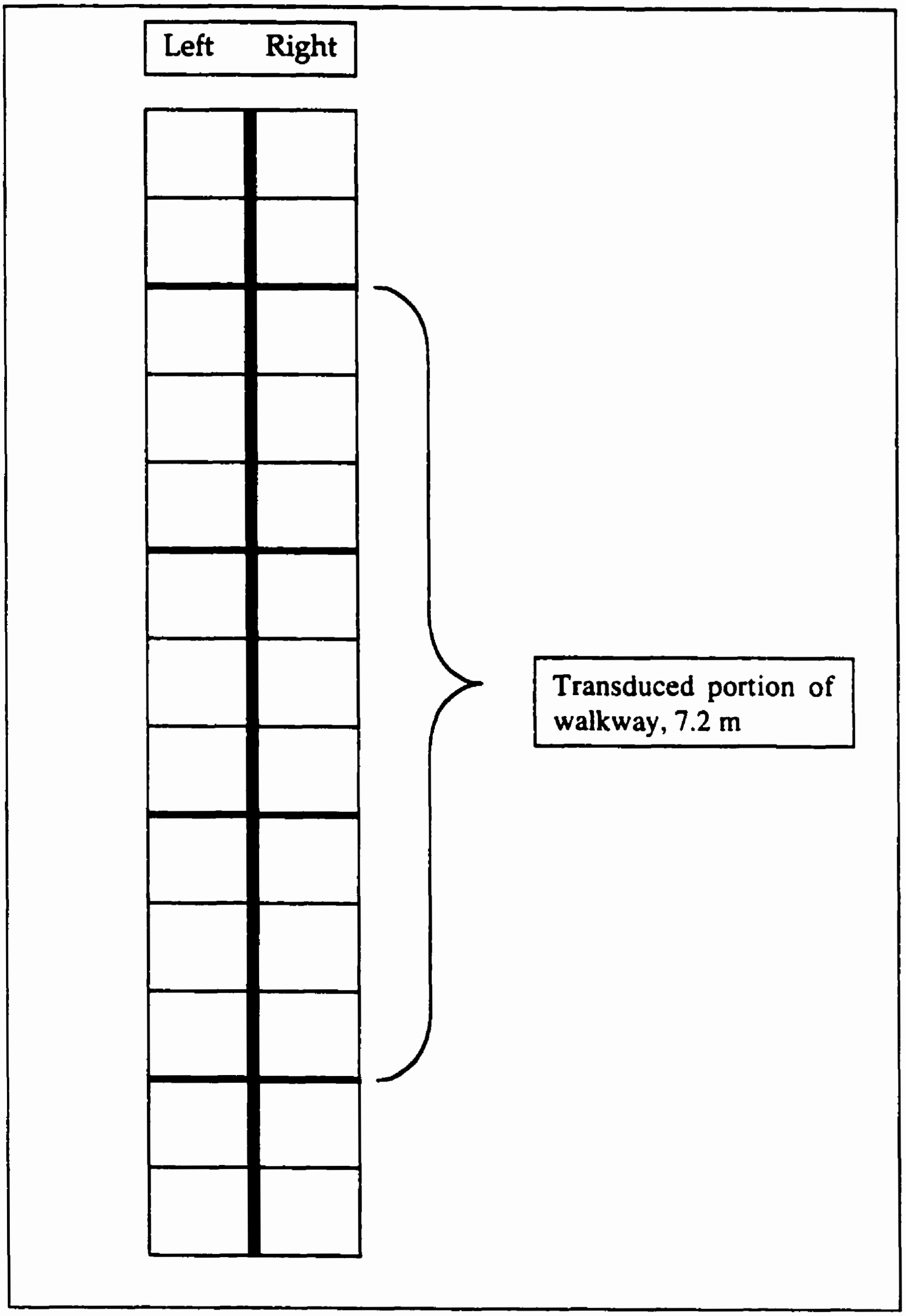


Figure 2. Walkway schematic. Walkway length was 10 m. and consisted of a left and right sides delineated with tape

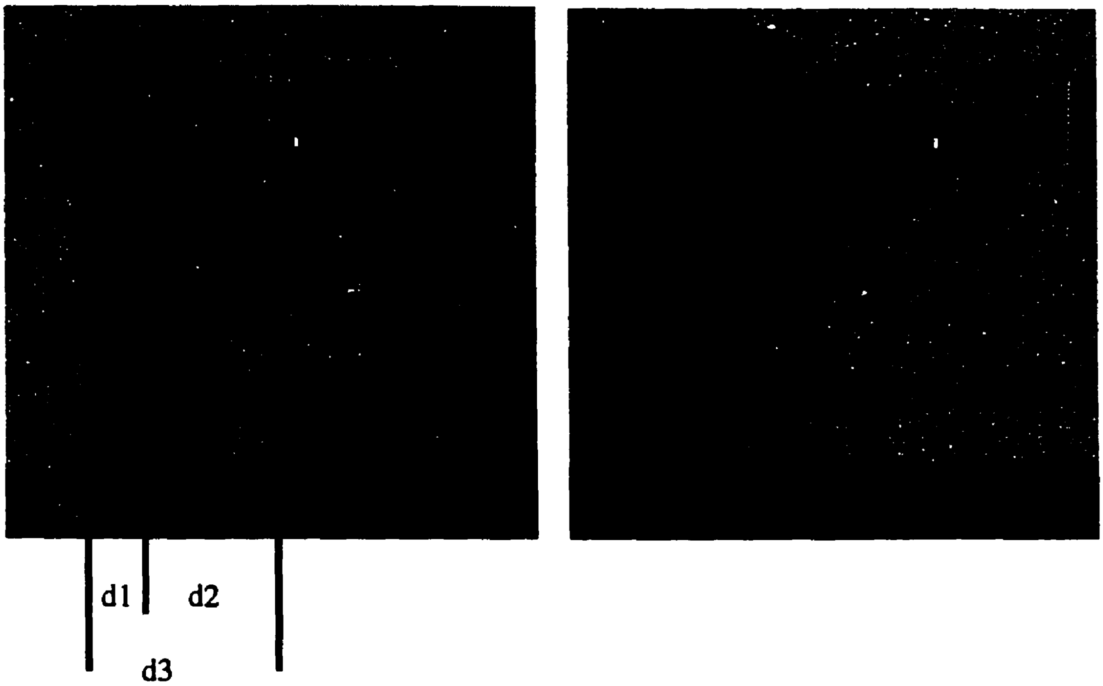


Figure 3. Modified FR. d3 = length of arm from acrominion to tip of middle finger. d1 = distance from medial malleolus to tip of great toe. d2 = the difference in between the arm and the partial foot measurement. d2 = d3 – d1 and represents the distance from the meter stick 10 cm mark that the footplate was placed.

The subject's ability to control balance during forward reaching was assessed using FR. For the purposes of this study, FR was considered a measure of static (feet not moved) balance. The subject stood with their feet together, arm flexed to 90 degrees, and the change in fingertip position was measured using a meter stick placed at shoulder level (level of acromion) as the subject reached forward. Due to the high degree of motor variability in IPD, the foot position was standardized to improve the reliability of measures. A foot-plate was placed so that the toe position equaled the difference between the arm (tip of acromion process to tip of third finger) and foot length (distance from medial malleolus and tip of great toe) from 10 cm mark of the meter stick. See Figure 3. The meter stick was also modified with a push bar to reduce the error introduced by paralax, rater reliability of the metacarpal head or fingertip position, and subject dyskinesia or tremor. Standardized FR instructions were as follows: "stand with your toes against the foot-plate, raise your left arm to shoulder level and push the bar slowly forward as far as you can without lifting your heels off the ground." The average of three consecutive FR measures was calculated and used to improve reliability.

Tremor was assessed using the drawing the partial Fahn tremor scale shown in Figure 4. The subject was videotaped as they completed the test using their right and left hands. The number of times the outer form-lines were touched was used as the quantitative measure. Standardized instructions were "connect the dots without touching the lines."

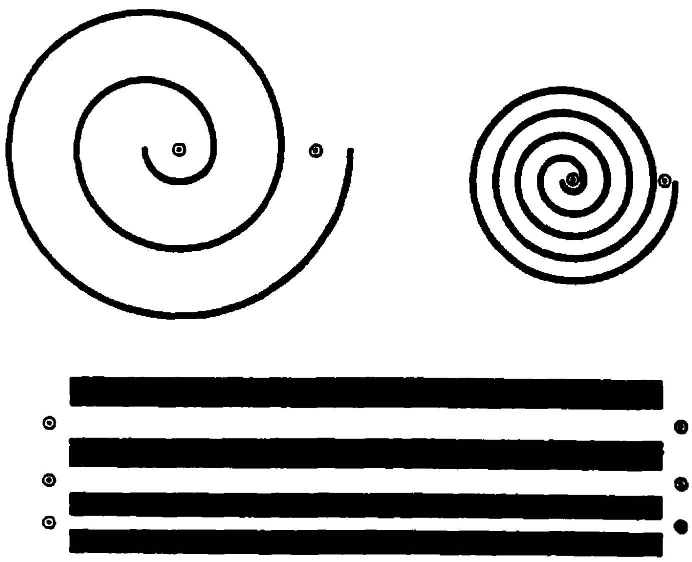

Figure 4. Partial Fahn Tremor scale, 50% original size.

The subjective fear of falling and quality of life questionnaires took less than 10 minutes to complete. Copies of the PIMS and MFES are shown in appendices J and K respectively. The PIMS were composed of the subject's ordinal ratings of how IPD impacted their emotional, social, leisure, safety, family, sexual, work, travel and community well-being. These ordinal ratings were provided for "best on" and "worst off" functioning and were weighted according to the following formula: [1.6 x self positive + 1.2 x leisure + 1.3 x feelings + 1.1 x safety + 1.3 x family + 1.1 x community = 0.6 x sexuality = 0.7 x work + 0.6 x traavel + 0.5 x financial security] (Calne *et. al.* 1996). The weighted PIMS scale values range from 0 – 40 with the higher numbers indicating more impact on life.

The MFES was composed of 14 Likert type scales for common activities performed by community dwelling elderly, including some outdoor activities. The two extremes of the 10 cm lines represented total confidence and complete lack of confidence in task performance without falling. The subjects marked on each of the 14 lines the position which best represented their confidence level. The length of each mark from the lack of confidence position (0 cm) was measured and all 14 values were added together to give an overall MFES rating. A minimum value of 0 represented severe fear of falling and the maximum value of 140 cm represented total confidence in balance abilities.

A short (< 5 minute) weekly health questionnaire was also administered to identify any general health or medication changes that might have affected the outcome measures (see Appendix L).

**Phase A1: Initial Baseline**

Nine pre-intervention baseline measures of gait, balance, fear of falling, quality of life and tremor were taken three times per week for 3 weeks. During this phase, subjects completed a daily logbook entry regarding number of falls.

## Phase B: Treatment

Subjects attended a 60 minute TCC class at a dance studio twice a week for 20 weeks and were taught four warm-up movements, 42 TCC forms, and basic meditation. The four warm-ups were the basic warm-ups taught for all Wu style TCC classes (loose hands, hip/shoulder coordination and mobility, loose knee, and kicks). See Figures 5-8 .

Figure 5. Warm-up 1.

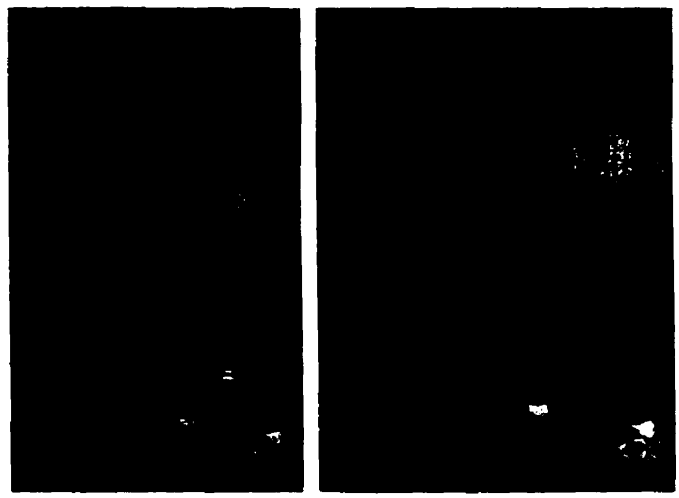

Figure 6. Warm-up 2.

Figure 7. Warm-up 3.

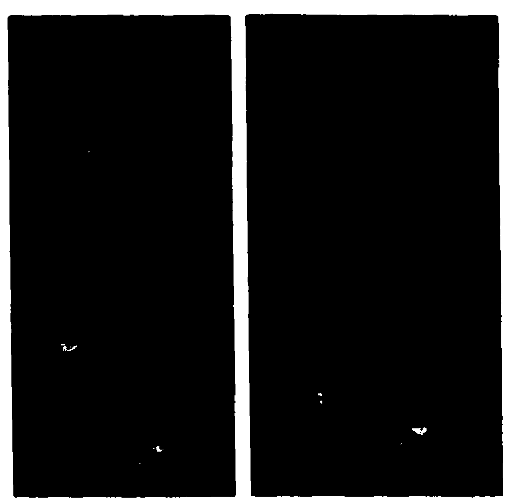

Figure 8. Warm-up 4.

The 42 forms included the one-leg movements to help improve balance, and the class progressed according to the subjects' abilities. The list of forms is located in Appendix M. One recurring form was single whip shown in Figure 9.

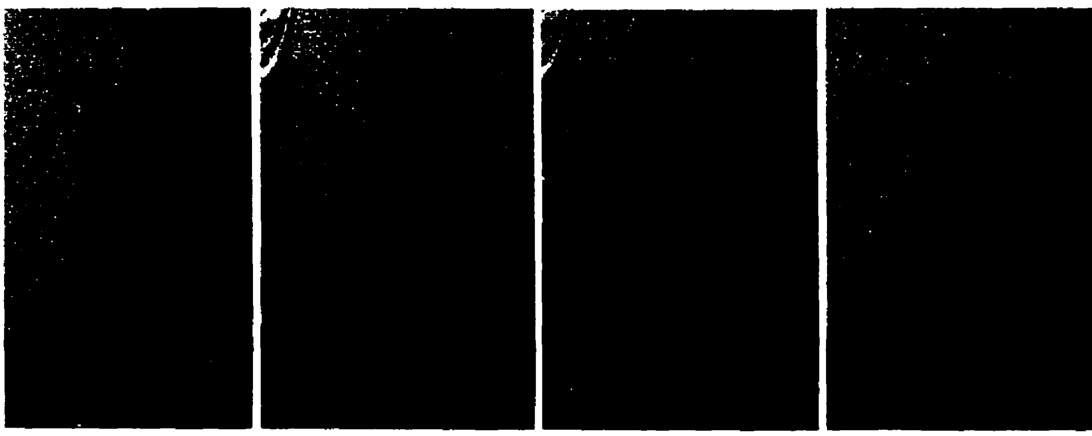

Figure 9. Sequence of single whip TCC form.

The forms were taught in the same sequence as the regular community TCC classes to represent community based TCC programs. The duration of the intervention was greater than previous studies in an effort to allow for measurable changes of outcomes studied. The instructor was a licensed physiotherapist and instructor of Wu style TCC with ten years experience. Safety personnel were present during each TCC class to provide balance support for subjects as required. The subjects were allowed to bring another individual with them to the TCC classes in an effort to improve compliance. A total class size of ten people, in the 50-70 age group, participated in the TCC class to improve group dynamics and compliance through the 20 weeks of TCC training.

Subjects were required to be tested for gait, balance, fear of falling, quality of life, and tremor once every two weeks during the 20 week intervention phase. During this phase, daily home practice was suggested and all subjects were asked to enter the number hours of TCC practice, answer five general questions regarding their TCC practice and falls into their log book (see Appendix N). A TCC video plus written instructions regarding the TCC forms were provided to the subjects to assist with their home practice. Near the end of the treatment phase the subjects were provided with audio-cassettes of the forms to help with home practice.

Subject's TCC forms were videotaped during the fourth and final TCC class to document improvement. The videos were not returned in a timely manner to allow inclusion of the data in these results.

## Phase A2: Final Baseline

Three weeks of follow up measures were taken following the TCC classes in the same manner as the pre-intervention phase. During this period subjects were asked not to practice any TCC and agreed to comply with this as part of the informed consent. Only falls and questions regarding falls were entered into the subject's logs during this phase.

## Final Interview

The final videotaped UPDRS and BDI assessments were performed at the end of the Phase A2 and rated by the same rater who performed the initial UPDRS ratings. A final interview using open-ended questions was performed (see Appendix D).

## Support Person's Questionnaire

A written questionnaire was administered to the support person who attended the TCC classes with the subject to gain their insight about the experience. See Appendix D.

**Follow up**

An open-ended phone interview was conducted one-month post study to identify any additional insights that the subjects may have had after completion of the study.

**Data Handling and Analysis**

The data of each subject was analyzed separately. Visual analysis of the graphed measurements of selected spatial and temporal gait kinematics (ie. walking speed and stride length), FR, MFES, PIMS and partial tremor scale were performed to identify changes from baseline data compared to treatment trends and variability. Visual analysis has been shown to agree well (86%) with statistical analysis for manufactured data without auto-correlation when introduced patterns were increased by 30-50% (Bobrovitz and Ottenbacher 1998). Visual analysis appears to be more affected by small effect sizes than statistical analysis (Bobrovitz and Ottenbacher 1998). The effect size was expected to be small for the outcomes studied. The serial dependency of SSD data violates assumptions of many statistical tests. Statistical methods specifically designed for SSD have the advantage of increased reliability if data has little variability (Nourbakhsh and Ottenbacher 1994). The split middle technique allows determination of a trend line for visual analysis. There are several common statistical methods used: two standard deviation bands, binomial analysis, and C statistic. The two standard deviation band method is only valid for normally distributed data with a stable baseline and is very sensitive to extreme values (Nourbakhsh and Ottenbacher 1994). Since motor performance is highly variable in people with IPD, normally distributed data was not anticipated and extreme values were expected, therefore, the two standard deviation band method was not selected.

**Split middle analysis of trend**

Data was plotted and graphed for visual analysis. The split middle technique was used to determine the slope (trend) of the results in different phases of the study (Barlow and Hersen 1984, Tripodi 1994, Wollery and Harris 1982). Celleration lines were calculated to examine linear trends and help predict future performance as described by Barlow and Hersen, (1984). Celleration lines divide data so that half the datum are above and half below the line. Each phase was divided into quarters and a vertical line extended at each quarter. The middle x coordinate for each half of each phase were determined and the median (if odd number of points) or half-way point (for even number of data points) were determined for the y coordinate. A straight line was drawn between these two points.

**Binomial Analysis of Level Change**

The binomial analysis as described by Barlow and Hersen (1984) was used to determine if there were significant level changes between the consecutive study phases. A horizontal line was drawn from the median score of the previous phase and all but one of the subsequent phase scores must fall on one side of the line for there to be considered a significant level change. For phases with 9 measures at least 8 datum need to be on one side of the line for a significant level change. For phases with 10 measures at least nine datum need to be on one side of the horizontal line. For example, a level change in the treatment phase would occur when nine of the ten data points were above or below the median value of the either baseline phase.

## C Statistic Analysis of Trends

The C statistic is not affected by serial dependency and can be calculated from as few as eight measures (Backman and Harris 1999). The C statistic was calculated to determine if the slope of the line of best fit for each phase was statistically different from zero. The calculation involves several steps (Tripodi, 1994). First, each subsequent (adjacent) score was subtracted from the immediately prior score. For example, the second was subtracted from the first, the third was subtracted from the second, and so on. Each value obtained in step 1 was squared, thereby eliminating negative values, and the sum of the squared values determined (D2). The mean value for the phase was computed. A mean-difference value for each score was calculated by subtracting the phase mean from each raw score and squaring the results [SS(x)]. This allowed the values to be centralized around zero. These squared values were then summed. The SS(x) was multiplied by two. The C score was calculated using the following formula: $C = 1 - [D2 / 2SS(x)]$. The standard error for the C statistic was computed using the following formula: $SE = (n - 2) / (n - 1)(n + 1)$, where n = the number of scores in the data series for which the C statistic was computed (the number of data in the phase). Z score was calculated by dividing the C statistic by the SE and compared to a Z table to determine statistical significance ($p < 0.05$ then $Z > 1.67$). The complete formula is shown in appendix O.

# CHAPTER 4

# RESULTS AND DISCUSSION FOR SUBJECT ONE

## Results

Subject one attended 32 of the 34 TCC classes (94%). Six of the 40 scheduled classes were cancelled due to poor attendance or high humidity levels. The instructor log data indicated that although hands-on balance assistance was required throughout the study, the amount of assistance was reduced as the TCC classes progressed. Frequent verbal cueing was required to allow progression to subsequent TCC forms and proper physical performance of the movements. Subject one retired from employment during the course of the treatment phase. No change was noted in the BDI scores between pre and post treatment phases. There were changes in the UPDRS scores. See Table 6 (page 77). There was a worsening of the subjective, motor "on", side effects, SE, and "off" H&Y scores (23%, 7%, 22%, 10%, 1.5 stages respectively). The "on" H&Y and "off" motor scores were unchanged and the dyskinesia scores improved 4%.

## <u>Monitored Extraneous Factors</u>

There were five IPD medication changes for subject one during this study shown in Table 6 (page 77). Four changes were suggested by the physician and one, in week 26, was self-directed by the subject. These prescribed changes were further confounded by the fact that the patient occasionally ingested allergy medications that were not prescribed. This was only documented in week 25 and the test log indicated a worse performance on that date. The effects of these medication changes are reflected in the increased variability of all walkway data beginning in week 9. See Figures 10 – 15 (pages 79-81). The effect is less clear in the other measures.

Table 6. Subject 1 pre and post BDI, UPDRS, and medication changes

| **BDI** | | **UPDRS** | | **IPD Medication changes** | | |
|---|---|---|---|---|---|---|
| Pre | Post | Pre | post | | | |
| 9 | 9 | **Subj:**19 | **Subj:**47 | June 7 | Sinemet ™ | ↑ 1/2 tab tid |
| | | **Motor** | **Motor** | June 21 | Sinemet ™ | ↑ 1 tab tid |
| | | On: 34 | On: 42 | June 30 | Sinemet ™ | ↑ 1 tab 5x/day |
| | | Off:43 | Off:43 | June 30 | Ropinirole | ↓ ? tid |
| | | **Sdeffect**:8 | **Sdeffect**:13 | Aug 11 | Sinemet ™ | ↓ qid |
| | | **Dysk**: 18 | **Dysk**: 17 | Oct 8 | Ropinirole | discontinued |
| | | **SE**(ADL). | **SE**(ADL). | | | |
| | | On: 80% | On: 70% | | | |
| | | Off:50% | Off:60% | | | |
| | | **H&Y:** | **H&Y:** | | | |
| | | On: 2 | On: 2 | | | |
| | | Off: 2.5 | Off: 4 | | | |

™Dupont Pharma, Toronto

Subject one reported no sick days in phase A1, 5 in the treatment phase (May 10 & 24, Aug. 16 & 19, and Sept. 13), and 3 in phase A2 (Oct. 1, 4, and 6). Subject one reported levels of increased stress occurred 4 times in phase A1 (April 12, 16, 21, and 26), 3 times in treatment phase (Aug. 16, 24, and 30), and 5 times in phase A2 (Sept. 27, Oct. 1,4,6, and8).

Fatigue scores for subject one were significantly lower during the treatment phase than the second baseline phase as determined by the binomial test for significance. There was no significant difference between the first baseline and the treatment phase, however, there was an insignificant trend toward increased fatigue as the treatment progressed. See Figure 22 (page 85).

The relative humidity was 90% or more for 25 of the 28 testing days as illustrated in Figure 20, page 84. From June to September the temperature was greater than 20 ° C during 8 of the 10 treatment phase test days as shown in Figure 21, page 84.

## Analysis

### Visual analysis

Visual analysis of the data for subject 1 was performed using the split middle technique and are shown in Figures 10-22 (pages 79-83). No trends were indicated in phase A1 fast SL, phase B fast ST and free SST, phase A2 fast and free SST, as well as the best and worst PIMS scores. Several times the fast walking speed tests were not attempted due to safety concerns. Tester logbook entries indicated that on the first PIMS evaluation subject one stated "I feel the same about my sexuality but my husbands behavior has changed."

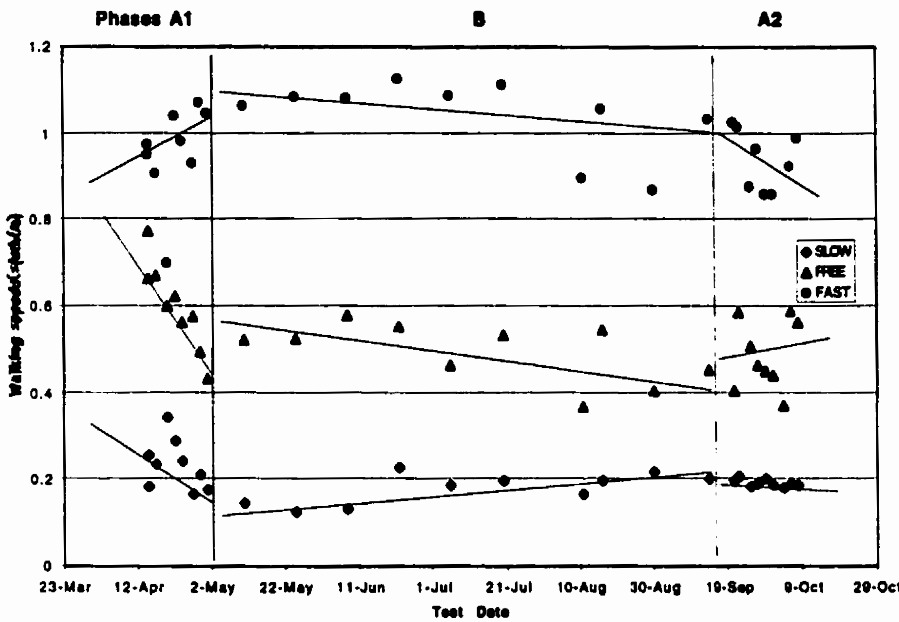


Figure 10. Walking speeds (stats/sec) of subject one for three self-selected speeds. Study phases are delineated with vertical lines.

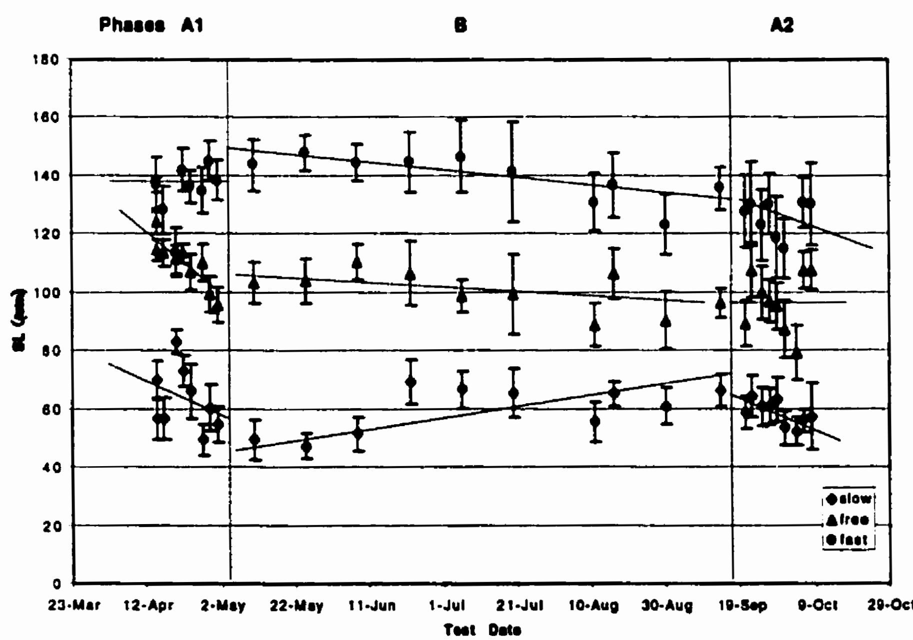


Figure 11. Right stride length (cm) for three WS for all phases. Study phases are delineated with vertical lines. Error bars indicate one standard deviation.

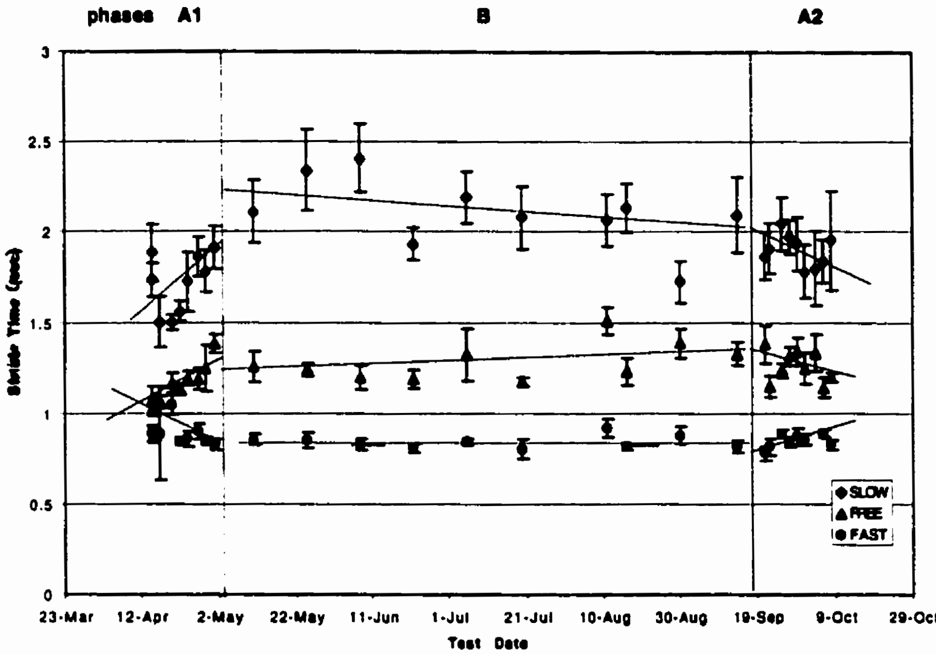


Figure 12. Right stride times (sec) for subject one plus standard deviations. Study phases are delineated with vertical lines. Error bars indicate one standard deviation.

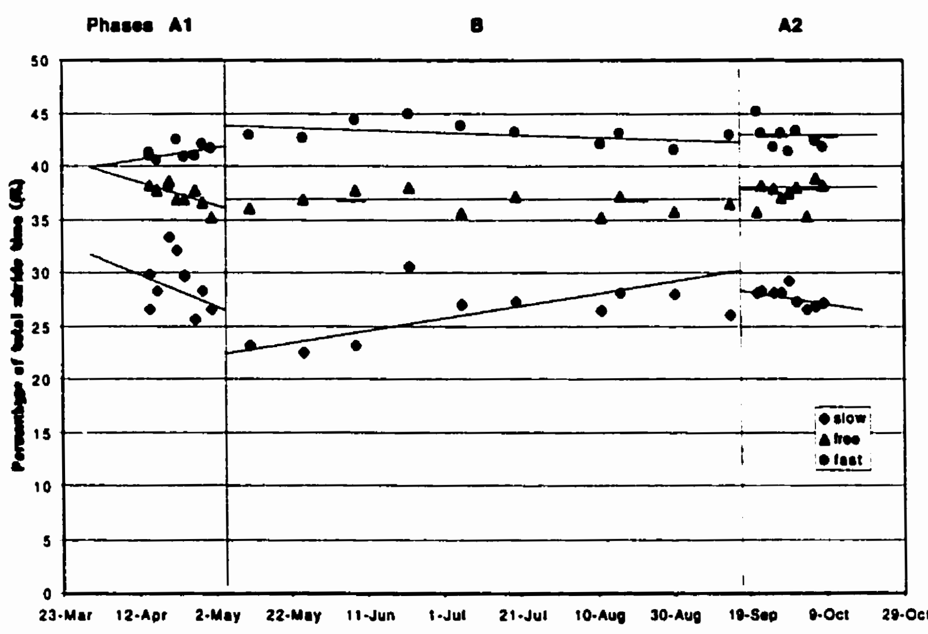


Figure 13. Single support time expressed as a percentage of total support for all three WS for subject one. Study phases are delineated with vertical lines.

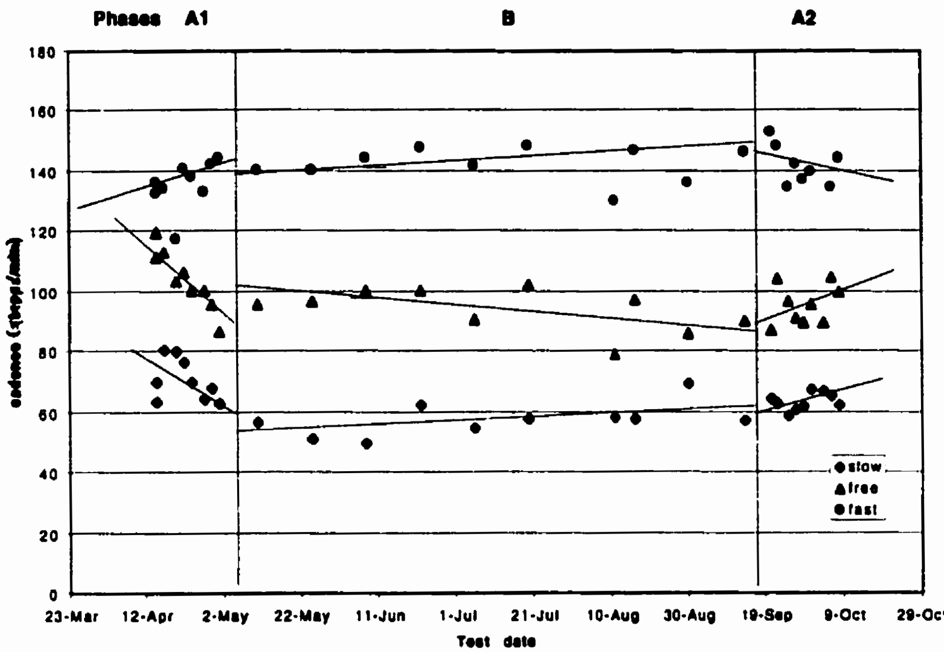


Figure 14. Cadence for three self-selected WS for subject 1. The study phases are represented by vertical lines.

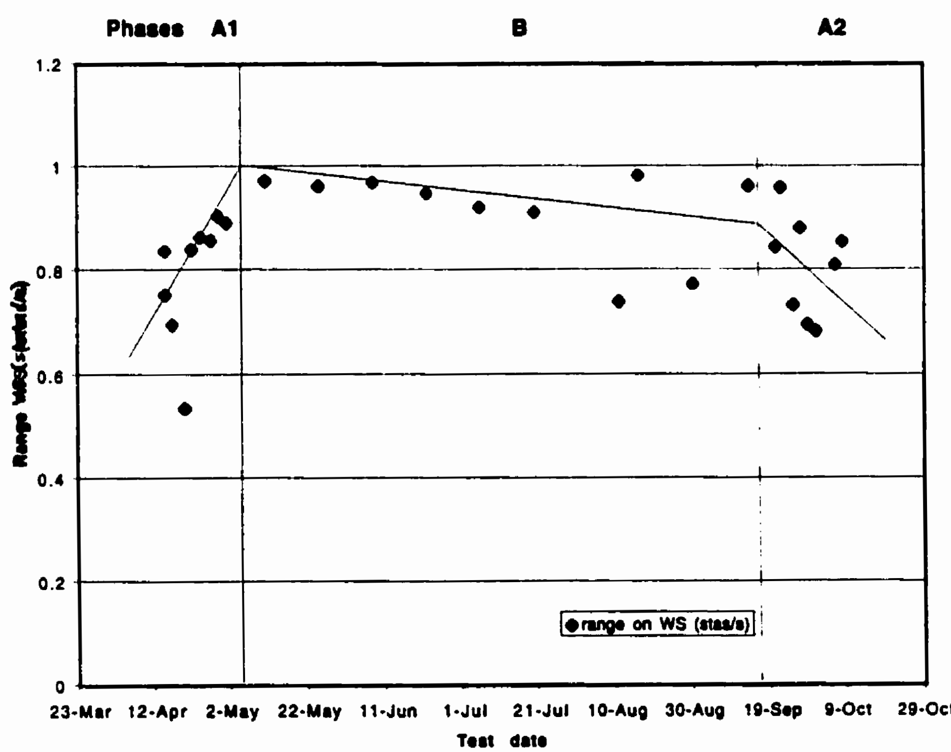


Figure 15. Range of walking speeds for subject one. The study phases are represented with vertical lines.

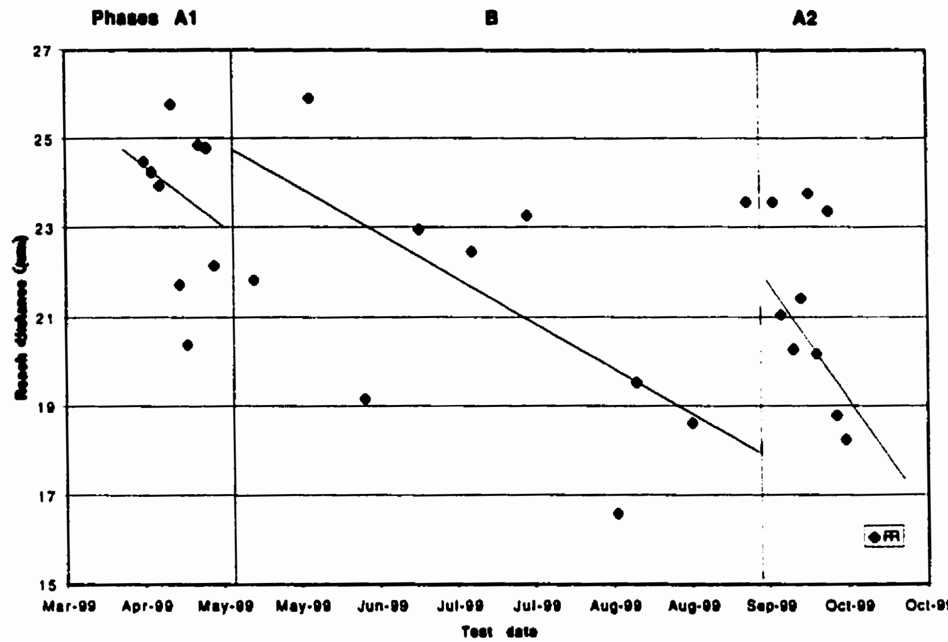


Figure 16. Functional reach measures for subject 1. Study phases are delineated with vertical lines.

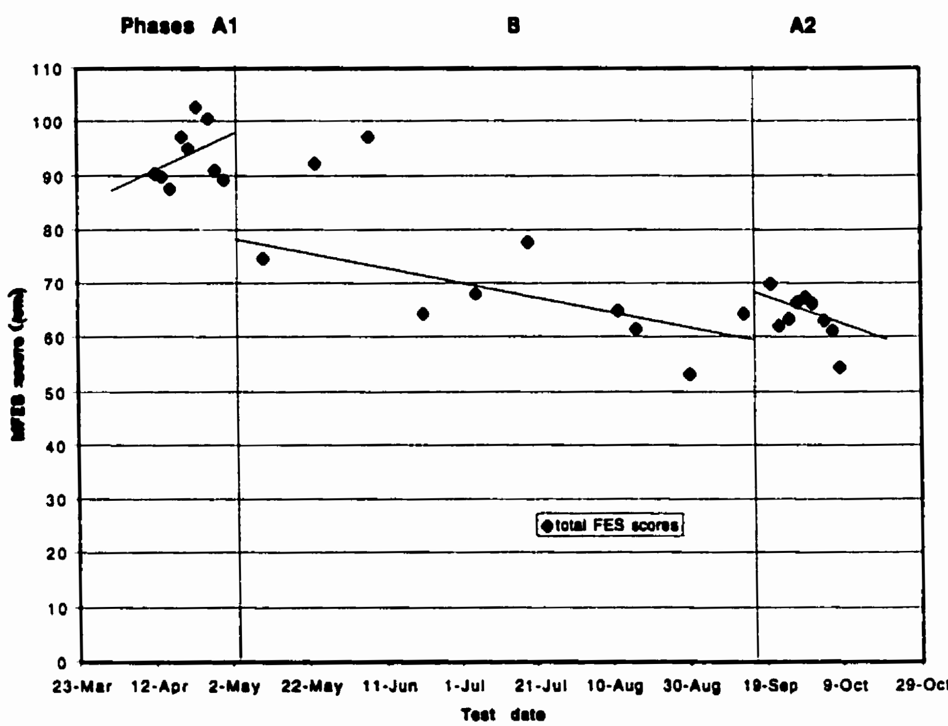


Figure 17. MFES for subject 1. Study phases are delineated with vertical lines.

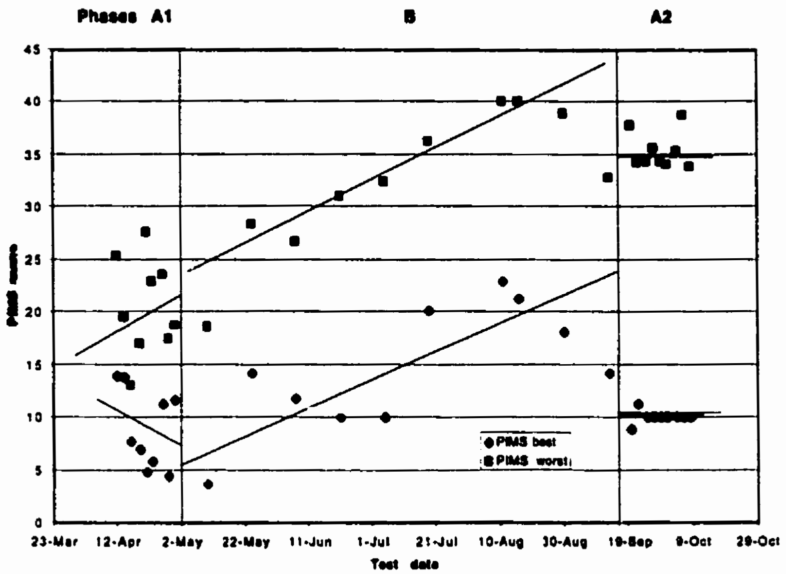


Figure 18. PIMS for all study phases for subject 1. Study phases are delineated with vertical lines.

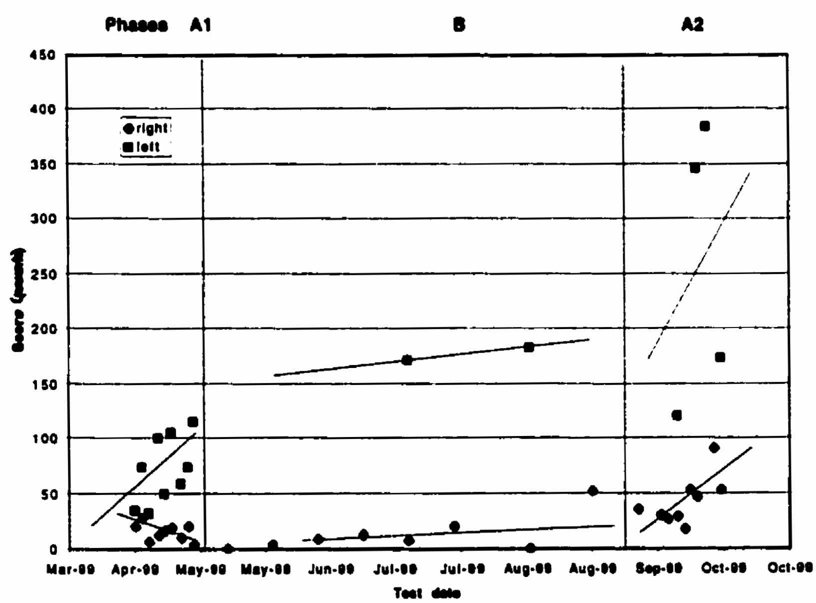


Figure 19. Right and left hand tremor scores for subject 1. The study phases are represented by vertical lines.

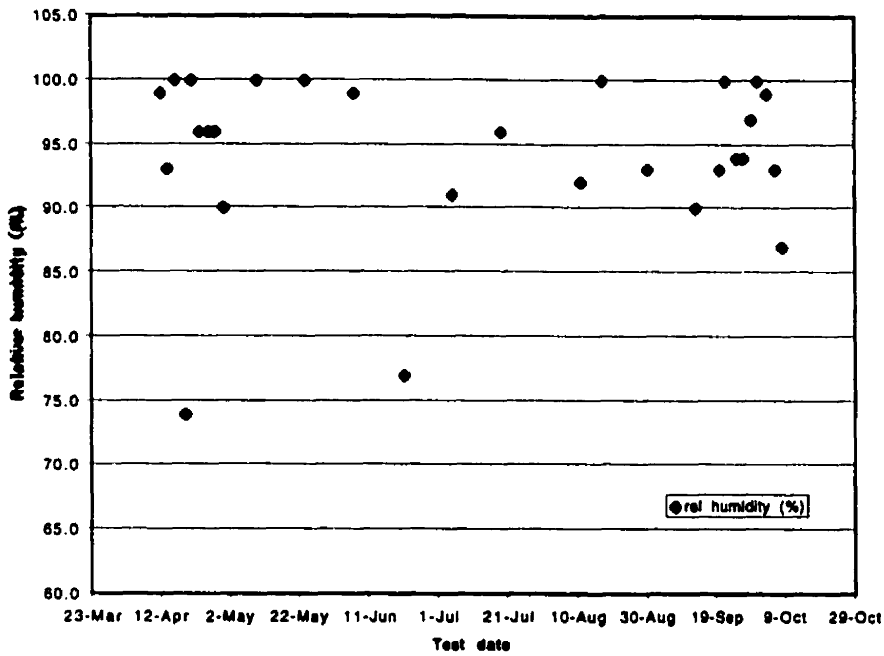


Figure 20. Average relative humidity on test days for subject 1.

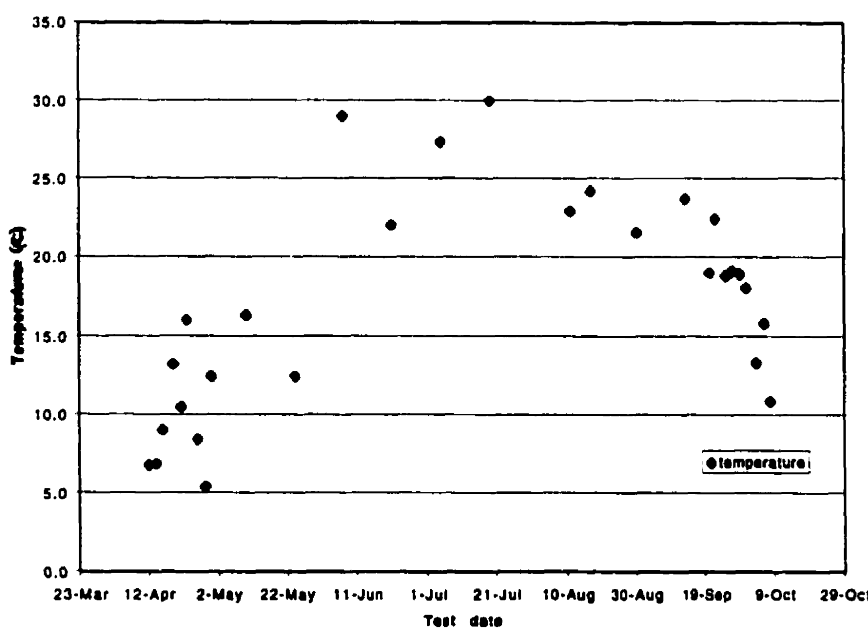


Figure 21. Temperature during test days for subject 1.

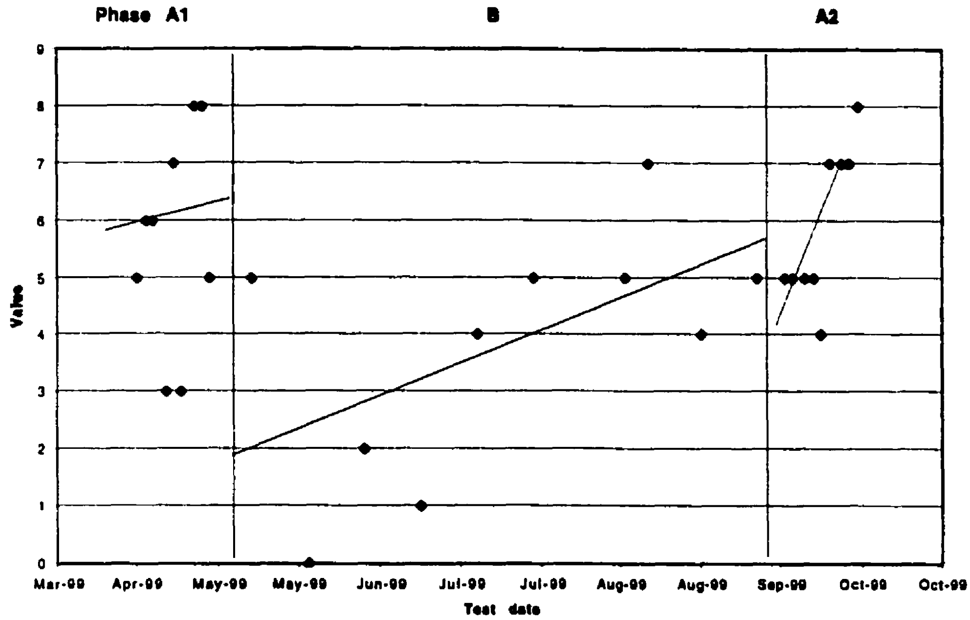


Figure 22. Fatigue scores for subject 1 on test days.

## Statistical Analysis of Trends.

The visual analysis did not agree with the statistical analysis using the C-statistic (Tripodi 1994). The slopes of data in all study phases were not significantly different from zero. See Table 1 in Appendix O.

## Statistical Analysis of Level Change

Level changes between phases were determined by a binomial test for significance and shown in Table 7, page 86 (Tripodi 1994). The MFES scores were most influenced by subjective assessments of confidence levels regarding reaching into closets and using front or rear steps scores.

Table 7. Mean and standard deviation for each outcome measure for each phase for subject one with indication of statistical significant level differences.

| measure | | phase A1 | | phase B | | phase A2 | |
|---|---|---|---|---|---|---|---|
| | | mean | SD | mean | SD | mean | SD |
| **WS** (stats/s) | slow | 0.23 | 0.06 | 0.18 | 0.04 | 0.19 | 0.01 |
| | free | † **0.60** | **0.10** | **0.49** | **0.07** | 0.49 | 0.08 |
| | fast | • 0.96 | 0.11 | **1.04** | **0.09** | **0.94** | **0.07** |
| **RSL** (cm) | slow | 63.38 | 10.63 | 59.87 | 8.14 | 58.63 | 4.13 |
| | free | 109.97 | 8.51 | 100.47 | 7.08 | 96.76 | 10.09 |
| | fast | 134.82 | 9.18 | **139.62** | **7.85** | **125.89** | **6.17** |
| **RST** (sec) | slow | *• **1.72** | **0.16** | **2.11** | **0.19** | **1.72** | **0.09** |
| | free | * **1.17** | **0.11** | **1.29** | **0.11** | 1.17 | 0.09 |
| | fast | 0.89 | 0.06 | 0.84 | 0.04 | 0.89 | 0.04 |
| **Cadence** (steps/min.) | slow | †° **70.61** | **6.91** | **57.55** | **5.53** | **63.34** | **2.81** |
| | free | † **104.09** | **9.96** | **93.92** | 7.26 | 104.09 | 6.56 |
| | fast | 135.66 | 7.90 | 142.46 | 5.80 | 135.66 | 6.55 |
| **SST%** | slow | †° **28.97** | **2.59** | **26.25** | **2.54** | **28.97** | **0.84** |
| | free | 37.68 | 1.67 | 36.62 | 0.93 | 37.68 | 1.11 |
| | fast | * **28.97** | **2.59** | **43.17** | **1.01** | 28.97 | 1.24 |
| **WS Range** (stats/s) | | 0.80 | 0.12 | 0.86 | 0.09 | 0.734 | 0.10 |
| **FR** (cm) | | † **23.60** | **1.77** | **21.40** | **2.82** | 23.60 | 2.06 |
| **MFES** | | 93.85 | 5.38 | 71.95 | 13.87 | 93.85 | 4.45 |
| **Tremor** | right | 15.11 | 7.64 | 20.29 | 17.56 | 15.11 | 23.29 |
| | left | *• **71.22** | **30.51** | **176.50** | **7.78** | 256.00 | 128.72 |
| **PIMS** | best | *• **8.93** | **3.79** | **14.64** | **6.02** | **8.93** | **0.60** |
| | worst | *• **20.60** | **4.60** | **32.52** | **6.77** | **20.60** | **1.76** |

* denotes a significantly greater treatment level change compared to initial baseline (A1)
• denotes a significantly greater treatment level change compared to second baseline (A2)
† denotes a significantly lower treatment level change compared to initial baseline (A1)
° denotes a significantly lower treatment level change compared to second baseline (A2)

## Logbook Results

Subject one completed 20 of the possible 164 days of logbook entries. The lack of compliance with logbook data was determined to be the adverse effects IPD had on this subject's writing capabilities. Dictaphone entries were discussed but abandoned due to the markedly affected speech of subject one due to IPD. Subject one stated that she did not want her spouse to write the log entries because she did not want to overburden him or to disclose her fears regarding IPD disease progression. Subject 1 was in the process of retiring and wrote four comments about employment (see below). She retired during the treatment phase of the study and stated that the reason was she could no longer do her job due to the IPD. The following is an excerpt from her logbook entries regarding employment.

> "Its hard to know if I give up work if I will improve or just get worse.... I mentioned perhaps it was time to go on disability. Dr. X- said it was my decision, but he would support me "all the way" if I decided to apply.... My Parkinson's is deteriorating rapidly since I gave up working. I guess I'm not adapting to "retirement" that well."

Eleven entries were made regarding family and friends. The test log indicated that "family matters & community relations improved since had IPD." The sixteen entries regarding physical issues emphasized safety issues and falls. A sample of the entries regarding safety is presented in the following paragraph.

> "Down I went on the hardwood floor, on the right side of my face. I was all alone & at first couldn't get up. Lay there for several minutes before I could figure out a way to turn myself over & get up.... I missed my footing on the very last step going down into the basement laundry room. I hurt my tailbone but don't think I did any serious damage. Fell again in the bathroom.... I was getting out of the car at S- and got my ankle twisted between the car and the curb, and fell down. Skinned both my knees and hurt my right leg, not to mention my dignity.... When we came out, I stepped off the curb and fell down. B- and S- picked me up. We

> live 5 min. away from S-. When I got out of the car and went down twice.... We have had grab bars installed on either side of the door, because the step up is so steep. I put one foot on the step and reached for the grab bar, lost my balance and fell backwards on the carpet. I wasn't hurt."

The other physical issues mentioned were the IPD signs and symptoms, pain, and medications. The following is a sample of the comments made regarding physical issues.

> "Must check with Dr. X-'s office tomorrow to see if he thinks I'm over medicated.... Went to see Dr. X- for a check up. I gave him a list of all my reactions, side effects, to the drugs. He studied it carefully, then said I was over medicated.... Have to get my medicine adjusted once again. They cause too many side effects."

Subject 1 only made two entries regarding psychological issues of anxiety and emotional reaction to falling.

A total of eight log entries were made regarding the study. The comments stated that the classes were not hard but balancing was difficult. There was no home practice because she felt unsafe without a safety person to provide balance support. The group classes provided the support necessary for safety. Subject one stated that the required study attendance 3 times per week interfered with her social plans, and when working, it was difficult making class for 7 pm. This subject's spouse did not attend classes but her daughter attended when possible. The following is a sample of her logbook entries regarding the study.

> "I enjoy doing it in the group, but doubt I would do it on my own & J- (daughter) seems to have so little free time.... No video today. I find it difficult to stay balanced when I have toe or heel up, and a one leg stance....I was finding it a bit much having to be there at 7 – not getting home from work until 4:30 or 4:45 & having to cook supper, clear the dishes & be ready to go at 6:45 (I am slow at food preparation these days). However, now that I'm home all day, it should be a little easier."

Subject 1 reported 10 falls during duration of study occurring with stairs, getting in or out of a car, or dressing. She reported using video once. The tester logbook entries suggest this subject tended to fall during fast walking trials and adopted a high steppage gait pattern. The tester entries stated "She occasionally has great difficulty generating the fast gait pattern for the entire length of the walkway. Subject one tends to perseverate the high steppage gait pattern once she has reached the end of the walkway."

## Final interview results

In the final interview subject one stated that the benefits she gained from training TCC were that she had "more social contact with other people with Parkinson's" and the "TCC was exercise." The main factors that stopped her from attending classes were "no drive and sickness." The only negative comment made in the final interview was that the classes were often "too hot." Subject one stated that safety was the only issue that stopped her from practicing at home. Her exact comments were: "need somebody to hold me up and somebody to tell me if I was doing it right, I did not have either." When asked if she found the video tape useful she said "not really. Good to see it but it would have meant more if it had been the same instructor that taught us." In response to being asked if the written material was useful she state " no, no one to practice with." When asked what aspects of testing were useful to her she responded that it "showed me what I couldn't do." From the test log many comments were made regarding this subject's apparent frustration with the testing, especially the tremor test. She often froze for long periods of time doing the spirals usually when changing direction. She also created reasons other than the tremor to explain her performance. She learned to cue herself by tapping her other hand if she froze. The following tester log entries support the concept that this subject found the testing emotionally difficult.

> "Subject lost balance 2 x during walk test.... And "hates" to rate "PIMS" (Not used to rating sexuality and laughed )....Stated she did not feel any different but felt her spouse was reacting differently. ....stated frustrated with tremor scale,.... Frequent comments re can't see, can't get hand to go "willing" it to move but it won't.... Suspect subject is creating reasons other than the tremor for her poor performance on test.... Subject froze 3x during tremor task.... Complained of blurring eyes, Tried to stabilized L hand with R during tremor test, required frequent reminders.... Complained of no reading glasses today therefore tremor scale more difficult (is true would be so for both hands not just left).... Used R hand tapping to attempt to cue L hand when freezing. States when freezes sometimes thinks about nothing & sometimes wills movement but nothing happens....complains of freezing with hands not feet.... freezes the same spot on the spirals as S3 had trouble. ? switching difficulty from L to R or R tp L.... Cried because did worse on the Tremor scale. Sees how much worse she is getting.
>
> ...So slow to complete questionnaires.... Subject was late arriving & stated she took meds at 6:45, tested at 7:45. Based on performance I suspect medication time was incorrect, ? trying to please me, make everything OK because embarrassed about forgetting test time.... Fearful of losing voice. Asked to be referred to speech language pathology but Dr. X- doesn't think it will be helpful. States does not want walker – will use husband but grabs his arm and hurts him. Renovated bathroom to be wheelchair accessible, is *constant reminder*. States received disability pension which was *good news*."

When asked what aspects of the testing were negative for her, subject one stated "the circles (tremor test), never really done anything like that since in grade school. Difficult to keep pencil still and keep on track." Other comments made in the final interview were "I didn't have the success I hoped to have to improve my balance" and "Some forms it was hard to put my weight on one leg." This observation was supported by comments in the instructor's log however with cueing and encouragement the instructor stated that subject one was able to adequately weight shift onto her left leg.

**Support person's questionnaire results**

Subject one's daughter attended many TCC classes with her. From the questionnaire provided to the daughter, information was gained regarding her insights and expectations. When asked why she participated, subject one's daughter answered "to provide moral support and assistance (as necessary) to my mother who was participating in the Parkinson's study, both in class and during home practice." When asked about benefits the daughter gained she responded "new method of stretching and movements. Breathing techniques helped physically and mentally. Increased awareness of mother's challenges with movements." The test log also indicated that "daughter appeared upset to see how difficult subject one found the testing sessions." No negative aspects of TCC were identified by subject one's daughter. Other comments included " An interesting class for both Parkinson's and non-affected students – will continue to practice at home!"

**Follow-up**

When contacted, subject one had no further insights or comments regarding the study. She has not attempted TCC since the completion of the study and was currently awaiting a consult with a neurosurgeon.

## Discussion

The lack of significant trends for all measures was possibly due to the variability of motor performance in subject one. The dyskinesias and unpredictable motor performance seen in subject one is common in individuals with IPD with disease durations longer than 5 years (Marsden 1994). The statistical analysis with SSD tends to be fairly broad requiring a large difference with little variability to be determine statistical significance (Tripodi 1994). The use of the average as a comparative measure with C statistic calculation results in extreme values having large influence on results. The use of the median may have been more appropriate for this type of data, especially the ordinal measures.

Also, medication and timing of ingestion is known to affect motor measures (MacKay Lyons 1998). With subject one, many medication changes occurred during the treatment phase of the study beginning week 9. These medication effects were represented in the increased variability in the gait data beginning in week 13. See Figures 10-15, pages 79-81. Information regarding medication changes was ineffectively communicated resulting in delayed testing after medication ingestion. When questioned the subject indicated that she had taken her medications one hour prior to testing. Unfortunately, it was not immediately apparent that the medications did not include her L-dopa medication. The test times were adjusted for the second baseline data.

The anticipated level of training was not achieved with subject one since hands on balance assistance was required to prevent falls and no home practice was performed. The level of assistance required throughout most of the TCC movements may have resulted in less exercise intensity than anticipated. Daily practice is an essential component of TCC training and subject one did not perform any home practice. Subject one's lack of compliance with the daily home exercise regime decreased the likelihood of gaining a treatment effect. Subject one identified home support and safety as factors that interfered with home practice. Providing the video and written material was not sufficient to ensure daily practice with this subject. Support personnel in the form of family, friends and / or care workers would be required to facilitate practice to decrease the risk of falling for subject one. The non compliance with home TCC training may have interfered with the attainment of the automatic level TCC performance, a level necessary to gain the meditative gains associated with improved perceived state of well-being (Brown *et. al.* 1995).

The MMSE identified that subject one had some spatial perception difficulties that may have affected her ability to practice from the videotaped material. Subject one's difficulties with perception were also identified by the instructor in the logbook entries that stated subject one had left / right confusion and an inability to mimic movements. The finding of spatial difficulties in subject one does not agree with previous research and likely reflected a personal characteristic rather than a symptom of IPD (Brown and Marsden 1986).

## Logbook data

The logbook data indicated that subject one was very concerned about her employment and physical safety. There appeared to be a lack of understanding of the medications and physical symptoms associated with IPD in subject one. Also, she indicated that relationships with family and friends had improved since her diagnosis. The participation of subject one's daughter in the TCC class likely improved the daughter's understanding of subject one's physical challenges as well as strengthened their relationship. As the disease progresses, it is likely that support from friends and family will become more important to ensure a good quality of life for subject one. Perhaps better education of spouses and family members is required early in the disease for individuals with IPD to ensure that people with IPD gain the social support necessary to maintain active within the community.

## Gait

Subject one's final interview overall subjective assessment of her motor performance agreed with the objective data. However, the instructor log indicated that with adequate verbal cueing appropriate weight-shift onto the more affected leg was possible. This finding agreed with previous research that indicated that verbal or visual cueing assisted in improving SL and improvements were maintained for at least one day (Morris *et. al.* 1996a and 1996 b). However, Morris *et. al.* (1996a) also noted that when the subjects were not being monitored the performance deteriorated to previous levels. It was hoped that 4 months of training would be sufficient to allow learning to occur. This did not appear to be the case with subject one. Morris *et. al.* (1996a) showed that learning occurs slower in people with IPD so perhaps the time period was not sufficient to see any difference in a subject who has had IPD for more than ten years. Since subject one was in stage III and individuals with advanced disease stages show greater variability and require longer to learn movements, more time may have been required to see the training effects in this subject.

Careful interpretation must be made when determining clinical significance of statistically different levels between phases. In the walkway data, the significantly greater initial baseline measures as shown in Table 7 (page 86) for free WS, free and slow cadence, slow and fast SST do not likely reflect greater initial baseline levels. Although the initial baseline was hoped to represent the disease variability and trend, the trends indicate that initial data was likely influenced due to anticipation over study participation. For example, the free WS initial baseline extrapolation of the trend would result in subject one not being able to walk within one month. See Figure 10, page 79.

This was not likely the case. The short duration of the initial baseline phases precludes direct comparison. If the data from the first week, the data most likely influenced by excitement over study participation, were excluded, statistical difference in level would not have been achieved. The same reasoning can be applied to the initial baseline scores of slow and free RST and FR.

There was a significantly greater treatment level for fast WS, fast RSL, and slow RST compared to the second baseline as shown in Table 7 (page 86). Due to direction of the non-significant trends, the greater treatment levels likely directly reflect effects of intervention. See Figures 10 – 12, pages 79-80. The longer RST was did not demonstrate the expected inverse relationship between the WS and ST and has been reported by previous authors (MacKay-Lyons 1998, Morris *et. al.* 1994a). Since slow WS and SL were not significantly different compared to the treatment phase, the SL appeared to be the largest determinant of WS in this subject and adjustments in ST are used to compensate for decreases in SL (Morris *et. al.* 1994a, MacKay Lyons 1998). The adjustment in the ST was reflected in the significantly greater levels of second baseline data for slow cadence and slow SST. See table 7, page 86. It was possible that TCC training had a negative influence over the ST in the slower speeds. Slower WS after TCC training have been reported by previous research but details regarding the walking speed components were not presented (Wolf *et. al.* 1996). It should be kept in mind that subject one walked very slowly and the reliability of the slow WS is questionable (Hausdorff *et. al.* 1998, Weller *et. al.* 1993, Blin *et. al.* 1991, Viereggi *et. al.* 1997, Mongomery and Reynold 1990).

The non-significant trend in the treatment phase for fast WS, as illustrated in Figure 10 (page 79), was positive until subject one had medication changes starting on week 9. These medication changes appeared to decrease the fast WS. Even with the medication changes there was determination of significant level changes between the treatment and second baseline data. This suggested that TCC training assisted in maintenance of fast WS for subject one. An alternative explanation for the significant difference was that the medication had become unreliable by the second baseline. The physician had been adjusting the medication levels since week 9 in an effort to regulate the unwanted side effects.

Subject one's fastest walking speed approximated normal free walking speeds (Grieve and Gear 1966). The data indicated that the fast WS was maintained through a consistent SL until the medication changes adversely affected motor performance. The ST data showed more variability. This would suggest that at the fastest WS, SL likely played a larger role in limiting WS than ST. The reported behavior of subject one's adoption of a high steppage gait and her inability to maintain that walking pattern the length of the walkway would suggest that her adaptive potential was exceeded when attempting fast WS. The perseveration of the steppage pattern after completion of the walk suggested that once a motor pattern was initiated, subject one had difficulty altering the program.

Subject one's average slowest WS per phase was extremely slow, 0.2 stat/s or less. The slow WS in the treatment phase was adjusted by increasing the SL and SST and not altering ST. This suggested that subject one chose not to adjust ST at the slow speed and possibly used ST as an indicator (or cue) for the slow WS. The improvements in SST and SL for the slow WS suggested an improvement in dynamic balance.

Subject one's average free WS per phase (.49-.6 stat/s) was well below the values seen in healthy individuals (between 0.8 and 1 stat/s, Grieve and Gear 1966). The free WS was comparable to the slowest speed of an individual unaffected by IPD (0.4 stats/s). Free WS are reported to be the most reliable (Hausdorff *et. al.* 1998, Weller *et. al.* 1993, Blin *et. al.* 1991, Viereggi *et. al.* 1997, Montgomery and Reynolds 1990). Subject one reduced her SL with little change in the ST and SST resulting in decreased WS during the treatment phase.

The fast SST (28.97% and 28.97%) during the initial and final baselines respectively were much less than the expected value ( 40%, Greive and Gear 1966). See Table 7, page 86. During the treatment phase subject one's SST (43.17%) approximated normal values that indicated TCC training improved duration of time spent in single support and possibly reflected an improvement in dynamic balance.

Cadence was apparently not adjusted to increase WS, see Figure 14 on page 81, as was found by Morris *et. al.* (1996a). Marsden (1994) also reported increased cadence as a compensatory mechanism for decreased SL. The lack of increased cadence, as shown in Table 7 (page86), suggested that although ST decreased over the duration of the study, SL increased adequately to compensate.

The range of WS for subject one was the greatest during the treatment phase which indicated that TCC training may allowed this subject more flexibility in her gait performance. Even though the range of WS was similar to the suggested normal values of 0.8 stats/s, this range was generated mainly by making the slowest WS even slower in an effort to compensate for lack of speed in the fast WS. See Table 7 (page 86) and Figures 10-15, pages 79-81.

Since all the motor measures were assessed in what was considered to be the "on" phase, the decreased free gait speed in the treatment phase did not correspond with the "on" UPDRS scores. The gait variables agreed with the subjective log entries that indicated worsening of the disease and the impact of life changes. This suggested that the gait scores may be a more sensitive measure than the UPDRS when considering functional changes in people with IPD.

It was likely that retirement negatively influenced subject one's physical activity outside the TCC class. Subject one's previous employment involved a lot of walking and social interaction. Removal of these influences combined with the medication adjustments and progression of the disease may have resulted in the worsening of the WS values.

## Balance

The average FR distance per phase ranged from 21-23 cm. Although the initial baseline FR scores were statistically greater than the treatment phase, as shown in Table 7 on page 86, this was possibly due to anticipation over study participation and did not likely reflect a deterioration of performance. There was no indication that FR was positively influenced by TCC training for subject one. The non-significant slopes of the FR scores were negative for all phases indicated a worsening of the disease and the lack of evidence that TCC training assisted with anterior (static) balance capabilities. See Figure 16 (page 82). Wolf *et. al.* (1997) found that the anterior – posterior sway measures worsened with TCC training but functional balance, as measured by reduction in number of falls, improved. Wolf *et. al.* (1997) found that TCC preferentially affected the lateral postural capabilities. Perhaps FR was unable to detect improvements in mediolateral weight shift capabilities since anterior perturbation was the major component of FR. Lateral FR might be assessed in a similar manner to anterior-posterior reach by having the subject stand with their back to the meter stick and would provide more information about the balance deficits seen in IPD.

Functional Reach has been shown by Duncan *et. al.* 1992 to be valid for predicting falls for subjects that included 13% people with IPD. In contrast to Duncan *et. al.* 1992, subject one's results indicated that the FR measure did not predict the appropriate number of falls. Duncan *et. al.* 1992 suggested that people who had a FR between 16 and 22 cm had an odds ratio (OR) of 2 for two falls within the next year. For FR distances greater than 22 cm the OR for one or two falls was 1. According to the log-book results, subject 1 experienced 10 or more falls. Since subject one completed only 12% of the possible log entries, more falls possibly occurred. In fact the fast WS data collection was not attempted on several dates due to safety concerns. No mention was made by Duncan *et. al.* (1992) studies of the medication or stage of the people with IPD. Perhaps the variable nature of the drug-induced dyskinesias increased the risk of falls in individuals with IPD. Subject one suffered from severe dyskinesias as a result of medication effects that might have caused destabilizing effects on balance. The disease duration for subject one may also have affected FR scores as previously reported by Grill (1999) in a three-year study that showed FR decreased as IPD progressed. The predictive value of the FR measure for individuals with IPD needs to be investigated to identify stages and medication influences over the FR scores. Functional reach is used in clinics to monitor people with IPD, and effects of medications on this measure need closer study.

## Fear of Falling

Visual analysis indicated that the MFES, see Figure 17 (page 82), showed non-significant negative trends towards less confidence in ability to perform usual daily activities without falling although no difference in level was noted, see Table 7 on page 86. Conclusions based on the MFES results are difficult. It may be said that the TCC training had a slight, or no negative, influence on subject one's perception of her ability to perform tasks without falls. The data might also reflect the adjustment period for the changes in medication. The non-significant trend toward less confidence, in subject one's MFES data, was reflected by the more objective FR data. Fear of falling, number of falls, and postural stability measures do not always show similar results (Wolf *et. al.* 1996, Providence *et. al.* 1995). Subject one's data did not agree with Wolf *et. al.* 1996 and Providence *et. al.* 1995 who showed reductions in fear of falling for healthy and frail elderly with TCC training. It is likely that TCC training was much more challenging for subjects with IPD since axial postural adjustments are poorly managed with medications (Steiger *et. al.* 1996). Also, TCC training requires frequent sustained single leg stance with self-perturbation. Such activities may not occur frequently in subject one's normal daily activities. Perhaps TCC training highlighted subject one's balance deficits and resulted in poorer confidence in balance abilities. This conclusion was supported by log entries indicating the testing and training "let her know how bad her disease was."

## Quality of Life

The PIMS was designed to reflect the subjective analysis of the degree IPD impacts a person's life. The non-significant trends, see appendix O, and consistent slope in the worst PIMS scores between the initial baseline and treatment phases, see Figure 18 (page 83), indicated that TCC had little effect on the worst PIMS score. The Worst score likely reflected the disease progression.

The Best score showed an insignificant change in the direction of the slope toward a worse quality of life as shown in Figure 18 (page 83). The scores indicated that during the treatment phase subject one felt that IPD adversely affected her life. The treatment phase showed significantly higher Best PIMS scores than either baseline phase, as shown in Table 7 (page 86), that indicated the challenging nature of the TCC movements or some other factor such as the record-breaking heat-wave experienced during the treatment phase. Unlike previous studies (Wolf *et. al.* 1996 and 1997, Providence *et. al.* 1995) TCC training did not improve perceived well being or quality of life. Subjects in previous studies usually met 2 times per week and average home practice was 4 times per week unlike subject one who only participated in biweekly TCC classes which resulted in less balance training intensity. Also, previous studies only included a limited number (usually 10) modified forms. This study included TCC as it was available within the community covering 42 forms. This meant that throughout the duration of the study subjects were learning new movements. It also meant that if classes were missed it was more difficult to learn the missed movements. The video and written material provided to assist with home practice was not effective with subject one. It is likely that musical cueing, repetition of a few representative forms, and less frequent measurement would increase the well being by removing the mental stresses of learning new movements during each class and inhibit remembrance of test scores. Other confounding factors may have been the record breaking heat-wave and humidity experienced over the treatment phase, changes in employment, frequency of measurements, and lack of daily practice.

## Tremor

There was a non-significant trend toward worsening of the tremor scores over subsequent test phases that possibly reflected the disease progression, see Figure 19 (page 83) and appendix O. The non-significant positive trend was more prominent for the left than right hand. The dominant hand has been shown through pilot work (shown in appendix A) to correlate better with the overall Fahn tremor score. Subject one was right handed. The tremor score as measured did not differentiate between tremor or dyskinesias. These data do not agree with the results of Reuter *et. al.* (1999) that indicated reduced UPDRS dyskinesia sub-scores with exercise. Also the variability in the scores in the second baseline phase unduly influenced the determination of the non-significant level difference between the two phases, even though the visual analysis showed worsening of the tremor. Several tests were discarded because they were not interpretable. Subject one tended to freeze at points where the spirals changed direction, a factor that suggested difficulties with switching abilities as have been reported in previous research (Benecke *et. al.* 1987a and 1987b, Kritikos *et. al.* 1995). The difficulty with tremor assessment experienced by other investigators was reflected in the questionable representational benefit of this data. Tai Chi Chuan training did not appear to have any effect on the tremor scores for subject one.

## General Comments

Overall, TCC training did not appear to positively influence any measured parameter other than the fast WS and range of WS. The slight improvements in the dynamic balance measures were not reflected in the static balance measures (FR) or subjective measures. The presence of dyskinesias possibly adversely affected the measures of motor performance. The frequent testing with subject one adversely affected this subject's well-being by identifying the rate of decline and deficiencies in her motor performance. The duration of disease in subject one may have precluded adequate learning of new TCC movements. Since new movements were taught each class, the meditative component of TCC training was likely not achieved lessening the likelihood of subjective improvements in quality of life. Education of the family as well as subject one may help improve the social support network and improve the quality of life for subject one.

# CHAPTER 5

## RESULTS AND DISCUSSION FOR SUBJECT TWO

### Results

Subject 2 attended 19 of 34 TCC classes (56%) and six of the scheduled 40 classes were cancelled due to poor attendance or high humidity. Subject two required minimal hands-on assistance throughout the study for balance support and frequent verbal and physical cueing was required to ensure correct body alignment, especially with backward walking movements. No change was noted in the BDI scores between pre and post treatment phases. There were changes in the UPDRS scores. See Table 8. There was a worsening of the subjective, motor "on", side effects, SE "off", and "off" H&Y scores (8%, 10%, 17%, 20%, 1 stage respectively). The "off" motor, dyskinesia, and "on" SE scores all improved (4%, 25%, and 10% respectively). The "on" H&Y remained unchanged.

Table 8. Subject 2 comparison of pre and post measures

| BDI score | | UPDRS | | Medications changes | | |
|---|---|---|---|---|---|---|
| Pre | Post | Pre | Post | | | |
| 9 | 9 | **Subj:** 27 | **Subj:** 36 | June 6 | Requip | ↑ 2 mg tid, |
| | | **Motor:** | **Motor:** | Aug 13 | Sinimet CR™ | ↑ 1tab 100/25 qid |
| | | On:12 | On: 23 | | | |
| | | Off:26 | Off: 22 | | | |
| | | **Sdeffect:**9 | **Sdeffect:** 13 | | | |
| | | **Dysk:**16 | **Dysk:**10 | | | |
| | | **SE(ADL)** | **SE(ADL)** | | | |
| | | On:70% | On:80% | | | |
| | | Off:70% | Off:50% | | | |
| | | **H&Y** | **H&Y** | | | |
| | | On: 3 | On: 3 | | | |
| | | Off: 3 | Off: 4 | | | |

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## Monitored Extraneous Factors

Medication changes, illness, stress, and temperature could all affect motor performance. There were two medication changes, shown in Table 8 (page 104), for subject two during this study. Occasionally subject two would delay or take medications early based on her motor function. Subject two reported being sick 5 times during the test days, three in phase A1 (Apr. 23, 25, and May 2) and two in the treatment phase (May 14, June 11). Increased stress was reported twice in phase A1 (Apr. 16,18) and once in the treatment phase (May 23). Subject two's fatigue level varied greatly during the study with the most consistent levels occurring during the second baseline phase. See Figure 35 (page 112). The relative humidity was 90% or more for 25 of the 28 testing days. From June to September the temperature was greater than 20 °C during 8 of the 10 treatment phase test days. See figures 33 and 34 shown on page 111.

## Analysis

### Visual analysis

Visual analysis of the data for subject 2 using the split middle technique are shown in Figures 23-35 (pages 106-112). No trends were indicated in phase A1 for free SL and ST; phase B all three WS, fast ST, free and slow SST, free and slow SL, tremor, Worst PIMS; phase A2 slow SST, PIMS, and FR.

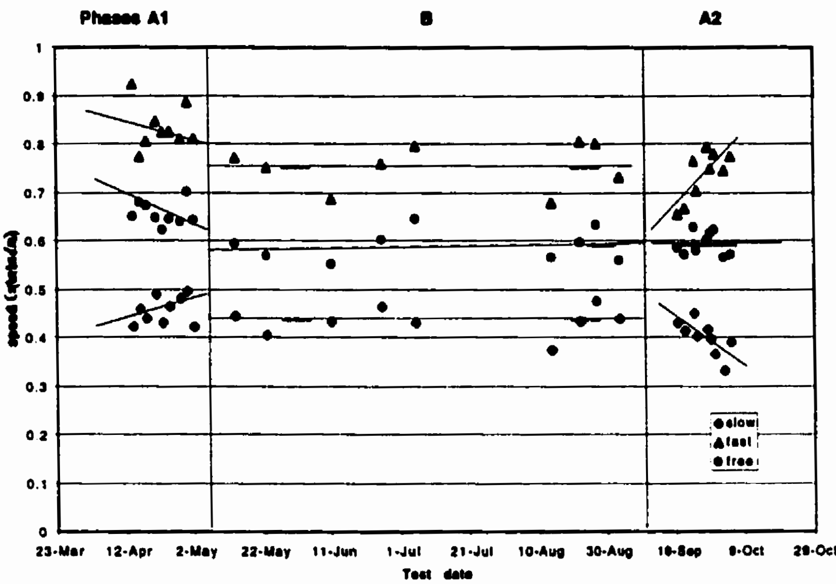



Figure 23. Walking speeds for subject two. Phases are delineated with vertical lines.

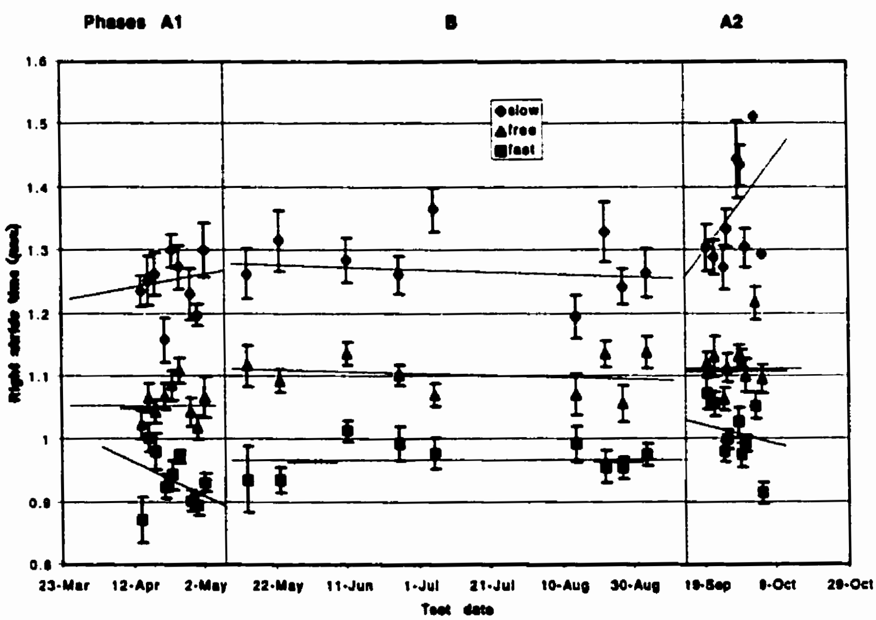



Figure24 . Right stride length for subject two. The study phases are delineated with vertical lines. The error bars indicate one standard deviation.

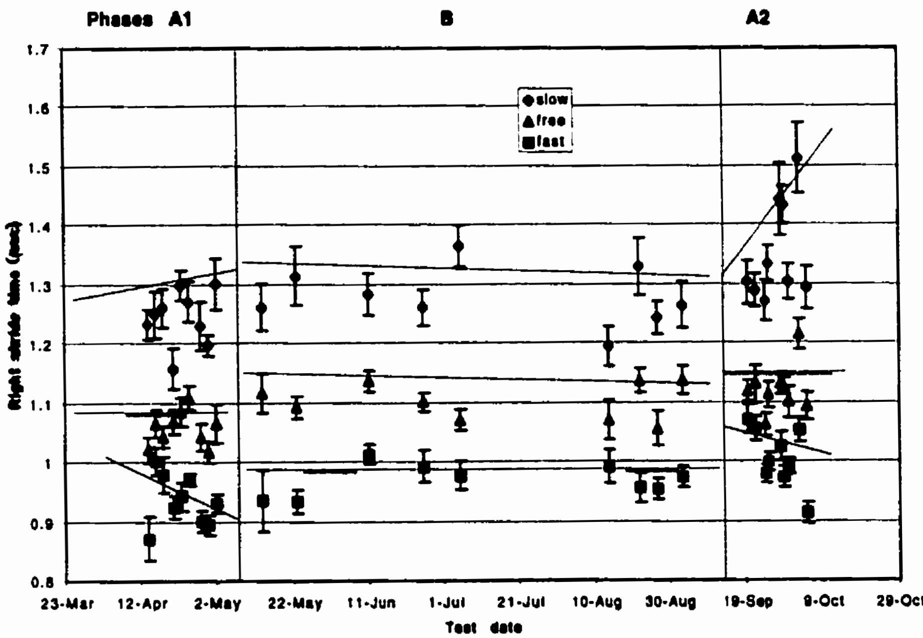



Figure 25. Stride time for subject two. Study phases are delineated with vertical lines. The error bars represent one standard deviation.

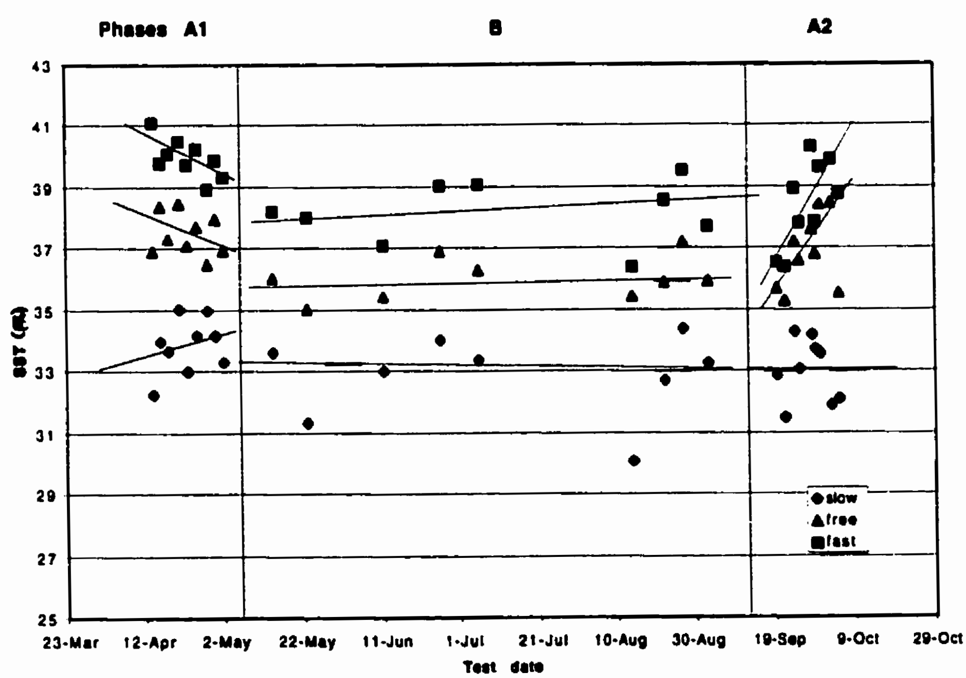



Figure 26. Single support time expressed as a percentage of total stride. The study phases are delineated with vertical lines.

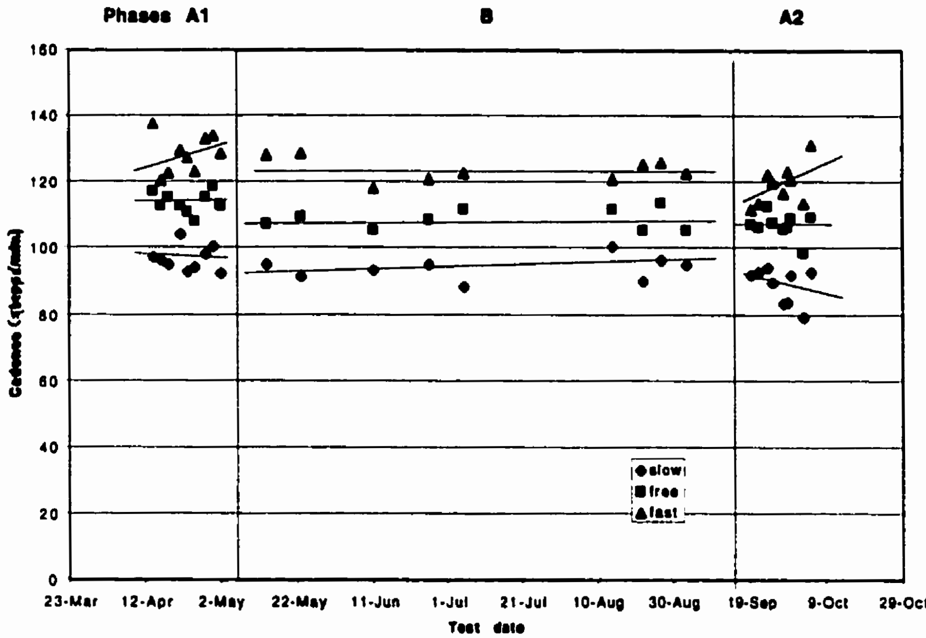



Figure 27. Cadence for subject two. The study phases are delineated with vertical lines.

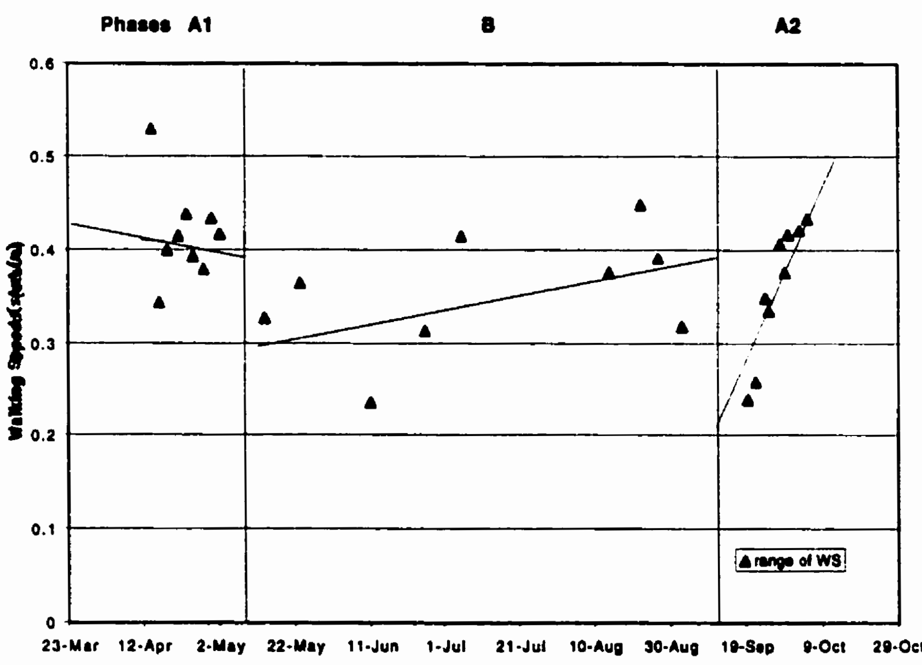



Figure 28. The range of WS for subject 2. The study phases are delineated by vertical lines.

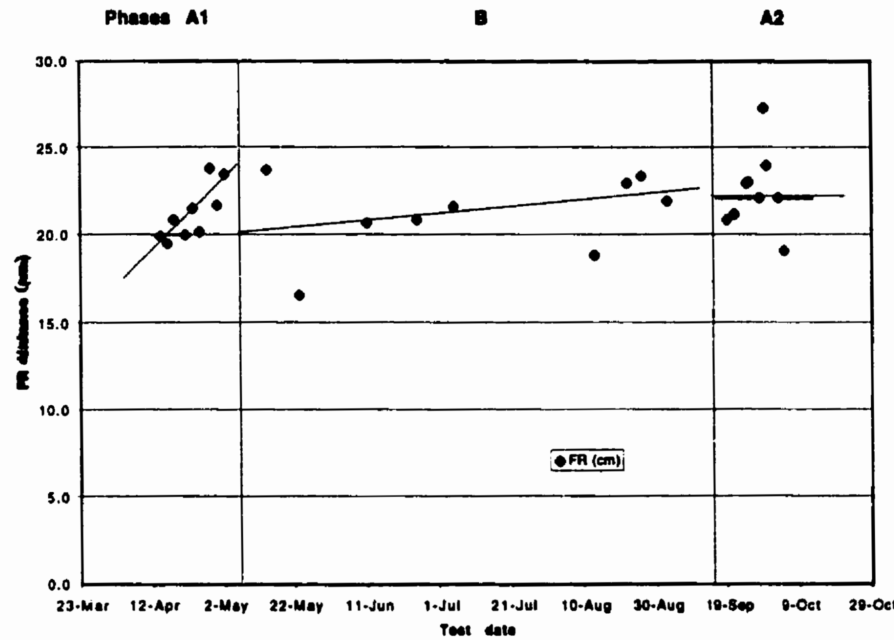
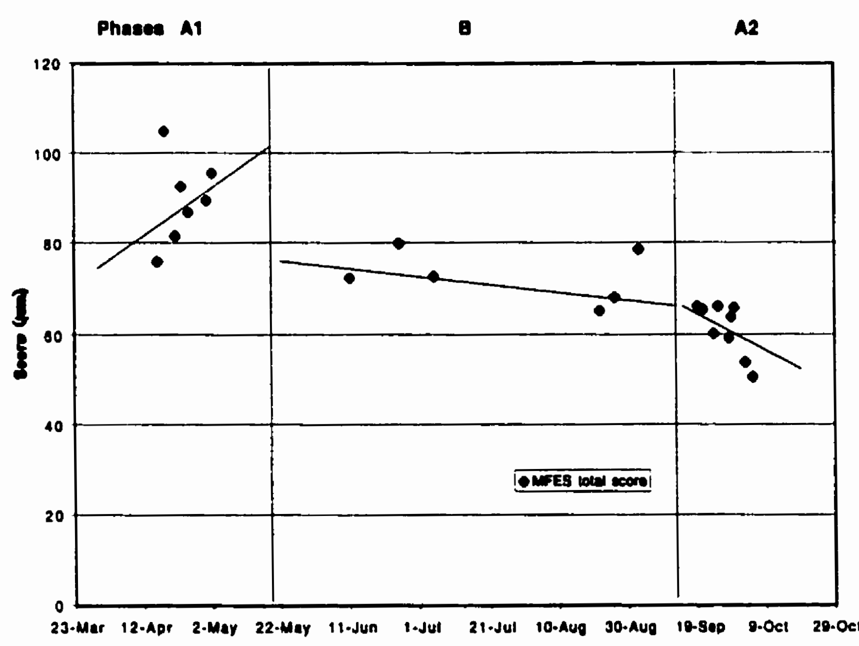



Figure 29. FR distances for subject 2. The study phases are delineated with vertical lines.




Figures 30 . MFES for subject 2. The study phases are delineated with vertical lines.

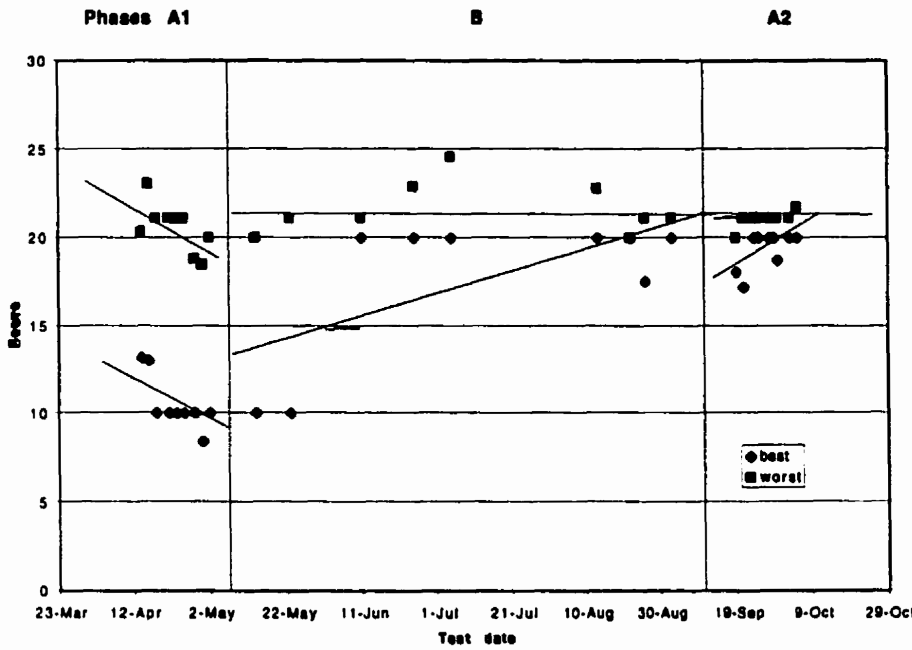



Figure 31. PIMS for subject 2. The study phases are delineated with vertical lines.

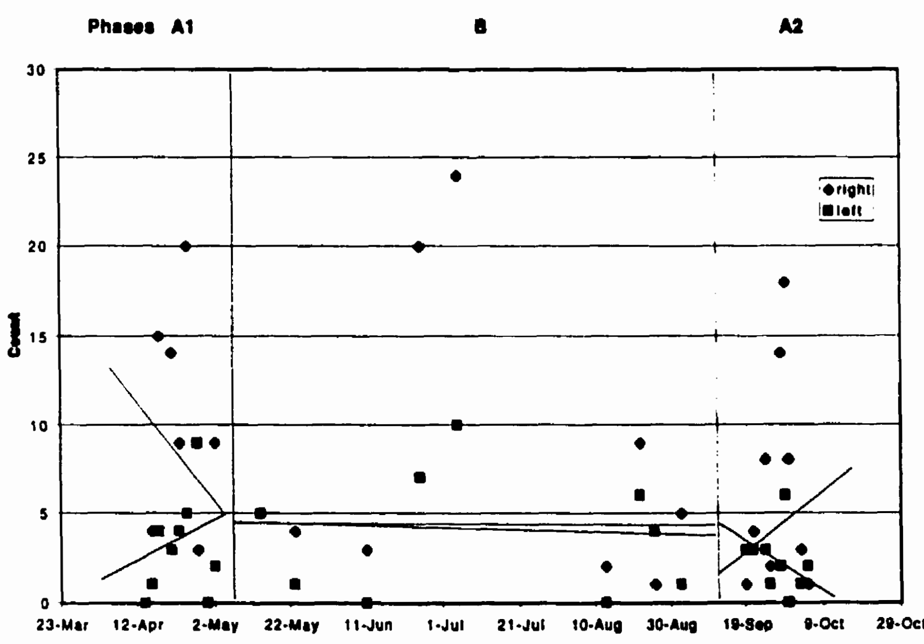



Figure 32. Tremor scores for subject 2. The study phases are delineated by vertical lines.

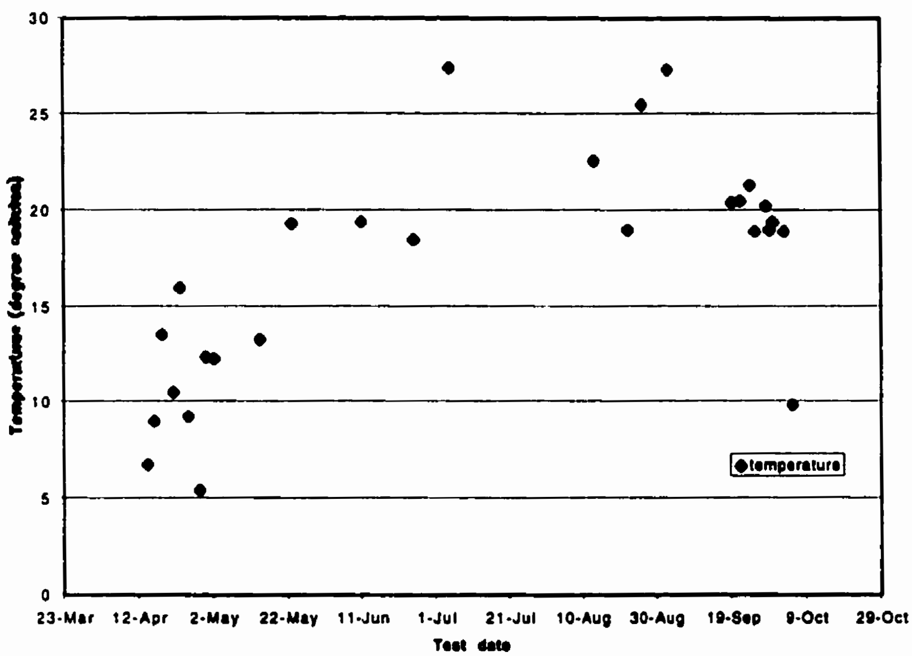



Figure 33. Temperature on testing days for subject 2.

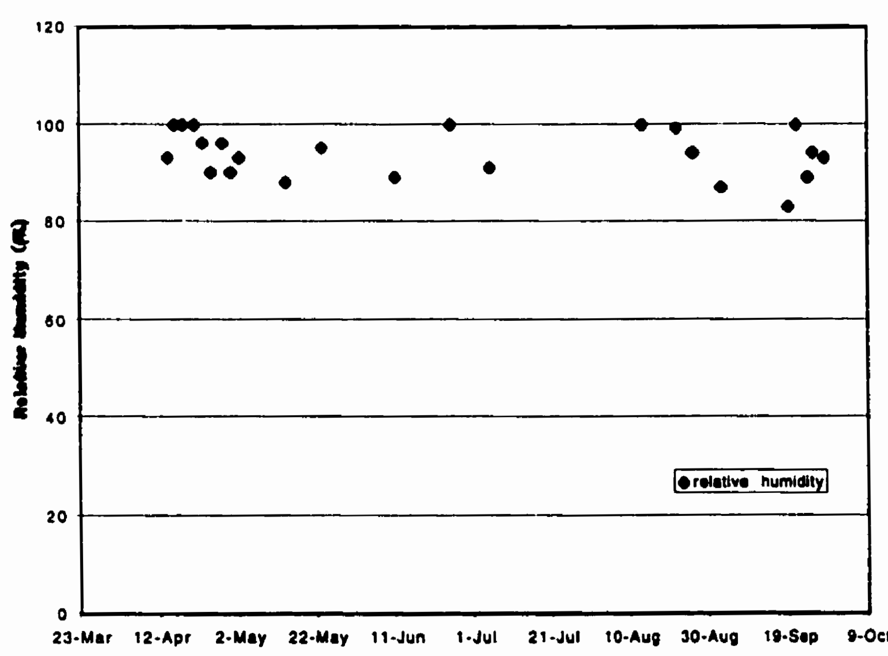



Figure 34. Relative humidity on testing days for subject 2.

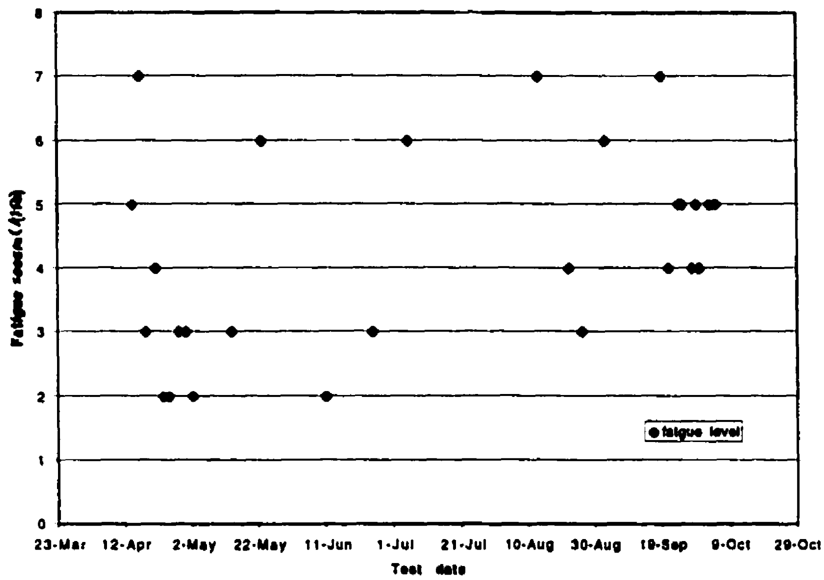



Figure 35. Fatigue ratings for subject two. Note the high degree of variability.

**Statistical analysis of trends.**

The visual analysis did not agree with the statistical analysis using the C-statistic. The slopes of all data in all phases were not significantly different from zero. See Table 2 in Appendix O.

**Statistical analysis of level change**

Level changes between phases were determined by a binomial test for significance and shown in Table 9, page113 (Tripodi 1994). The components of the MFES score in which this subject was least confident that she could perform without falling, were the "reaching in to cabinets or closets", "answering the phone", and "using public transit." The component of the PIMS scored highest was the "worst" rating of community relationships. Safety, sexuality, self-positive and self-negative scores occasionally were rated higher than the other factors. At the initial PIMS assessment subject two reported to the tester that she felt the same toward her sexuality but that her spouse acted differently toward her.

Table 9. Mean and standard deviation of outcome measures with indication of significant level changes per phase for subject two.

| measure | | phase A1 | | phase B | | phase A2 | |
|---|---|---|---|---|---|---|---|
| | | mean | SD | mean | SD | mean | SD |
| **WS** (stats/s) | slow | • 0.46 | 0.03 | **0.43** | **0.03** | **0.40** | **0.04** |
| | free | † **0.66** | **0.02** | **0.59** | **0.03** | 0.59 | 0.02 |
| | fast | † **0.83** | **0.05** | **0.75** | **0.05** | 0.74 | 0.05 |
| **RSL** (cm) | slow | 88.61 | 3.73 | 86.61 | 6.71 | 84.43 | 6.27 |
| | free | † **108.22** | **3.41** | **101.63** | **4.49** | 103.82 | 3.60 |
| | fast | † **121.62** | **3.72** | **114.21** | **5.89** | 115.50 | 6.62 |
| **RST** (sec) | slow | ° 1.25 | 0.05 | **1.28** | **0.05** | **1.35** | **0.09** |
| | free | * **1.06** | **0.03** | **1.10** | **0.03** | 1.12 | 0.04 |
| | fast | * **0.94** | **0.04** | **0.97** | **0.03** | 1.01 | 0.05 |
| **Cadence** (steps/min) | slow | †• **96.9** | **3.79** | **94.02** | **3.65** | **88.93** | **5.42** |
| | free | † **113.84** | **3.28** | **109.00** | **3.08** | 107.22 | 3.84 |
| | fast | 128.67 | 5.80 | 123.77 | 3.46 | 119.37 | 6.05 |
| **SST%** | slow | 33.85 | 0.91 | 32.87 | 1.36 | 33.02 | 1.02 |
| | free | † **37.50** | **0.69** | **36.03** | **0.71** | 36.85 | 1.20 |
| | fast | † **39.98** | **0.64** | **38.21** | **1.01** | 38.49 | 1.41 |
| **Range of WS** (stats/s) | | 0.42 | 0.05 | 0.35 | 0.06 | 0.36 | 0.07 |
| **FR** (cm) | | 21.24 | 1.56 | 21.19 | 2.32 | 21.24 | 1.56 |
| **MFES** | | †• **91.34** | **11.35** | **72.92** | **5.81** | **61.23** | **5.74** |
| **Tremor** | right | 8.22 | 7.07 | 8.11 | 8.25 | 5.11 | 6.07 |
| | left | • 8.22 | 7.07 | **8.11** | **8.25** | **2.33** | **1.73** |
| **PIMS** | best | 10.51 | 1.56 | 17.50 | 4.33 | 19.32 | 1.08 |
| | worst | 20.54 | 1.38 | 21.63 | 1.51 | 21.04 | 0.44 |

* denotes a significantly greater treatment level change compared to initial baseline (A1)
• denotes a significantly greater treatment level change compared to second baseline (A2)
† denotes a significantly lower treatment level change compared to initial baseline (A1)
° denotes a significantly lower treatment level change compared to second baseline (A2)

## Log book results

Subject 2 completed 150 of possible 164 entries. The most frequent comment written in the logbook related to the physical symptoms of IPD. The frequency of physical comments were in the following descending order: safety, fatigue, sleep, ADL, medications, gastrointestinal, pain, physician comments, menstruation effects on physical abilities, and illness. The comments about the medications indicate that subject 2 self-adjusts her medication as she deems fit. The following is a sample of her logbook entries regarding her physical issues.

> "Energy level nil. Can't get dusting going or dishes… .No falls but plenty of near falls catching myself on doors, walls, floors, etc….Fell in supermarket-caught myself on counter….Freezing at mall….Falling, falling, falling all day….Very tired – lots of dyskinesias which turned into dystonias. Painful in legs from knees to toes, could not find any way to rest so lay on floor with feet on sofa,…When I came home I was carrying a package upstairs and must have lost balance. I grabbed the top of the railing at the top of the stairs & kept falling to the left – still trying to steady myself but went on knees to carpet. Shaken up – maybe a few bruises….Very slow and tired. Can't seem to do anything. Warm and sweaty after any exertion. Can't even lift legs…."

> "took myself off requip 2 mg & started 1mg, Don't know what else to do….took myself off 2 mg Requip and started 1 mg 4x/day…..Took 1/2 tab Sinimet before going to help me get through (this 1/2 tab was part of my next dose). It helped some…"Took 1/2 Sinimet from 9 pm dose. Helped a little."

Comments about psychological issues occurred 43 times while comments about the weather occurred 17 times. The comments regarding mood were mostly negative, however, when the weather was good and medications working as intended the comments tended to be more positive. A sample of subject two's logbook entries about psychological issues are shown in the excerpt below.

> "terrible on nerves….L- (husband) walked me down the pew due to freezing, scary….Shaken up…..I'm afraid I am going to hurt myself….Horrible….Some

> stress and strain on weekend but OK now....Fell to the ground but caught myself by touching pavement – embarrassed....Hard on nerves.... Very agitated.....Very agitated and feeling blue.....Feeling very helpless....Getting upset with meds not giving me much reprieve...Trying to be cheerful but getting harder to do...Wish I had energy to do things I want to do... My mind seems to be going around and around...:"

> "feeling good today...Great day, feeling better....Went to supermarket and actually walked around by myself and helped Mom with groceries. Great feeling to be able to do that."

Educational comments only occurred twice. Social comments occurred 91 times which indicated the importance of friends and family in this subject's life. Comments related to the study participation occurred 49 times.

Subject 2 reported that transportation was the major factor that limited attendance. The instructor log indicated that subject 2 had difficulty and required assistant at all times to prevent falls. Subject 2 also stated disappointment that there were no specific hand warm-ups. One fall was reported in phase A1, more than 70 falls occurred in the treatment phase, and no falls were reported in the A2 phase. Subject two reported only 45 minutes of home practice.

**Final interview**

In the final interview subject two indicated that benefits gained by doing TCC were "I don't think it helped my balance a great deal, but it helped my flexibility." "Transportation, heat & humidity (which made me tired)" were identified as the main factors that limited class attendance. No negative aspects were identified. When asked what issues stopped her from practicing at home, subject two stated, "nothing particular. It was easier in a group." The videotape was not useful but the written material was. Beneficial testing effects were identified by subject two as "the walking – I now know I can walk if there is nothing in my way." Negative testing effects included "doing the tremor scale. Tremor changes all the time and not accurate." Other general comments included "I enjoyed out talks about Parkinson's and your helpful information and your genuine interest."

## Support person Questionnaire

Subject two's husband stated that he only participated "to assist" his wife." He stated that he benefited by "better balance, good exercise, and gained new friends." No negative factors were identified.

## Follow-up

At the one month follow up subject two stated that she had more energy the next day when doing TCC class than she was experiencing now even though she complained about being fatigued during the study.

## Discussion

As was previously stated, subject two's data was highly variable reflecting the variable motor performance which occurs with medication effects and increased disease duration. The data variability made determination of statistical significance less likely. Since SSD have serial dependent data, the analysis required large differences with small degree of variability to obtain statistical significance.

The medication changes, which are known to affect motor performance, during the treatment phase were well represented in the drastic increase in the best PIMS scores, after week 10, reflecting a worsening of perceived well-being.

The effects of sick days, stress and fatigue were noticeable in the measures tested. However the effects were not consistent. A combination of factors was necessary for the scores to reflect the change of state. The exact impact of these factors will be specifically discussed in respect to specific outcome measures in subsequent sections.

**Logbook**

Subject two completed 91% of possible logbook entries with safety and fatigue being the most frequent entries. Fear of falling, number of falls and postural stability are not necessarily correlated (Wolf *et. al.* 1996, Providence *et. al.* 1995). This may be due to the reduction in activities that might increase the risk of falls in individuals who are afraid of falling. Also, postural stability measures often do not accurately reflect activities that result in falls (Duncan *et. al.* 1992).

The intensity of TCC training for subject two was less than expected due to hands-on balance support provided by the safety volunteer and non-compliance with daily home training. The balance support was deemed necessary to reduce the risk of falls in this subject. For future TCC classes, a chair might be a better alternative that would provide support but promote more independent balance. Subject two identified home support and safety as factors that interfered with home practice. The postural instability of subject two increased concerns over safety and fear of falling and was partially responsible for non-compliance with home exercises. Although her husband also attended TCC class, he and subject two could not perform home practice at the same time. Often subject two would watch her husband performing the TCC movements which may have assisted with retention of the sequence. The video and written material was not sufficient to ensure daily practice with this subject. The TCC forms would have to be adapted to allow subject two to perform solo home practice. The poor class attendance plus the lack of home practice prevented attainment of the automatic stage of

TCC performance which is thought to be important to gain the meditative effects and positive influence over perceived well-being (Brown *et. al.* 1995).

**Gait**

Even though the initial baseline data for the free and fast WS were significantly greater level than the treatment phase, the lack of replication of this effect in the second baseline suggested that something unique was occurring in the initial baseline phase (See Table 9, page 113). The most plausible explanation was anticipation over participation in the study in the initial baseline that had waned by the second baseline. A similar pattern was noted in the free and fast SL that indicated SL was the predominant determinant of WS in subject two (see Table 9, page 113). With the different phase lengths, direct comparison between phases was not possible. There appeared to be a tendency to stabilize gait performance trend during the treatment phase. See Figures 23 – 28, pages 106-108. The second baseline free and fast WS measures indicated that there was carryover of treatment benefits to the second baseline (no significant difference). For the slow WS, the second baseline was significantly slower than the treatment phase which likely reflected a conscious choose of the subject to walk slower since slow WS are not as reliable as free WS (Hausdorff *et. al.* 1998, Weller *et. al.* 1993, Blin *et. al.* 1991). An inconsistent opposite pattern was noted for the ST that suggested the expected inverse relationship between ST and WS was not fully attained in subject two (MacKay-Lyons 1998, Morris *et. al.* 1994a).

Another explanation was that TCC training actually slowed subject two's WS similar to results found by Wolf *et. al.* (1996 and 1997). The reason for this may be improved balance and less need to rush through the single support phase in order to achieve the more stable double support phase. The SST for subject two, shown in Table 9 (page 114), showed similar patterns to the WS, with values approximating normal for the fast WS ( 40%), where as the slow SST were less than expected that indicated a greater amount of time spent in double support (Greive and Gear 1966). In the Wolf *et. al.* (1997) study, the WS were reduced in the elderly subjects but the number of falls was also reduced. No other gait parameters were reported, making judgements about methods used to adjust WS impossible. Wolf *et. al.* (1997) suggested that the TCC training allowed the subjects to use a greater number of possible balance strategies and increase their mediolateral sway to compensate for deficient anteroposterior sway. Since individuals with IPD also have deficient anterioposterior balance, subject two may have also developed similar compensatory mechanisms (Deitz 1988). Also, subject two had a medication change in week 8 that had a noticeable effect on the motor measures by stabilizing WS spatial and temporal parameters.

As with previous studies, the average free WS (range 0.66-0.59 stat/s) was the most reliable (Hausdorff *et. al.* 1998, Weller *et. al.* 1993, Blin *et. al.* 1991). The free WS were slower than age matched normative values for healthy people (0.8-1 stat/s, Grieve and Gear 1966) and in the range of the slowest WS for healthy individuals (0.4-0.6 stats/s). This finding agreed with previous research that indicated that people with IPD walk more slowly usually due to decreased SL (Morris *et. al.* 1994a, 1996a and 1996b). Subject two slowed her free WS in the treatment phase by decreasing her SL and increasing ST. The SL and ST alterations reduced her cadence and SST. For the slower WS, these changes in SL, ST and SST would be expected. Previous studies indicated that increased cadence was used by individuals with IPD to compensate for reduced stride length (Morris *et. al.* 1994a). Subject two's data does not support this claim. Differences in subject disease stage could explain the discrepancy.

The initial baseline fast WS was not significantly different in level from the treatment phase, as shown in Table 9 (page 113), which indicated that whatever was happening in the other two WS was not achievable for the fast speed. It was possible faster speeds, subject two was likely less able to alter the gait variables. The treatment phase fast WS was significantly greater than the second baseline, as shown in Table 9 (page 113), but the range of WS was similar across phases indicating that the significant difference in fast WS was likely due to only the differences in phase length. See Figures 23 – 28, pages 106-108. Although subject two's free and fast WS decreased over the study period, this did not drastically affect her perception of how IPD affected her life since no significant change in PIMS were noted. See Table 9 (page 113).

Subject two had slightly slower cadence than normal (Normal 120 steps/min, subject 2 range 113-107 steps/min) for her free WS as shown in Table 9 (page 113) and Figure 27, page 108. This result does not agree with previous research in which subjects with IPD had increased cadence (Morris *et. al.* 1994a, 1996 a and 1996b). Healthy individuals reduce cadence as one component to reduce WS (Grieve and Gear 1966). Morris *et. al.* 1996b found that individuals with IPD had their best gait performance during peak doses of medication and are best able to maintain more normal gait parameters. Subject two's data showed that she could maintain sufficient SL during "on" phases so compensatory increased cadence was not necessary. A slower cadence would be expected for a slower WS. Subject one's cadence data showed a significantly slower cadence for the free WS in the treatment phase compared to the initial baseline which, as stated earlier, may simply reflect anticipation over study participation. In addition, the cadence for the slow WS significantly decreased over subsequent phases of the study.

For subject two there was no significant difference in the levels of the range of WS between study phases. See Table 9 (page 113) and Figure 28 (page 108). The non-significant slopes did change from negative to positive between the initial and treatment phases. The variability in the range of WS was similar between phases. There was no indication that TCC training improved the range of WS for subject two.

**Balance**

Subject two showed no significant change in trend or level for FR over the period of the study. See Table 9 (page 113), Figure 29 (page 109), and appendix O. Functional reach is a clinical measure used to record changes in anterior static balance but may be too gross to detect the small changes with the large variability in this subject's performance. Subject two had been diagnosed with IPD for ten years and individuals with IPD require longer duration to learn motor skills (Davous *et. al.* 1987, El-Awar *et. al.* 1987). The lack of significance may have reflected the necessity of longer training time to demonstrate change in the FR score. The FR scores of this individual appeared to be adversely affected by increased fatigue levels (greater than 6/10) on week 7 and week 17. The initial measure of FR in the treatment phase appeared to be positively affected by sickness. A possible explanation of this would be the lack of food in the subject's stomach allowed for better L-dopa absorption. The aberrantly large FR score in the second baseline on week 25 was possibly due to trick movements. There was no indication that TCC training improved the static balance, as measured by FR, in subject two.

The FR scores were not particularly predictive of subject two's function. The mean score for each phase was greater than 20 cm that indicated a risk for between one and two falls over the next year (Duncan *et. al.* 1992). Subject two had more than 70 falls over the following four months and the FR score remained essentially unchanged. Functional reach was not useful in predicting the number of falls for subject two and may reflect an inability of FR to accurately predict falls in dyskinetic individuals with IPD. This subject did not appear to alter activities to reduce the likelihood of falls. As reported earlier, fear of falling, falling, and postural stability measures may not agree (Wolf *et. al.* 1996)

## Fear of Falling

The MFES scores statistically reduced levels over the subsequent phases of this study, as shown in Table 9 (page 113), with an unfavourable change in the non-significant trends during the treatment and second baseline phases. The MFES indicated that subject two became less confident about her ability to carry out tasks which required balance over the duration of the study (See Figure 30, page 109). This could have been because TCC training highlighted balance deficits or the medication changes that occurred early in the treatment phase. The MFES results were supported by the logbook data that indicated subject two only fell once in the initial three-week baseline, whereas over the four-month treatment duration the subject fell greater than 70 times. The difference in phase duration precludes direct comparison regarding the number of falls per phase, however, the 70 falls over a four month period would be expected to adversely affect subject two's confidence about her ability to perform activities without falling. Reaching, answering the phone, and using public transportation were the components of the MFES with the worst rating. These results were supported by the tester log entries where subject two reported the attempted fast motion when answering the phone resulted in freezing episodes and falls. The tester log entries also reported that subject two stopped driving when first diagnosed with IPD and always had a friend or family member as an escort. It should be noted that the MFES was developed to assess balance confidence in the elderly for 14 specific daily activities and may not have been sufficiently sensitive to the specific balance challenges in people in stage II or III IPD.

## Quality of Life

There was no significant level or trend changes seen in the best or worst PIMS scores across phases. However, the "worst" scores were more consistent. See Table 9 (page 113), Appendix O, and Figure 31 (page 110) for level and trend statistical analysis plus visual analysis respectively. The effect of the medication change was well represented in the sharp increase in the "best" PIMS scores in week 8. See Figure 31 page 110. This drastic alteration in "best" PIMS scores created a non-significant positive trend which was greatly influenced by the two initial treatment scores. Once the medications were changed the scores were very stable showing little trend. The "worst" PIMS score remained virtually unchanged. Also, the TCC group dynamic did not appear to alter subject two's perception of the disease's impact. It should be noted that subject two and one other were the only individuals in the TCC class of ten that had the severely impaired balance reactions associated with longer disease duration. The high "worst" rating of community relationships suggested that subject two might have difficulty attending community events due to transportation issues. Since safety, sexuality, self-positive and self-negative scores were rated higher than the other factors, these areas should be addressed by rehabilitative professionals to improve subject two's quality of life. Sexuality of females with IPD has not been well researched and has been identified by subject two as a issue affecting quality of life (Basson 1996, Waters 1997). Further investigation into the sexuality of females with IPD is warranted.

## Tremor

Subject two was left-handed and her left tremor scores were significantly greater over the treatment phase compared to the second baseline as shown in Table 9 (page 113). There was no difference between the first baseline and the treatment phase that indicated TCC did not affect tremor. The improvement in the second baseline scores likely reflected medication effects. Non-significant trends were inconsistent as illustrated in Figure 32 (page 110) and Appendix O. As previously stated, the tremor scale as administered could not differentiate between dyskinesias and tremor. There was no doubt subject two was having more difficulty completing the modified writing task. However, according to the test log the tremor scale appeared to be greatly influenced by the amount of dyskinesias present at the time of testing. It was possible that subject two's dykinesias were enhanced during the treatment phase by the physician prescribed and self initiated medication changes during the treatment phase. There was insufficient evidence to support the anecdotal reports that TCC training reduces tremor.

## General Comments

Safety and fatigue were identified by subject two as important issues related to IPD. The exercise intensity of subject two was less than expected due to hands on balance assistance and lack of compliance with daily home exercise, factors that reduced the likelihood of determining training effect. Tai Chi Chuan training appeared to provide a vehicle to stabilize gait performance and curve negative trends toward adoption of the classic IPD gait pattern in subject two. Little change was noted in static balance as measured by FR. However, subject two became less confident about balance abilities as the study progressed. Functional reach was not predictive of falls in subject two that possibly reflected the destabilizing effects of dysinisias. The subjective impact of IPD on quality of life was directly reflected in the PIMS score and was greatly influenced by medication changes. The ability of the Tremor score to differentiate between tremor and dykinesias was questionable making conclusions about TCC impact on tremor impossible. The long disease duration and presence of dyskinesias made measurement of motor function very difficult for subject two.

# CHAPTER 6

## RESULTS AND DISCUSSION FOR SUBJECT THREE

### Results

Subject 3 attended 17 of 34 TCC classes (50%), six of the originally scheduled 40 classes were cancelled due to high humidity or poor attendance. An increase of 2% was noted in the BDI scores between pre and post treatment phases. There were changes in the UPDRS scores. See Table 10. There was a worsening of the motor "on"(3%). The subjective, "off" motor, SE , and H&Y "off" scores all improved (3%, 7%, 10%, and 0.5 stages respectively). The side effects, dyskinesias, and H&Y "on" scores remained unchanged.

Table 10. Subject 3 pre and post measures are in table

| BDI score | | UPDRS | | Medications changes |
|---|---|---|---|---|
| Pre | Post | Pre | Post | |
| 1 | 2 | Subj: 16<br>Motor:<br>On:13<br>Off:21<br>Sdeffect:4<br>Dysk:0<br>SE(ADL)<br>On: 90%<br>Off:90%<br>H&Y<br>On: 2.5<br>Off:3 | Subj: 12<br>Motor:<br>On: 16<br>Off:13<br>Sdeffect:4<br>Dysk: 0<br>SE(ADL)<br>On: 100%<br>Off:100%<br>H&Y<br>On: 2.5<br>Off: 2.5 | none |

### Monitored Extraneous Factors

Factors such as illness, stress, fatigue and humidity can adversely affect motor measures. Subject three reported being sick 5 times during the test days, 4 days in phase B (May 25, June 21, Aug. 13 and 30) and once in the phase A2 (Sept. 20). She did not report any sick days in the initial baseline. Subject three reported consistent stress level, exercise level, and coffee intake over the course of the study. Subject three's fatigue level varied greatly during the study with the most consistent levels occurring during the treatment phase as illustrated in Figure 48 (page 134). The relative humidity was 90% or more for 25 of the 28 testing days, see Figure 47 page 133. From June to September the temperature was greater than 20 °C during 8 of the 10 treatment test days, see Figure 46 page 133.

## Analysis

### Visual analysis

Visual analysis was performed using the split middle technique as described by Portney and Watkins (1993). The trends are shown in the Figures 36-48 (pages 128-134). Note that no trend was noted for right tremor all phases; FR and SST fast WS in phases A1 and B; left tremor and SST slow WS for phase A1; PIMS, fast ST SST free WS for phase B; slow WS cadence and MFES for phase A2.

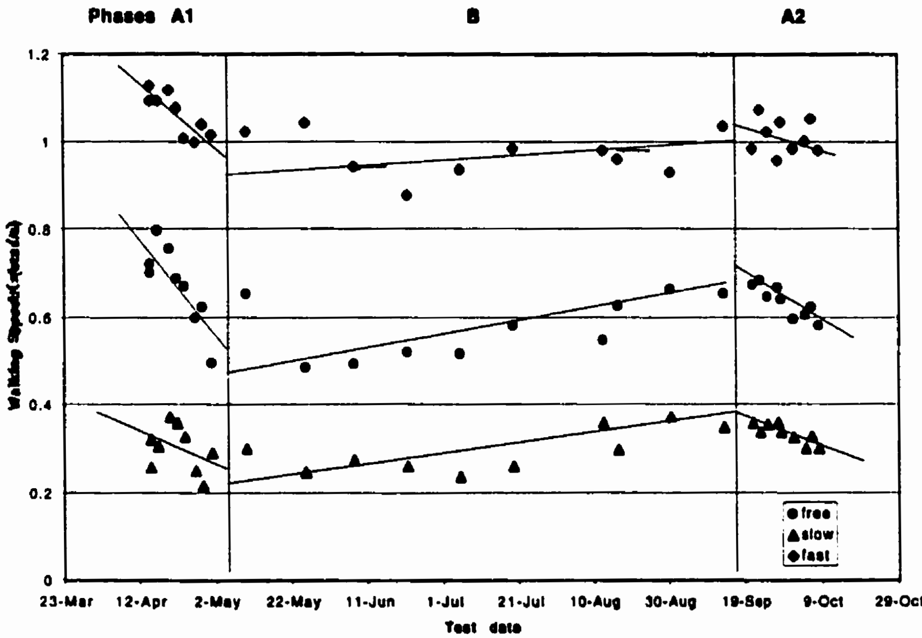



Figure 36. Walking speed for subject 3. The phases are represented by vertical lines.

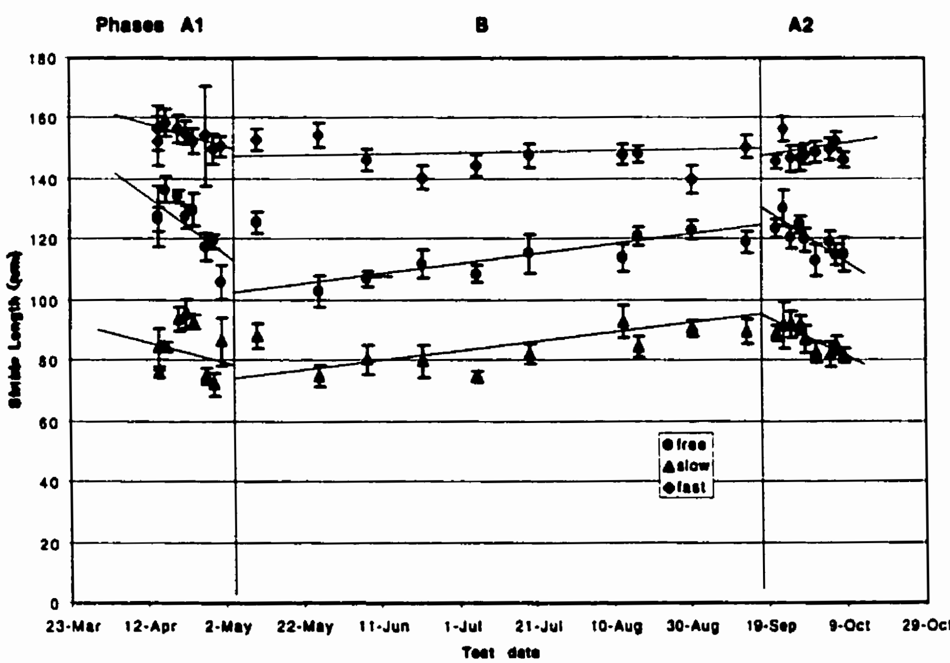



Figure 37. Right stride length for subject 3. The study phases are represented with vertical lines. Error bars represent one standard deviation.

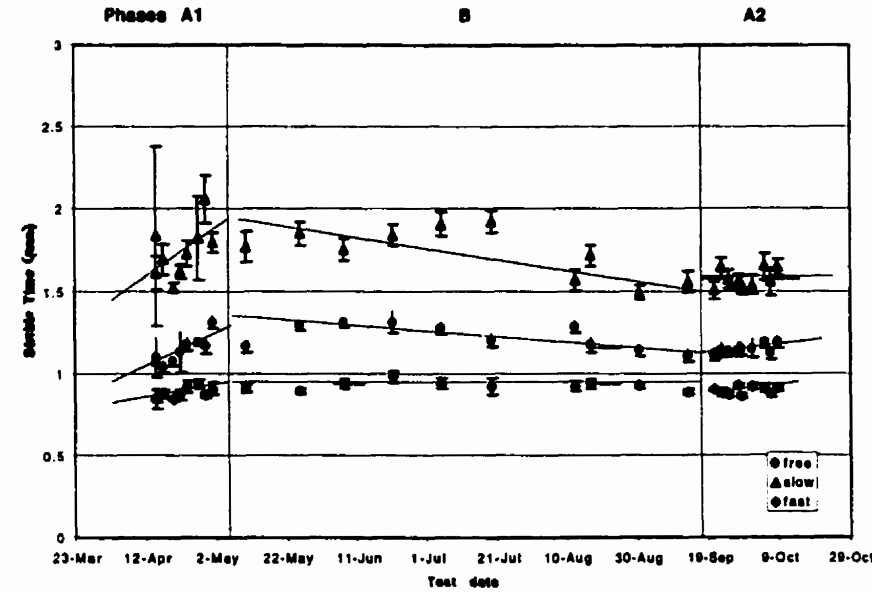



Figure 38. Right stride time for subject three. The study phases are represented with vertical lines. The error bars indicate one standard deviation.

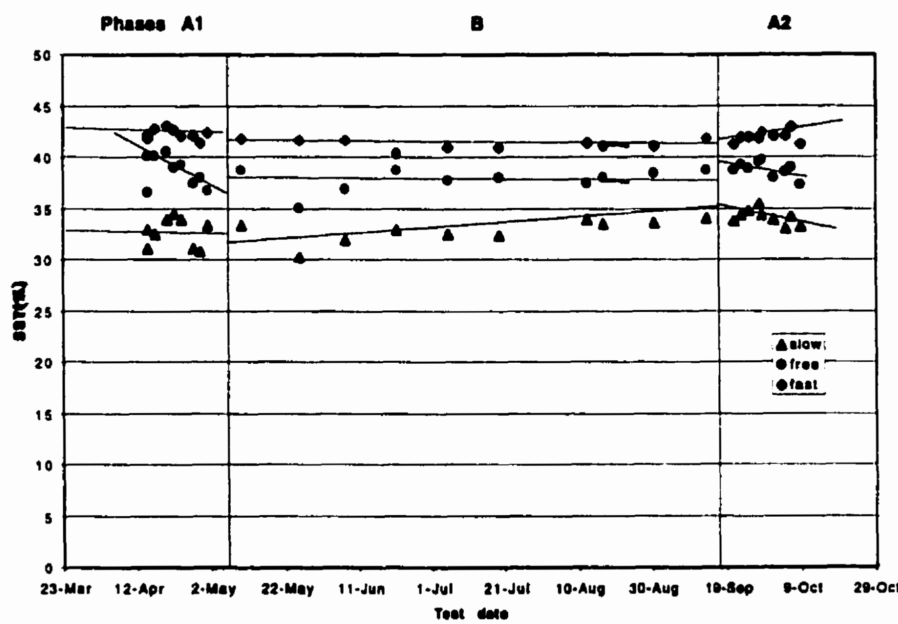



Figure 39. Single support time for subject three expressed as a percentage of total stride. The study phases are represented with vertical lines.

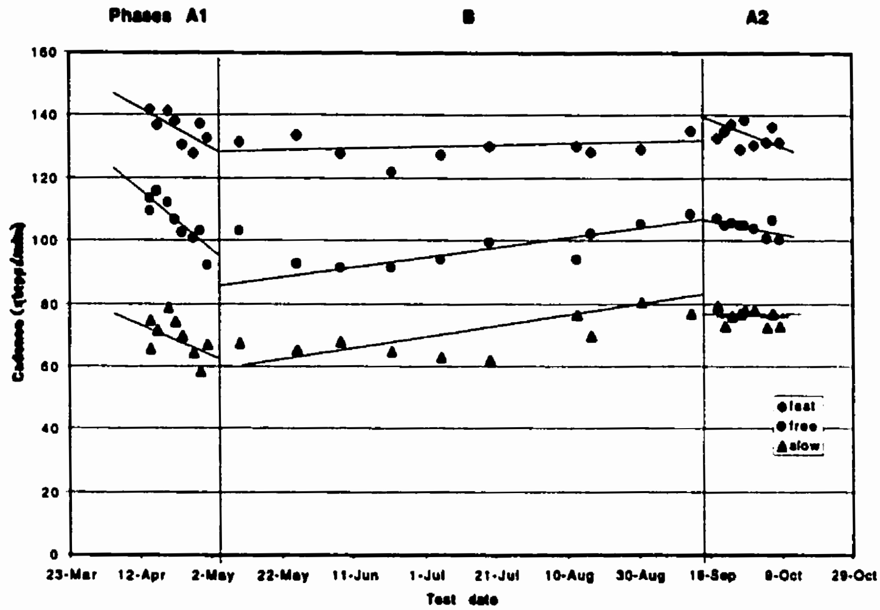



Figure 40. Cadence for subject three. Study phases are represented with vertical lines.

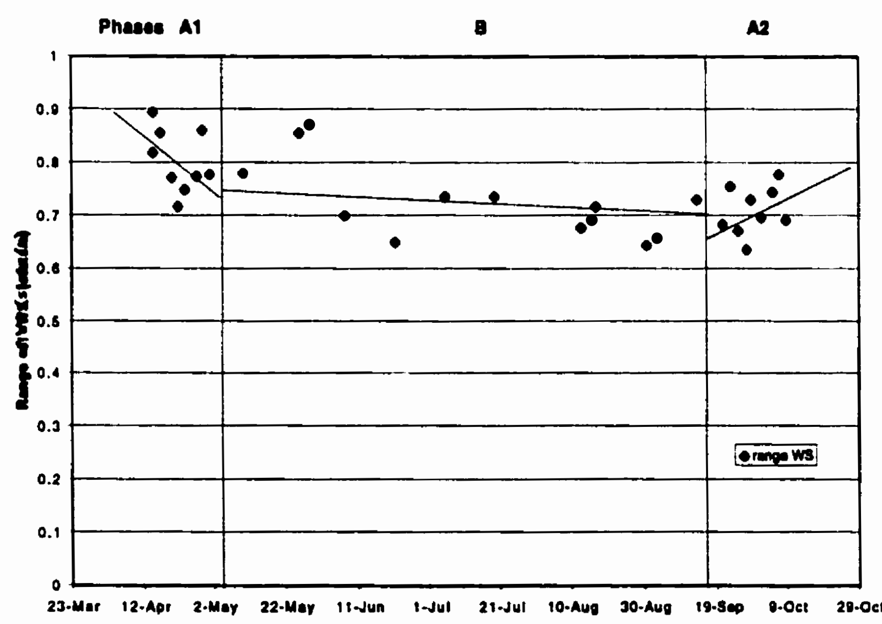



Figure 41. Range of walking speed for subject three. The study phases are represented by vertical lines.

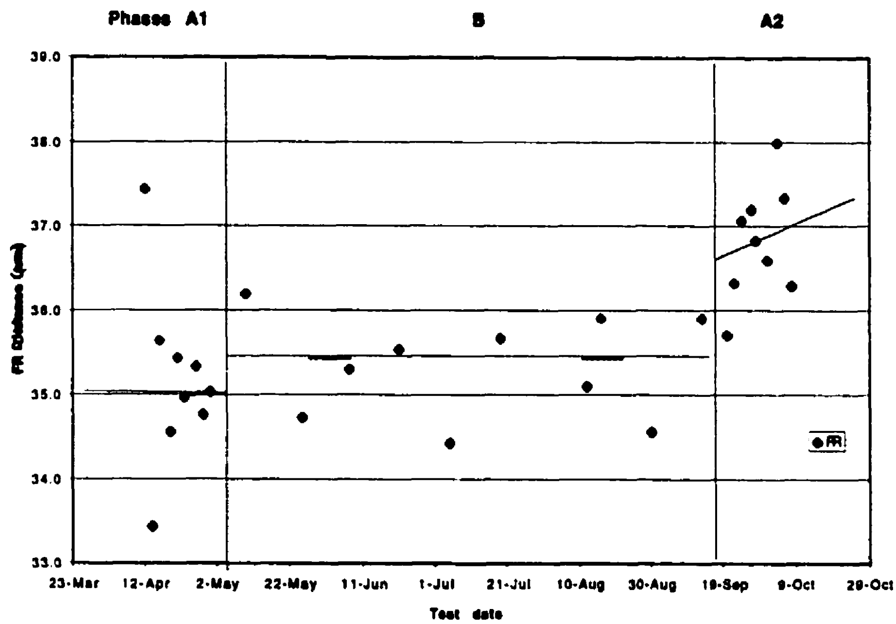



Figure 42. Functional reach for subject three. The study phases are represented by vertical lines.

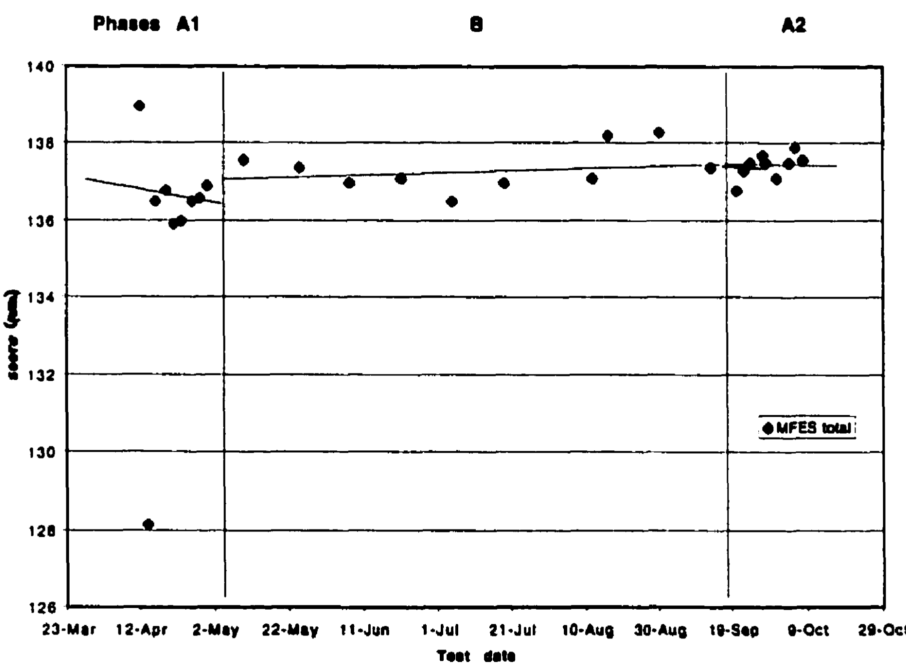



Figure 43. MFES for subject three. The study phases are represented with vertical lines.

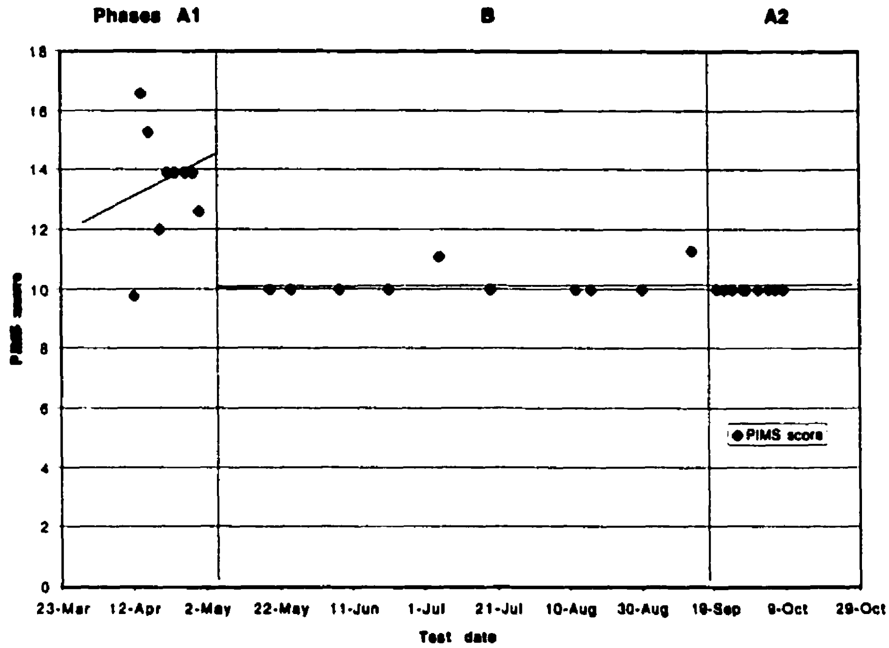



Figure 44. PIMS for subject three. The study phases are represented with vertical lines.

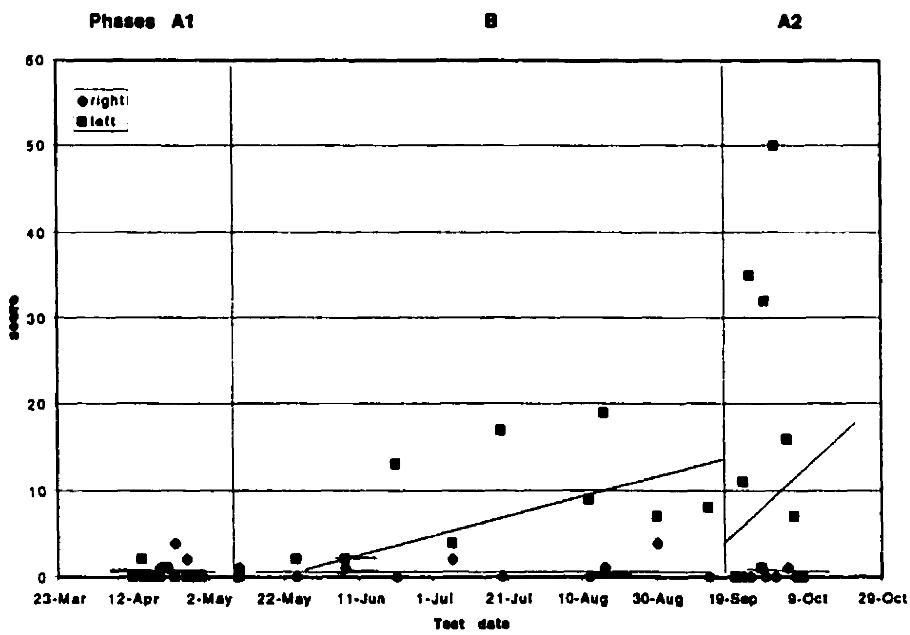



Figure 45. Tremor scores for subject three. The study phases are represented with vertical lines.

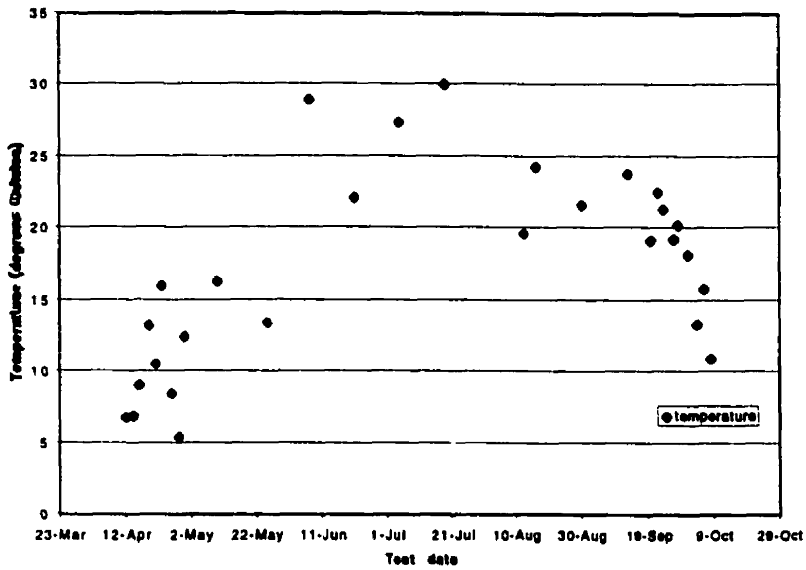



Figure 46. Test day temperatures for subject three

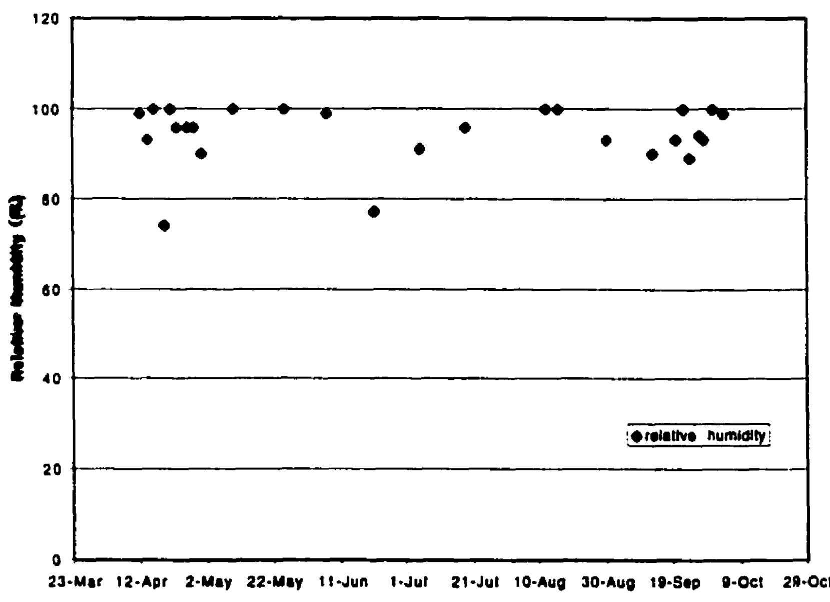



Figure 47. Relative humidity on test days for subject three

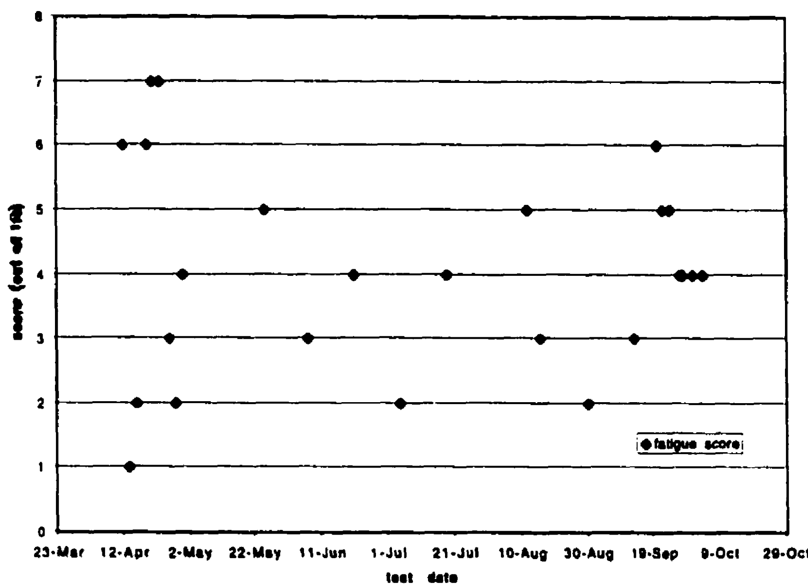



Figure 48. Fatigue scores for both hands for subject three.

**Statistical analysis of trends**

The visual analysis did not agree with the statistical analysis using the C-statistic. The slopes of all data in all phases for all data measured were not significantly different from zero. See Table 3 in appendix O.

**Statistical analysis of level change**

Level changes between phases were determined by a binomial test for significance and shown in Table 11, page 135 (Tripodi 1994). The PIMS scores indicated that during the initial baseline this subject had more concern over work, self-positive and negative thoughts, family relationships, and community relationships. After the TCC class began these concerns were no longer identified in the PIMS score as an issue except for 2 reports of self-negative thoughts.

Table 11. Subject 3 mean and standard deviation for each measure for each phase with indication of statistically significant level differences.

| **measure** | | **phase A1** | | **phase B** | | **phase A2** | |
|---|---|---|---|---|---|---|---|
| | | mean | SD | mean | SD | mean | SD |
| **WS** (stats/s) | slow | ° 0.30 | 0.05 | **0.30** | **0.05** | **0.33** | **0.02** |
| | free | † ° **0.67** | **0.09** | **0.57** | **0.07** | **0.63** | **0.04** |
| | fast | † ° **1.06** | **0.05** | **0.97** | **0.05** | **1.01** | **0.04** |
| **RSL** (cm) | slow | 63.38 | 8.66 | 83.86 | 6.41 | 87.08 | 4.24 |
| | free | 126.83 | 8.73 | 114.97 | 7.42 | 120.31 | 5.53 |
| | fast | * **148.73** | **15.92** | **147.45** | **4.81** | 149.26 | 3.53 |
| **RST** (sec) | slow | • 1.75 | 0.16 | **1.74** | **0.15** | **1.58** | **0.05** |
| | free | * • **1.14** | **0.09** | **1.23** | **0.08** | **1.15** | **0.03** |
| | fast | * • **0.88** | **0.03** | **0.93** | **0.03** | **0.90** | **0.02** |
| **cadence** | slow | ° 69.52 | 6.24 | **69.59** | **6.47** | **76.02** | **2.49** |
| | free | † ° **106.34** | **7.42** | **98.32** | **6.32** | **104.55** | **2.30** |
| | fast | † ° **136.68** | **5.14** | **129.69** | **3.65** | **133.84** | **3.33** |
| **SST%** | slow | ° 32.72 | 1.40 | **32.87** | **1.14** | **34.13** | **0.73** |
| | free | 38.65 | 1.48 | 37.79 | 1.13 | 38.79 | 0.75 |
| | fast | † **42.31** | **0.49** | **41.31** | **0.45** | 41.96 | 0.54 |
| **Range of WS** (stats/s) | | 0.802 | 0.059 | 0.722 | 0.063 | 0.334 | 0.022 |
| **FR** (cm) | | ° 35.18 | 1.06 | **35.33** | **0.61** | **36.82** | **0.68** |
| **PIMS** | | † **13.54** | **1.94** | **10.24** | **0.53** | 10.00 | 0.00 |
| **MFES** | | * **135.81** | **3.00** | **137.36** | **0.56** | 137.43 | 0.33 |
| **Tremor** | right | 0.89 | 1.36 | 0.90 | 1.29 | 0.22 | 0.44 |
| | left | 0.33 | 0.71 | 8.10 | 6.51 | 16.89 | 18.06 |

* denotes a significantly greater treatment level change compared to initial baseline
• denotes a significantly greater treatment level change compared to second baseline
† denotes a significantly lower treatment level change compared to initial baseline
° denotes a significantly lower treatment level change compared to second baseline

## Log book results

Subject 3 attended 17 of the 36 TCC classes, six classes were cancelled due to high humidity and poor attendance. No falls were reported over the duration of the study. The primary identified reason for missing class was work schedule where she worked nights every other week. Also her mother died July 21 and her attendance fell drastically after that point. The most frequent (90) entries into subject 3's log-book dealt with physical concerns. Of the physical entries, 29 related to sporting activities (mainly her regular morning aerobic workout and golf), 15 related to feelings of fatigue, 13 related to ability to perform ADL, 12 related to pain, 8 related to medication concerns, 6 related to sleep issues, 6 related to tremors, 6 related to comments about the negative impact her menstrual cycle had on her physical performance, and 2 related to safety. The following are excepts from the logbook entries.

> "golfing our first round this year. Played 18 holes as well as I played last year. The tremor has little effect on my swing but does affect my putting, but I can put with right hand only and it works. Great game maybe I can continue to play for a long time."

> "Has a bad tremor today, had 1/2 cup of coffee carrying in my left hand and it began to shake, spilled the coffee on my shirt, lucky it was not hot. Usually I foresee this happening but this time it took me by surprise....Also, eating supper, lost 1/2 my rice on the floor, was cutting my pork-chop and without warning left hand began a sudden tremor causing the food to fly off the plate...Thank goodness it's Friday, was really busy at work today, got stressed and my tremor always worsens when I'm nervous"

Social and employment issues represented 19 entries each and psychological statements, usually relating to mood, occurred 18 times. Subject there continued with a very active social life but was concerned with how the Parkinson's affected her employment. Most entries regarding mood were positive except for the occasional very negative comment. Sample comments are shown in the following logbook excerpt.

> "Had 2 clients, they noticed my tremor but never said anything and I volunteer nothing. I don't know what I'll say if they ask. I hate to say Parkinson's because I don't want to be treated differently or have people feel sorry for me, since I don't feel sorry for myself....Applied for position of______ at _______. Really feel I can do the job.... Doubt I will get the job though. The decision makers are aware of my Parkinson's condition and even though I take minimum sick days, I'm sure that will affect their decision."
>
> "New stuff happening all the time, its great, there is hope for all of us.... Feel upbeat today even though it is snowing outside....Where art thou God, who would beset this affliction upon me?"
>
> "Dreamt of someone telling a joke about Parkinson's disease and I got up and walked away. They did not know I had the condition....
>
> "I wonder what I would have done differently in my life had I known this ailment would affect me in my later years?"

Only one entry occurred that related to education regarding IPD. Entries that specifically related to the study occurred 24 times and are represented in the following excerpt.

> "feel fortunate to participate in this study....I like it so far, seems to give me a purpose and adds some structure to my time....Testing tonight went wee, takes less time than I thought in the beginning....Another session of TC, this is going to take some time to master. I love the slow movement, its so controlled and when Linda moves it seems so effortless and fluid. That is my goal to reach that stage before the disease renders me unable to perform the movements.... Missed TCC again working this stupid shift...TC tonight. Glad M- (husband) takes part in the program. I feel he is really interested in learning the moves and that helps me. I am so licky to have such a supportive partner....Practiced some TC, find it good but easier to learn from Linda's class in the group...Can't seem to dedicate myself to practicing TCC, the mind is willing but the flesh is weak." TCC "always feel better after the session". "12-8 shift this week means no TCC. Hate to miss so much" However at one month follow up stated felt better that evening but did not carry over to next day. Also found had so much more time for activities after study was over that didn't know what to do with herself at first."

According to the test log subject three tended to walk faster normally than when tested on the walkway.

## Final Interview

At the final interview with subject three indicated that TCC was a "great stress reliever." The main factor that interfered with attendance was shift-work. No negative aspects were identified for the TCC training by subject three. Subject three stated that she "found it difficult to practice to a tape rather than a leader." The video was useful "only to watch." For this subject the written material was not useful. Beneficial aspects of testing included "finding out the many aspects of the condition and monitoring the progression." The negative aspects of the testing identified by subject three was "the duration, I found the length, 6-7 months, a bit tedious."

## Support Person's Questionnaire

Subject three's husband attended most classes with her. When asked why he participated he replied " My wife, J-, has been diagnosed as having Parkinson's. This condition naturally impacts both our lives. My most important role is to support J- and to actively participate in any activity which may improve her condition or provide greater knowledge of her condition." When asked what benefits he gained from participating in the TCC classes, he responded "Prior to participating in Tai Chi classes, I had little knowledge or interest in this activity. After attending the Tai Chi sessions, that changed. The meditation, the chanting, the warm-up and breathing exercises, the relationship between the Tai Chi, the martial arts and self-defense all intrigued me. The opportunity to spend time with others afflicted with Parkinson's taught me again how vulnerable we all are. I found myself feeling very badly: but soon realized these courageous people need little more than acceptance, friendship and love." When questioned about negative aspects of the TCC classes he commented " I found no negative factors whatsoever!"

## Follow-up

At the one month follow up subject three stated that she had more energy immediately after TCC class that did not carryover to the next day. She also reported having so much more time to do social activities since completing the study.

## Discussion

Subject three had little variability in the outcome data and significant trends were not achieved, as shown in Appendix O, likely due to the broad nature of C statistic calculations to account for the serial dependent data. The low variability in subject three's data reflected the short duration of IPD and, as such, had not yet begun the unpredictable motor side effects associated with long term medication use. This subject was assessed by video as being in stage III "off" medication; However, the assessment was heavily influenced by the tendency to fall on the retropulsion test. Subject three did not have the classic small step retropulsion but did have faulty postural responses that would have lead to a fall on the test. The stage III "off"rating for subject three may be overestimated because the reliability of video analysis of people with IPD has yet to be established.

As previously discussed the different phase lengths confounded the determination of statistically significant level changes. Greater initial data values may have occurred in the initial baseline solely due to anticipation about participation in the study.

Safety was not a factor in home practice for subject there. However, she failed to comply with the suggested home TCC exercise lessening the likelihood of treatment effect. Subject there was already performing daily home aerobic and weight training and stated that she did not have time in her busy schedule. Although her husband also attended TCC class, subject three appeared to lose interest once her mother died. The home exercise material, provided to subject three, provided insufficient support to achieve daily practice. The failure to practice as suggested decreased the likelihood of attaining the automatic level of motor performance of TCC necessary to achieve the meditative gains associated with TCC training that are thought to be associated with improve perceived well-being (Brown *et. al.* 1995).

## Gait

There were non-significant trends toward faster WS, cadence, longer SL, and slower ST in the treatment phase compared to both baselines, as shown in Figures 36-38, and 40 (pages 128-130) as well as Appendix O. These non-significant trends suggested that subject three increased the WS by increasing the SL and decreasing the ST. Single support time remained relatively unchanged, as shown in Table 11(page 135), which resulted in increased trends in cadence to allow increased the WS. The range of WS for subject 3 showed no significant trends or level changes over the course of the study as shown in Appendix O and Table 11 repectively (page 135). As the fast WS was increased the free and slow WS increased by similar amounts thereby maintaining the same range, see Table 11 (page 135) and Figures 36 and 41 (pages 128 and 130). The WS trends, though not significant, were in a negative direction for the baseline phases and in a positive direction for the treatment phases as illustrated in Figure 36 (page 128). This result suggested that the duration of TCC training may not have been sufficient to obtain significance differences in gait parameters even though TCC appeared to positively impact gait parameters.

The values of the average free WS per phase (0.57-0.67 stats/s) were slower than the normal free WS (0.8-1 stats/s, Grieve and Gear 1966). Subject three's free WS were in the range of a healthy individuals slowest WS (0.4-0.6) and her fastest WS were comparable in speed to the average healthy individual's normal WS (0.8-1 stats/s). These results were similar to many previous studies that indicated people with IPD walk slower than most healthy individuals (Morris *et. al.* 1996a and 1996b).

For the most part SST was unchanged over the different phases, as shown in Table 11 (page 135), indicating that although SL increased and the ST decreased, the duration spent on the support limb during forward advancement of the opposite leg remained stable. The SST for the free and fast WS (greater than 38% and 41% respectively) were very close the normal 40% value for free WS (Greive and Gear 1966).

The cadence was significantly slower during the treatment phase compared to both baselines as shown in Table 11 (page 135), except for the initial baseline for slow WS. Since the treatment cadence level was significantly slower but there was also a non-significant positive change in the trends (see Appendix O), the significant change was likely a reflection of the different phase lengths and not greater baseline levels. Also the training duration may not have been sufficient to see significant trend changes since subject three attended less than half the classes due to her work schedule and death of a family member. The average slow cadence was reflected in the average slower WS during the treatment phase. The average free WS cadence was slower than other studies of individuals with IPD (Morris *et. al.* 1996 a and 1996b). Previous studies reported individuals with IPD increased cadence in an effort to increase WS (Morris *et. al.* 1996 a and 1996b). Since subject three was newly diagnosed (2 months), the characteristic increased cadence may not yet be apparent. In contrast to previous research, subject three walked faster by increased SL without increased the duration in single support, thereby created a faster step (Morris *et. al.* 1996a and 1996b).

## Balance

The FR for subject three was statistically greater for the last baseline compared to the treatment phase as shown in Table 11 (page 135). Also, there was a non-significant positive trend in the second baseline data only as illustrated by Figure 42 (page 131) and Appendix O. No trend was indicated in the other two phases. The reasons for this result remains unclear. Possibly boredom or emotional upheaval due to the death of a family member during the treatment phase influenced the results. Subject three identified that she found the duration of this study very long. Perhaps the improvement in the final baseline phase indicated anticipation of study completion. Regardless of the reason, there was no indication in the data that TCC training improved anterior static balance for this subject as measured by FR.

Subject three's FR indicated little risk of falls in the next year since FR distances greater than 22 cm have been reported to have only a slight risk of a fall (Duncan *et. al.* 1992). These results were supported by the logbook data that did not identify any falls over the six months of the study. Subject three was in the early disease process and had no signs of dyskinesia or motor fluctuations that may affect the predictive abilities of the FR.

## Fear of Falling

There was a significant improvement in the level of confidence for subject three in regard to falls as measured by the MFES between the initial baseline and the treatment phase which was carried over to the second baseline as shown in Table 11 (page 135). These data indicated that TCC had a positive effect on improving subject three's confidence that she could perform common daily activities without falling. These results differ from the FR results. The failure of objective balance measures to directly represent perceived fall risk or number of falls after TCC training has been identified by earlier research (Wolf *et. al.* 1997 and 1996, Providence *et. al.* 1995). Tai Chi Chuan uses whole body reactions to self-perturbations and may facilitate the development of a greater number of neuromuscular and sensorimotor responses to balance challenges. Successful performance of the challenging balance tasks involved in TCC likely positively influenced the MFES results for subject three.

## Quality of Life

The impact that IPD had on subject three's life as indicated by the PIMS score was significantly lower for the treatment and second baseline phase compared to the initial baseline as shown in Table 11 (page 135) and Figure 44 (page 132). These data show that TCC may have a positive influence on the subject's perception of the disease and this effect might carry on after a person discontinues TCC. The significantly lower treatment PIMS scores may also reflect the fact that during the initial phase, the subject was not in contact with others who were suffering from IPD. Once the treatment phase began, subject three was involved in a group class that included people in much more advanced states of the disease. Perhaps the change in score simply reflected awareness that she was in the early stages of the disease. It could also reflect the importance of social contact with others with IPD. Newly diagnosed people often do not want to join IPD groups because they find seeing people at late stages in the disease depressing and alarming. They see their own future and become afraid. In contrast subject three has a positive response to the interaction with other individuals with IPD. Interaction with the group in an exercise environment improved subject three's outlook about the impact IPD had on her life. Certain issues identified by the PIMS are not adequately addressed by the medical treatment, specifically the effect of menopause and hormone replacement therapy on IPD. Also, sexuality was identified as an issue with this subject. The improvements in perceived quality of life with TCC training have also been found in previous research on healthy individuals (Wolf *et. al.* 1997 and 1996).

## Tremor

There were no significant level changes or trends in the tremor data as shown in Table 11 (page 135) and Appendix O respectively. The left-hand tremor scores indicated a non-significant trend toward worsening as illustrated in Figure 45 (page 132). Subject three was right handed and, as discussed earlier, preliminary testing results indicated that the scale used was less reliable and valid for the non-dominant hand (see Appendix A). The increased tremor scores over the duration of the study were supported by both the subject's and tester log entries. Since subject three did not suffer from dykinesias, the increased tremor scores can be assumed to be solely due to tremor. The tremor was noted at points where the subject was required to change direction possibly reflecting difficulty switching direction, as identified by previous research (Benecke *et. al.* 1987a and 1987b, Kritikos *et. al.* 1995). The log entries indicated that the tremor influenced function and resulted in spilt hot coffee and poor customer response at work.

## General Comments

TCC training appeared to have a positive influence on gait parameters with little influence over static postural control as measured by FR. Subjective assessment of functional abilities related to balance were very high and improved little during TCC training. The subjective assessment of disease impact improved by TCC training possibly secondary to interaction with other individuals much further advanced in the disease.

# CHAPTER 7

## RESULTS AND DISCUSSION FOR SUBJECT FOUR

### Results

Subject four attended 18 of 34 TCC classes (53%). As mentioned earlier, six of the scheduled 40 classes were cancelled due to high humidity levels or poor attendance. She reported no falls and no use of the video over the duration of the study. There was a 5% reduction in the BDI scores between pre and post treatment phases. There were changes in the UPDRS scores. See Table 12. There was a worsening of the motor "on" and "off", and side effects (9%, 5%, 4% respectively). The subjective scores all improved by 3%. The dyskinesia, SE and H&Y scores remained unchanged.

Table 12. Subject 6 pre and post BDI and UPDRS measures

| **BDI score** | | **UPDRS** | | **Medications changes** |
|---|---|---|---|---|
| Pre | Post | Pre | Post | |
| 9 | 6 | **Subj:** 21<br>**Motor**<br>On: 11<br>Off:20<br>**Sdeffect:**4<br>**Dysk:**0<br>**SE(ADL)**<br>On: 90%<br>Off:80%<br>**H&Y**<br>On: 2<br>Off:2 | **Subj:** 18<br>**Motor:**<br>On: 21<br>Off:25<br>**Sdeffect:**5<br>**Dysk:**0<br>**SE(ADL)**<br>On: 90%<br>Off:80%<br>**H&Y**<br>On: 2<br>Off: 2 | July 20 added Sinemet™ |

™Dupont Pharma, Toronto

### Monitored Extraneous Factors

Illness, increased stress, environmental conditions, and fatigue have been identified as factors that might adversely affect motor performance (Calne *et. al.* 1996). Subject four reported being sick 6 times over the study period, twice in each phase (May

3 and Apr. 12, July 20 and Aug. 24, Sept. 6 and 8). Subject four reported higher stress 4 times in the treatment phase (May 24, June 1, 8, 22, and July 5) and 7 times in the initial baseline (Apr. 16, 19, 23, 25, 26, and May 3). No increased stress levels were reported for the second baseline phase. The relative humidity was 90% or more for 25 of the 28 testing days, see Figure 60 page 153. From June to September the temperature was greater than 20 °C during 8 of the 10 treatment test days, see Figure 59 page 153. The level of fatigue was rated at 6/10 or higher for the treatment phase. The fatigue ratings slowly increased during the first baseline and were highly variable for the second baseline. Over all subject four reported higher levels of fatigue during the treatment phase than the baselines. See Figure 61 page 154.

## Analysis

### Visual analysis

Visual analysis of the data using the split middle technique, for subject 4, are shown in Figures 49-61 (pages 148-154). No trends were indicated for phase A2 for range of WS, slow, free, and fast ST, free and fast cadence.

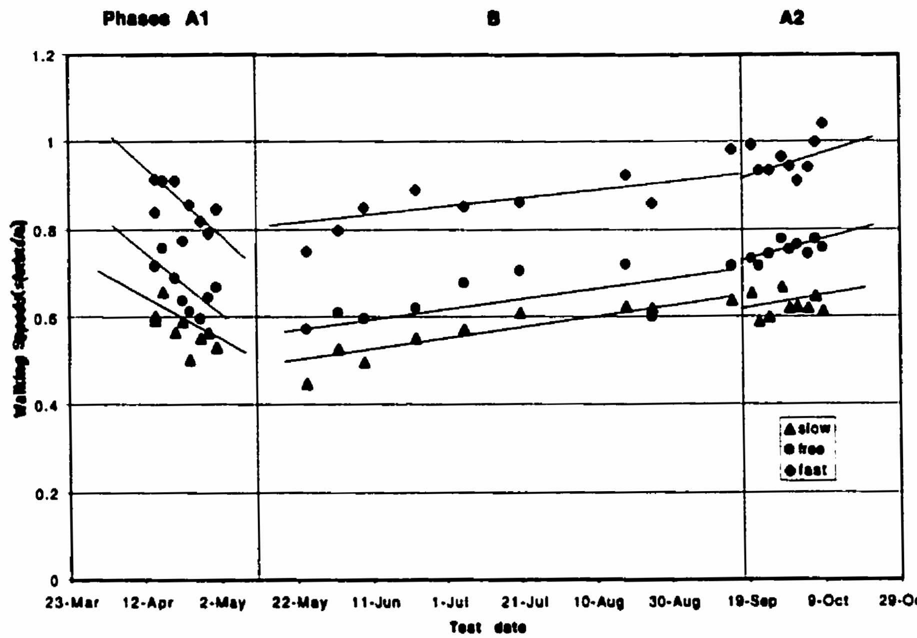



Figure 49. Walking speed for subject 4. The vertical lines represent study phases.

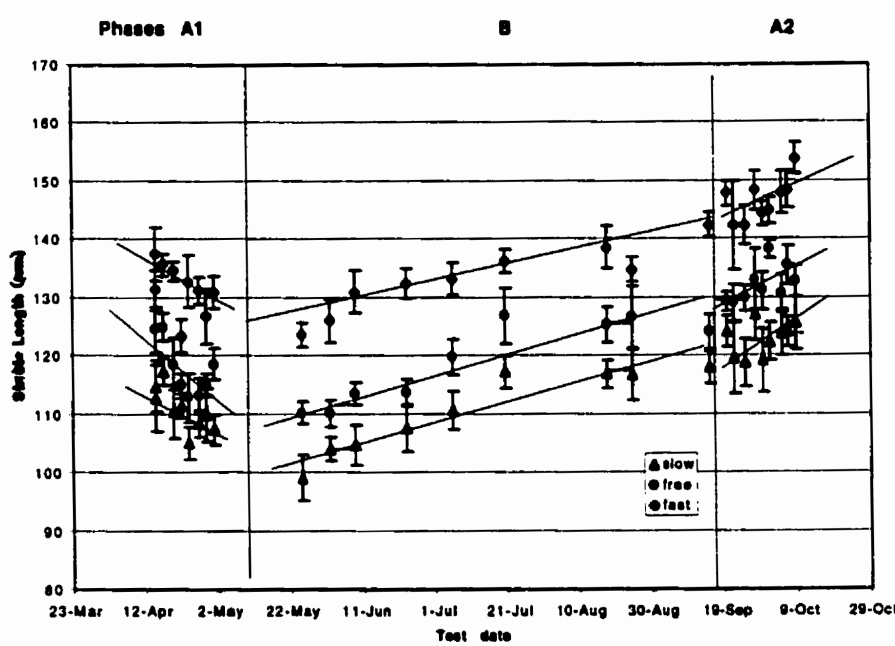



Figure 50. Right stride length for subject 4. The study phases are represented with vertical lines and the error bars represent one standard deviation.

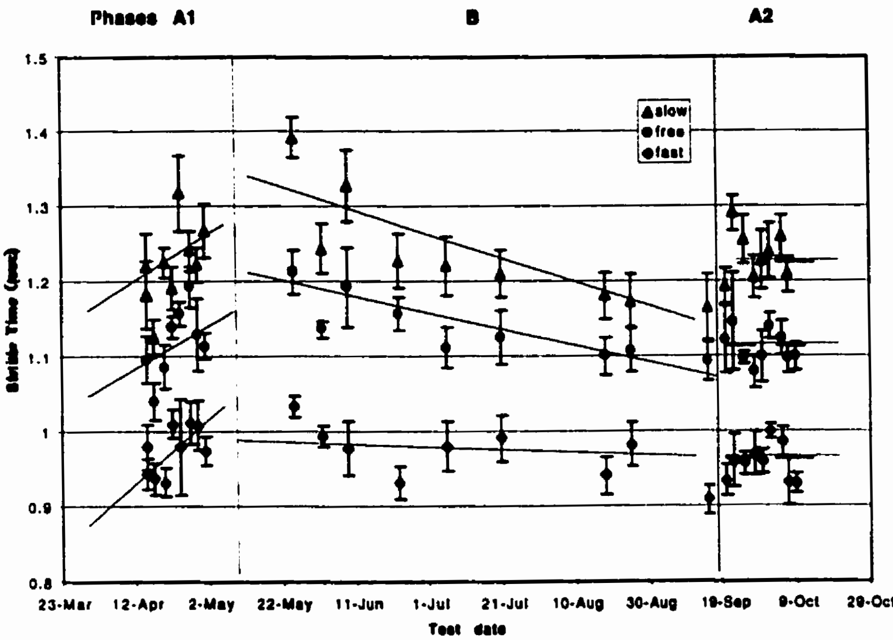



Figure 51. Right stride time for subject 4. The vertical lines represent study phases and the error bars represent one standard deviation.

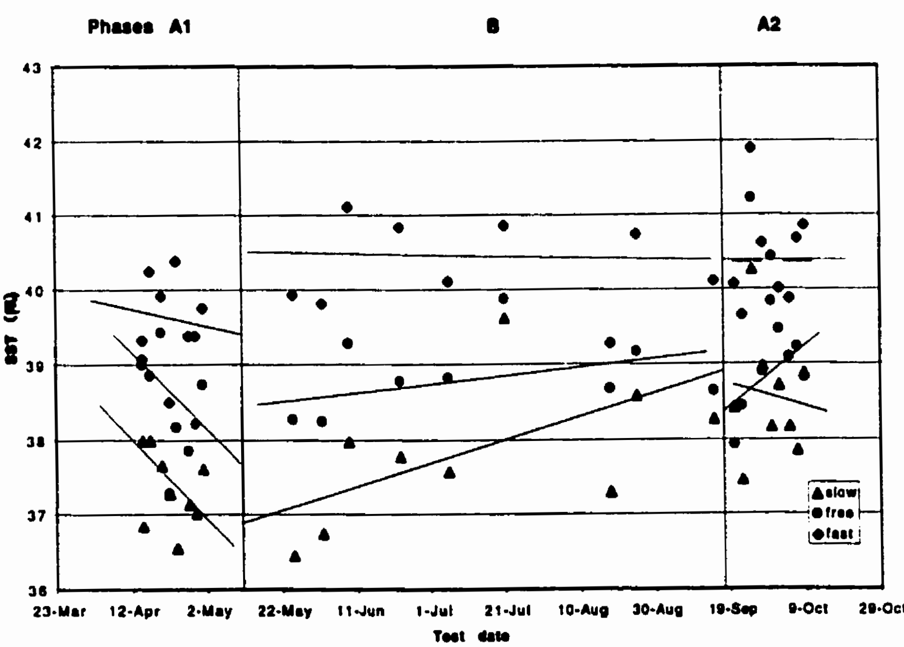



Figure 52. Average single support time expressed as a percentage of total stride for subject 4. Study phases are represented with vertical lines.

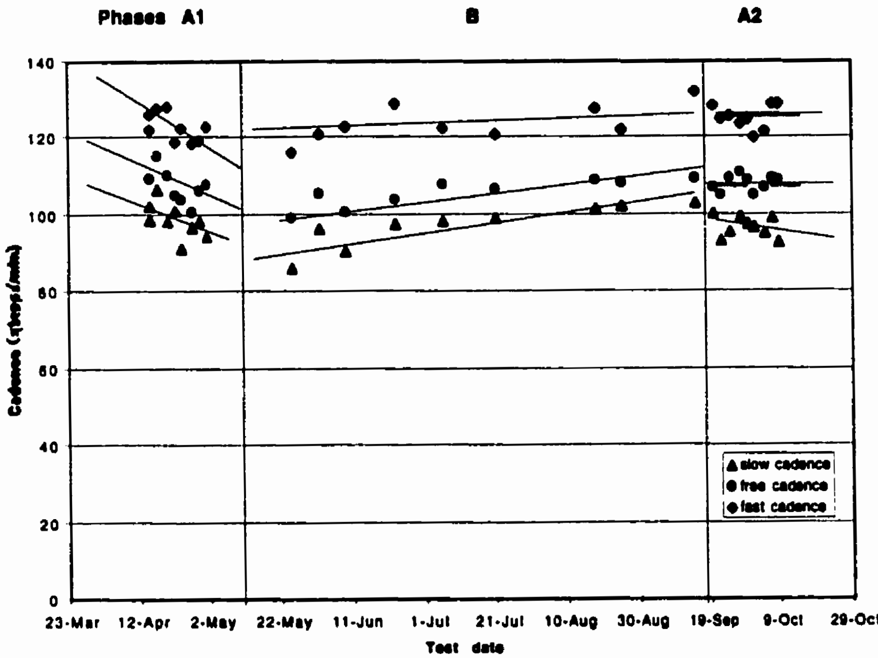



Figure 53. Cadence for subject 4. Study phases are represented with vertical lines.

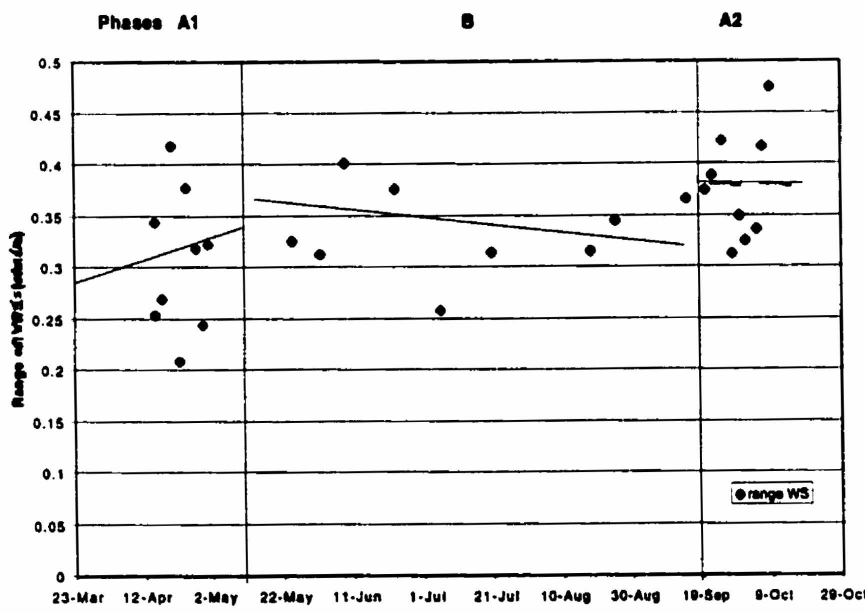



Figure 54. Range of walking speeds for subject 4. The study phases are represented with vertical lines.

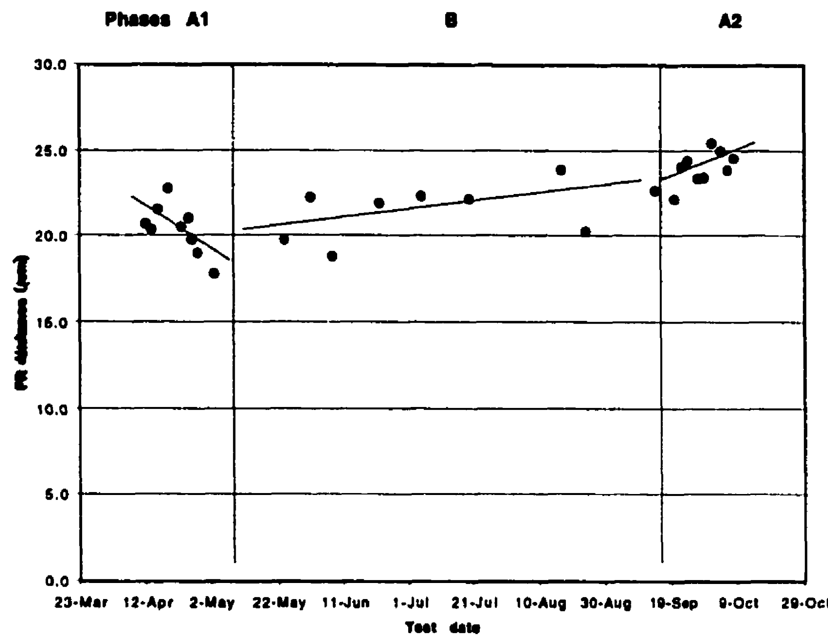



Figure 55. FR for subject 4. The study phases are represented with vertical lines.

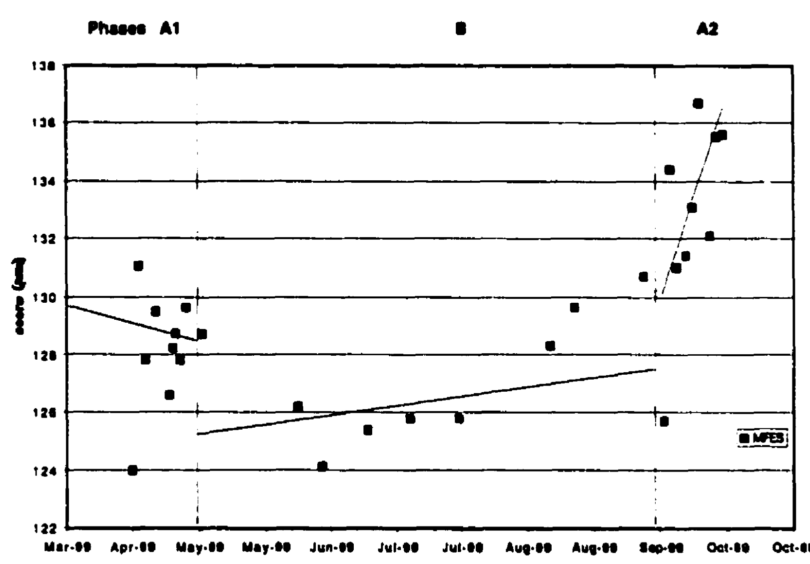



Figure 56. MFES for subject 4. The study phases are represented with vertical lines.

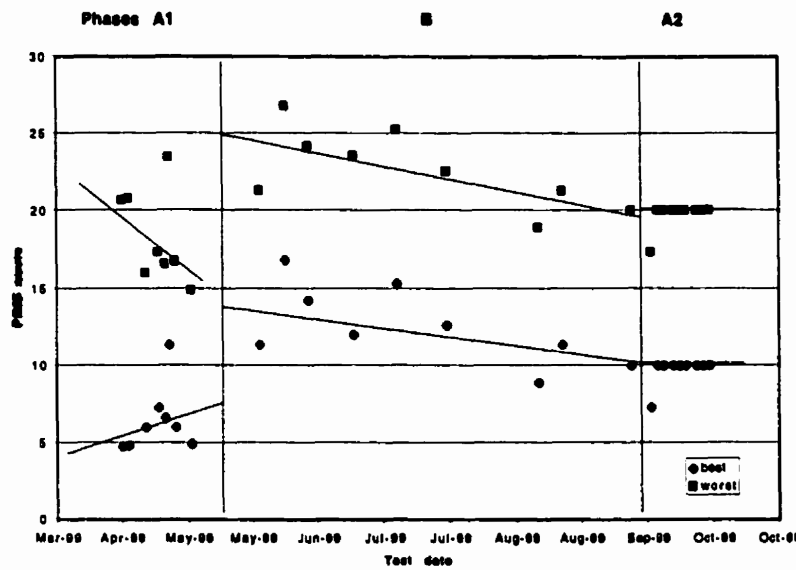



Figure 57. PIMS for subject 4. The study phases are represented with vertical lines.

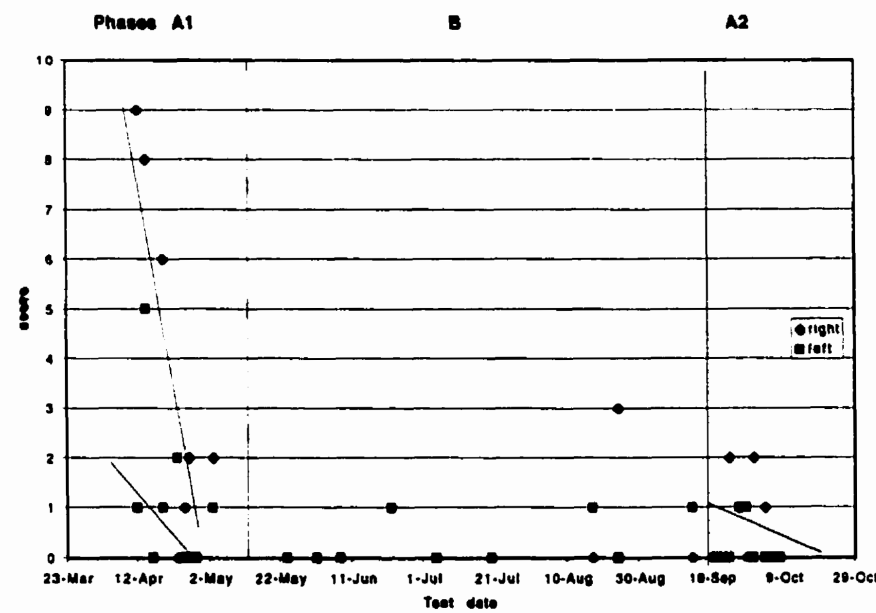



Figure 58. Tremor scores for subject 4. The study phases are represented with vertical lines.

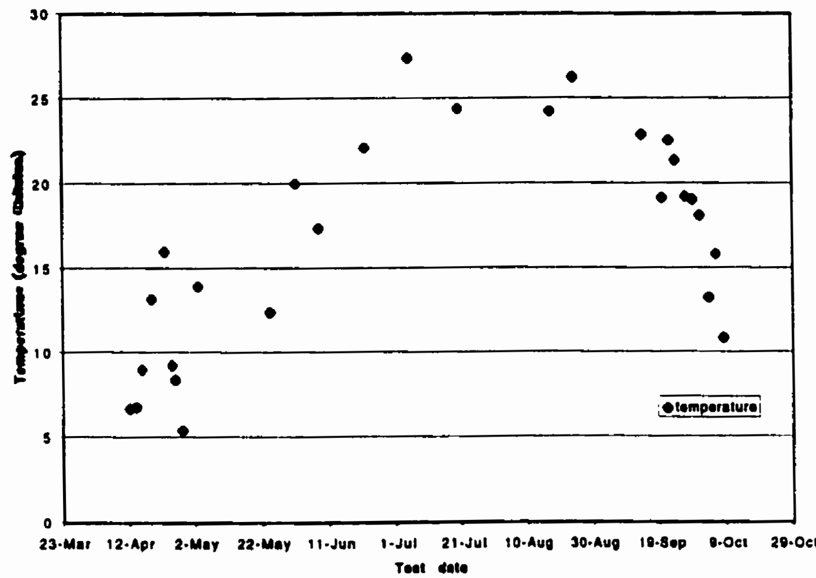



Figure 59. Temperature on testing days for subject 4.

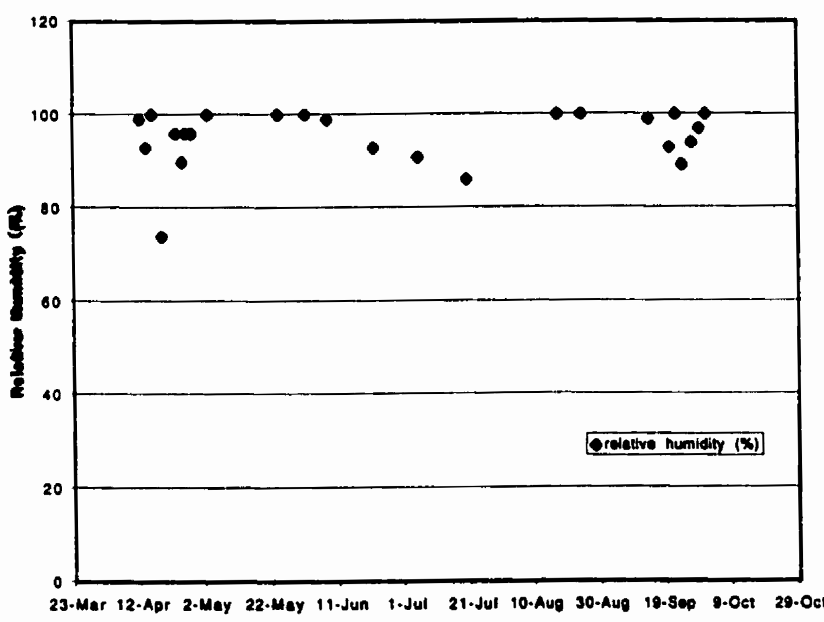



Figure 60. Relative humidity for testing days for subject 4.

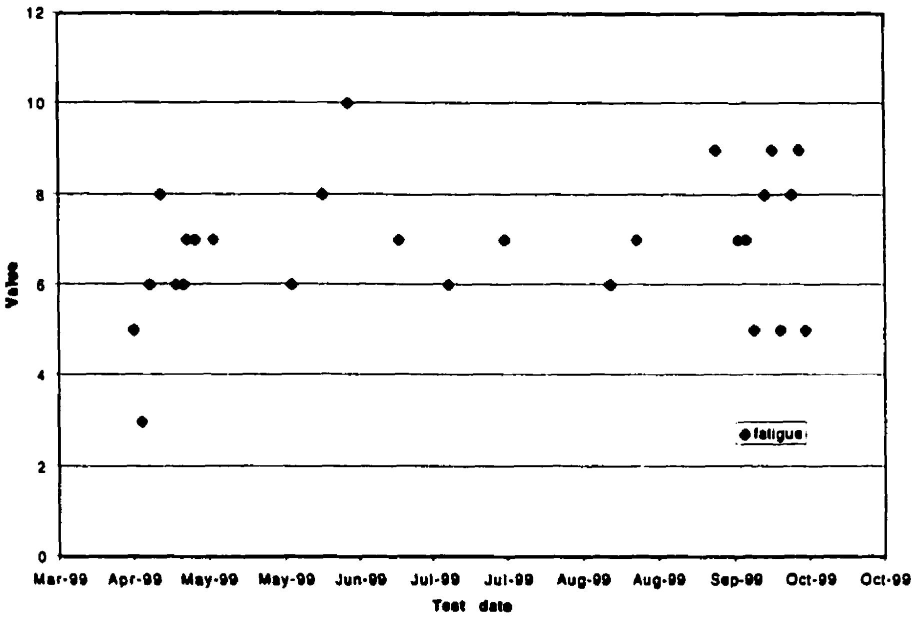



Figure 61. Subjective fatigue ratings for subject 4.

**Statistical analysis of trends**

The visual analysis did not agree with the statistical analysis using the C-statistic. The slopes of in all phases, for all data measured, showed no significant difference from zero. See Table 4 in Appendix O.

**Statistical analysis of level change**

Level changes between phases were determined by a binomial test for significance and shown in Table 13, page 155 (Tripodi 1994). The PIMS scores indicated that in the first baseline financial security, sexuality, and work received the highest impact scores. At the initial PIMS assessment subject four stated that her sexuality had altered due to her spouse's reactions to the diagnosis of IPD. In the treatment phase the focus shifted to work and self-negative thoughts. In the second baseline those self negative thoughts were reduced. Subject four stated that she was going through menopause over the course of the first two study phases.

Table 13. Mean and standard deviation for each outcome measure per phase with indication of statistically significant level changes for subject four.

| **measure** | | **phase A1** | | | **phase B** | | **phase A2** | |
|---|---|---|---|---|---|---|---|---|
| | | mean | | SD | mean | SD | mean | SD |
| **WS** | slow | • | 0.57 | 0.04 | **0.57** | **0.07** | **0.63** | **0.03** |
| (stats/s) | free | • | 0.67 | 0.05 | **0.65** | **0.06** | **0.75** | **0.02** |
| | fast | • | 0.85 | 0.05 | **0.86** | **0.07** | **0.96** | **0.04** |
| **RSL** | slow | • | 63.38 | 3.80 | **110.58** | **7.03** | **122.79** | **3.00** |
| (cm) | free | • | 117.86 | 4.77 | **118.93** | **7.08** | **132.22** | **3.09** |
| | fast | • | 131.59 | 4.37 | **133.20** | **5.85** | **146.74** | **3.64** |
| **RST** | slow | • | 1.22 | 0.05 | **1.24** | **0.08** | **1.24** | **0.03** |
| (sec) | free | * | **1.12** | **0.05** | **1.14** | **0.04** | 1.11 | 0.02 |
| | fast | † | **0.98** | **0.03** | **0.97†** | **0.04** | 0.96 | 0.02 |
| **Cadence** | slow | | 98.69 | 4.46 | 97.20 | 5.59 | 96.71 | 2.80 |
| (steps/min) | free | | 107.36 | 4.48 | 105.59 | 3.78 | 108.08 | 2.04 |
| | fast | | 122.96 | 3.72 | 123.76 | 4.83 | 125.23 | 3.14 |
| **SST%** | slow | | 37.35 | 0.51 | 37.81 | 0.96 | 38.55 | 0.81 |
| | free | | 38.44 | 0.69 | 38.87 | 0.52 | 39.22 | 0.94 |
| | fast | | 39.56 | 0.59 | 40.33 | 0.60 | 40.47 | 0.67 |
| **Range of WS** (stas/s) | | | 0.31 | 0.07 | 0.34 | 0.04 | 0.38 | 0.05 |
| **FR** (cm) | | • | 20.39 | 1.45 | **21.56** | **1.60** | **24.02** | **0.98** |
| **MFES** | | • | 128.19 | 2.02 | **127.12** | **2.18** | **132.83** | **3.34** |
| **Tremor** | right | † | **3.11** | **3.59** | **0.44** | **1.01** | 0.67 | 0.87 |
| | left | | 1.11 | 1.62 | 0.33 | 0.50 | 0.22 | 0.44 |
| **PIMS** | best | *• | **6.45** | **2.17** | **12.49** | **2.54** | **9.70** | **0.90** |
| | worst | *• | **18.31** | **2.98** | **22.67** | **2.56** | **19.70** | **0.90** |

* denotes a significantly greater treatment level change compared to initial baseline
• denotes a significantly greater treatment level change compared to second baseline
† denotes a significantly lower treatment level change compared to initial baseline
° denotes a significantly lower treatment level change compared to second baseline

## Log book results

Subject 4 attended 18 of a possible 34 TCC classes since six scheduled classes were cancelled due to humidity levels or poor attendance. She reported no falls and no use of the video over the duration of the study. The most frequent entry (55) into her logbook regarded psychological issues. The rest of the entries in descending order except physical entries are as follows: social, employment, study, transportation and travel, weather and education. The physical entries occurred in the following order: fatigue (45), ADL (23), pain (13), symptoms (12), illness (8), sports and exercise (6), medication (6), physician visits (2), menstruation (1), and falls (1). Subject four reported being menopausal during the study. Excerpts for subject fours log are shown below. The number of positive and negative entries were roughly equal.

> " Felt relaxed and happy, more energy – reason talking to Linda and her understanding.... Feeling good and nothing else to report....I enjoyed the day....Feeling so much better today was able to do a lot of housework and that makes me feel good about myself

> "very up-tight, cranky, nervous....I've been thinking a lot about the lady I met the other day. It bothered me to see how I might look in the near future, how selfish I am – I know what this disease can do to my body and mind but I guess I thought it would progress slower than it has.... I seem to be getting upset easily and crying....Everyone seemed to be picking on me....People don't realize what an effort it is to stand tall and walk or even write I got very angry at a girl at work as she has been saying to me can't you do that any faster, if only I could.....I thought today I must feel like an ant – they are so small but they carry a heavy load....

> Employment was identified by subject 4 as a very important part of her life.

> My biggest wish is to be able to continue working and holding on to my job....I am getting worried that I might not be able to continue work.

Subject four reported muscle soreness after she returned from vacation the day after her first TCC class. This side effect of TCC training was not reported again. The exact log entry is shown below.

"finding my back and leg muscles a bit sore"

Specific comments about the class indicated that subject four reported increased energy after class and enjoyed doing TCC in a group. She did identify that seeing people further advanced in the disease did bother her. Specific log entries are shown below.

> "Felt good after class was over....I wish I was dedicated because I really believe that TCC helps....I enjoy doing it in the group. If I could bring the group home with me. Ha Ha. To night I came away feeling very relaxed and happy....I think TCC is helping my walk ....After class a group of us stood outside and talked about PD and our meds. I enjoyed to hear about other people's problems sometimes mine are so small. I had a feeling that I didn't want to do a thing so I put on the tape and just tried to do it. I did feel better after and should try it more often....I enjoy meeting the other members and talking to them but it hurts so bad to see someone your own age not being able to walk as well as I do. I feel sorry for the person with PD but I also feel sorry for the caregiver, it must be a strain on them. I know B-(husband) worries unnecessarily about me but I am able to take care of myself so far.....Linda and I walked up to TC and I was tired when I got there but after doing TCC my energy level picked up....

Subject four had one surgery during the study on week 8. According to the testing log subject four often expressed "anxiety about having dyskinesias like two other people in study." Subject four stated that she could not lie flat due to rigidity prior to medication.

**Final interview**

When questioned regarding the benefits subject four gained from attending TCC class, she stated, "Yes, my body needs to be stretched and Tai Chi is so slow and easy on your body. I feel we must keep moving and not give in. I also enjoyed meeting and talking to others." She identified "travelling and tired after working all day" as factors which stopped her from attending class. This was supported by entries into the instructor's log that indicated she often missed Thursdays, a day she identified as a busy work-day. A negative aspect identified by subject four in regards to the TCC class was "rushing to get there on time." Home practice was not performed because of "lack of time. Found with IPD it takes longer to do housework." Subject four stated that both the video and the written material were useful. No factors were identified by this subject as either beneficial or negative in regards to the testing. Other general comments made by subject four were: "...very good instructor and your positive attitude helped me in so many ways....I am sorry I did not give 100 percent that I should."

## Support Person's Questionnaire

Subject four did not have a support person attend the TCC classes with her.

## One month follow-up

Subject four reported she had completed menopause and believed that during the treatment phase she was experiencing her worst menopausal symptoms.

## Discussion

Subject four's motor performance appeared to be affected by sickness, stress, and medication effects. Only one medication change occurred during the treatment phase with this subject, July 20, so medication changes likely did not affect the motor scores in this subject.

The likelihood of attaining treatment affect was diminished due to the non-compliance with the home exercise portion of the TCC training. Subject four identified fatigue as the major factor that limited home practice. Compliance was likely affected by the lack of support person. The video and written material did not seem to encourage home practice in this subject. Training impact was also negatively affected by the attendance in only 53% of possible TCC classes that lessened overall training intensity. No balance support was necessary for subject four therefore in TCC classes attended the exercise intensity for each class would have been as intended.

Subject four reported menopausal symptoms during the initial and treatment phases of the study. She suggested that in the second baseline she felt emotionally and physically better because the menopause symptoms had receded by the second baseline. Subject four reported an associated increased stress level in the initial and treatment phases that may have adversely affected the motor scores.

### Gait

Subject four had a non-significant change in slopes from negative to positive between the initial baseline and treatment phases that indicated an improvement in all WS over the treatment phase as illustrated in Figure 49 (page 148) and Appendix O. These trends were maintained during the second baseline phases. Subject four's overall free WS was slower than healthy normative values. The normal free WS of an adult is reported to be between 0.8 and 1 stat/s and subject four's WS were between .65 and .75 stats/sec. (Greive and Gear 1966). There were significant level increases in WS in the second baseline phases over the treatment phase as shown in Table 13 (page 155). The significant level change should be interpreted with caution since it apparently reflected purely a continuation of trends established during the treatment phase and likely did not reflect any change in the second baseline. This pattern was also reflected in the SL data demonstrating the normal direct relationship between SL and WS (MacKay-Lyons 1998, Morris *et. al.* 1994a). The ST showed a normal indirect relationship to WS during the treatment phase that did not carry over to the second baseline (MacKay-Lyons 1998, Morris *et. al.* 1994a). Tai Chi Chuan appeared to maintain the normal inverse relationship of the ST to WS, a relationship that has been reportedly lost as the disease progresses (MacKay-Lyons 1998, Morris *et. al.* 1994a). Subject four was able to maintain WS but was unable to maintain the normal ST relationship in the second baseline. A longer second baseline would have allowed determination if subject four would revert completely to the classic IPD ST – WS relationship.

Single support time showed a non-significant negative trend in the initial baseline and a positive trend in the treatment phase that suggested an improvement of dynamic balance as shown in Figure 52 (page 150) and Appendix O. No significant level changes were noted for SST for subject four as shown in Table 13 (page 155). However the mean fast SST scores for subject four (>39.5%) were very close to normative values ( 40%, Greive and Gear 1966).

Subject four's free speed cadence was between 105-108 steps per minute, slightly less than the average 120 steps per min. (Morris *et. al.* 1994a and 1996a). As with the SST no significant level changes were noted (See Table 13 page 155). This indicated that the reported increased cadence seen in classic IPD gait was not yet present in subject four (Morris *et. al.* 1994a).

There were no significant level or trend differences in any phases for the range of WS for subject four, as shown in Table 13 (page 155) and Appendix O respectively, which indicated a consistent ability to vary gait performance. The variability per phase was around 8% of the free WS that indicated a tendency toward inconsistent ability to vary WS. Functionally, inability to modulate WS could result in an inability to cross streets at a traffic light.

## Balance

The non-significant negative trend in FR indicated worsening of static balance over the initial baseline phase as illustrated in Figure 55 (page 151) and shown in Appendix O. The slope became positive in the treatment phase and was maintained over the second baseline, demonstrating the positive influence of TCC training on FR trends. The values (20-25 cm) indicated that subject four would be at risk of at least 1 fall over the next year (Duncan *et. al.* 1992). No falls were reported subject four over the 26 week study duration. The second baseline phase of FR had significantly greater values than the treatment phase that, as discussed earlier, reflected a continuation of the treatment trends. Also, two extreme negative values in the treatment phase, when the subject reported being sick, may have adversely influenced treatment results. The test values were not always adversely affected by sickness, increased stress level or fatigue. It was likely that a combination of factors alter motor scores. As with the dynamic balance assessed during gait, the static balance of subject four appeared to be positively influenced by TCC training.

## Fear of Falling

The direction of the slope in the MFES data changed non-significantly from negative to positive between the initial and treatment phase suggesting improved confidence as shown in Figure 56 (page 151) and Appendix O. These results agreed with other measures (FR, WS) that indicated that the treatment phase resulted in improved balance. Subject four reported a negative emotional reaction to initial interaction with others more advanced in the disease. Unlike the objective measures, the significantly greater second baseline scores compared to the treatment phase can not be explained as continuation of treatment trends. Subject four did report in logbook entries that she was glad the study was over and hormonal fluctuations associated with menopause were resolved in the second baseline. These subjective reports may be the cause of greater second baseline levels for MFES. Alternatively, these results may be due to the subject's ability to implement balance strategies learned during the TCC training. The second baseline data had significantly greater level than the initial baseline indicating something different, more than TCC training, was occurring in the second baseline.

## Quality of Life

The PIMS scores for the treatment phase had significantly higher levels compared to the baseline phases likely reflecting the negative emotional reaction subject four reported to seeing the other subjects more advanced in the disease as shown in Table 13 (page 155). The PIMS agreed with the log entries where she reported experiencing harsh emotional reactions to seeing the other individuals with IPD who were at later disease stages. Subject four also reported having difficulty attending the classes due to extreme fatigue associated with employment. Regardless of the cause, the data suggested that during TCC training subject four felt that IPD had a greater impact on her life. See Figure 57, page 152.

In the initial phase, sexuality was rated as the most impacted where as in the treatment phase the focus shifted to work and self-negative thoughts. Alterations in mood, cognition, mobility, and fatigue level have been identified as factors that can negatively affect the sexuality in subjects with IPD (Basson 1996, Waters 1997).

However, the previous research involved predominantly male subjects and may not reflect issues related to females (Basson 1996, Waters 1997).

In the second baseline self-negative thoughts were reduced, a fact reflected by both the log entries and improvements in the motor test data in the second baseline. Subject four's reported improved emotional state may have positively influenced the second baseline data.

## Tremor

The non-significant negative trend in the tremor data during the initial baseline phase possibly reflected initial testing anxiety or a learning effect as illustrated in Figure 58 (page 152) and Appendix O. Subject four was left handed and therefore, as previously stated, the right hand tremor scores do not likely adequately reflect the overall Fahn tremor score (see Appendix A). However, there was significantly lower right-sided tremor in the treatment phase. The left hand (dominant hand) tremor scores indicated no significant difference between phases indicating TCC training had no effect on the tremor for subject four. See Table 13, page 155.

## General Comments

The log book data indicated that hormonal fluctuations associated with menopause may have confounded both motor and subjective measures of IPD. Also, psychological entries were the most frequent logbook entries. Sexuality and employment were issues subject four highlighted as important related to IPD. There was an indication that TCC training may positively affect gait parameters in subject four, and the benefits may carryover for at least three weeks after stopping TCC training. Static balance, as measured by FR, may also be positively affected but may not agree with self-reported confidence in balance abilities. There was insufficient evidence to support previous anecdotal evidence that TCC reduces tremor.

Perceived well being was negatively affected by TCC training apparently due to the adverse emotional reactions to interactions with people more advanced in the disease. The meditative effects of TCC training were likely not achieved with this individual do to poor class attendance, non-compliance with home exercise and failure to achieve automatic level of performance of TCC movements.

# CHAPTER 8

# FINAL CONCLUSIONS

## Common trends

Non-compliance with the home exercise portion of this study was consistent between subjects. Therefore the videotape and written material provided did not address issues which interfered with home practice. Fatigue, time, and safety were identified as issues that stopped home TCC training. Attendance in the formal class training was roughly 50% for three of the four subjects with transportation, fatigue, and employment identified as factors limiting attendance. The poor class attendance and the lack of home practice resulted in less training intensity than intended and may have adversely influenced the results. The two individuals with longer disease duration required hands-on physical assistance during the TCC classes that decreased the exercise intensity and possibly reduced the treatment effects in these individuals.

Logbook data indicated that individuals with IPD have concerns over their physical safety and psychological well being. There appeared to be poor education regarding physical signs and symptoms of IPD as well as the specifics regarding medications. The logbook data helped to highlight individual concerns regarding their disease as well as factors that might adversely affect their motor performance and function. The tester logbook data suggested that some individuals attempt to cover-up their motor deficits by employing distraction strategies and confabulating reasons why their motor performance was affected. Instructor logbook data indicated that frequent verbal cueing was required in the class to ensure proper weight-shifts and cue the next movement. The amount of physical assistance was reduced over the duration of the study.

## Gait

Although the statistical analysis provided inconclusive evidence, visual inspection of the data indicated that TCC training improved gait parameters for individuals with shorter disease duration. There was also some indication from the visual analysis that TCC training may stabilize gait performance in individuals with longer disease duration. Though inconclusive results were obtained, visual inspection indicated that the normal healthy positive relationship of SL and WS and the indirect relationship of ST and WS may be preserved with TCC training. The variability and dyskinesias seen in the two subjects with longer disease duration may have masked the training effects. Also, the training duration or intensity may not have been sufficient to find significant differences. Since the two subjects with longer disease duration required hand-on balance assistance, the exercise intensity was less for these individuals. There was a slight indication that SL improved more for the slow than the fast WS. Again, visual inspection indicated that the non-significant SL trends may be positively influenced by TCC in the two subjects with the least disease duration. Stride time tended to be reduced the greatest amount for the faster WS. Visual inspection of the SST trends indicated a greater amount of time was spent in double support for the slower WS. This possibly reflected the difficulty the subjects had in maintaining balance while walking slowly. There were fewer trends in the fast WS, possibly because at the fast speed, the system was maximally stressed and there was a decreased ability to vary the gait parameters to create the motion. Cadence at the fast WS remained consistent during the treatment phase for all subjects. Visual inspection suggested increased cadence at the slower speeds for the two subjects with shorter disease duration. There were no consistent trends in the range of WS for the four subjects studied.

## Balance

There was no statistical evidence that static balance, as measured by FR, positively influenced by TCC training. Visual analysis did indicate improvement in FR for three of the four subjects tested. The one subject that FR did not increase had the longest disease duration and frequent medication changes over the course of study, possibly confounding the results. Since FR has been reported to decline as the disease progresses (Grills 1999, Smithson *et. al.* 1998), these non-significant trends toward improved FR indicate that TCC training may improve the static balance capability of people with IPD. As metioned earlier, TCC training appeared to be more likely to improve static balance in subjects with shorter disease duration.

## Subjective Measures

The fear of falling significantly increased during the treatment phase for three of the subjects tested. The one subject that showed reduced fear of falling had the shortest disease duration. This possibly reflected the challenging nature of the TCC training as it is taught within the community. Tai Chi Chuan addresses the specific balance issues that are adversely affected by the development of IPD. Perhaps a modified program with a limited number of movements, as has been used in previous research, would be more appropriate for people with more advanced IPD. The draw back of such a program is that the community availability of the TCC training becomes limited.

The lack of consistent trends (visual or statistical) in the subjective assessment of the impact of IPD on the subjects possibly reflected the different coping abilities of individuals with IPD. The amount of home support and ability to remain employed were identified as major determinants of the perceived impact of IPD on people's lives. The subject's sexuality also was reported by all subjects as being negatively impacted by the diagnosis of IPD.

## Tremor

There no indication that TCC impacted tremor in the four subjects. The inability of the tremor test to differentiate between dyskinesias and tremor may have confounded results. These data do not support the anecdotal reports of improved tremor with TCC training. Perhaps people reporting improvements are not able to differentiate between resting tremor, action tremor, and dysinesias. Exercise has been shown to improve dyskinesias and may explain the reports of tremor improvement with TCC training (Reuter *et. al.* 1999).

## Overall

The visual analysis did not agree well with statistical analysis of trends. The visual analysis suggested trends that may gain statistical support in future larger studies. Statistical determination of phase level changes were often inconclusive due to phase length differences and presence of non-significant trends.

Although statistical analysis failed to indicate any significant trends in gait parameters, visual analysis of the gait trends in the four subjects indicated the two individuals with shorter duration, who participated in TCC exercise, may improve WS, SL, and range of WS. The anticipated negative trends in the ST data were not indicated with statistical analysis but suggested in the visual analysis of the two subjects with shorter disease duration. Tai Chi Chuan training had little influence over SST and cadence. There were also positive trends in the visual analysis of the static balance measure for the two individuals with shorter disease duration that were not supported by statistical analysis of trend data. Since the two individuals with longer disease duration required hands-on balance support, the intensity of balance training may not have been sufficient to gain treatment effects. Also the non-compliance of all four subjects with the home TCC practice lessened the exercise intensity. Medication alterations were well represented in the objective measures and resulted in increased variability in the motor performance

Subjective impression of confidence of ability to perform activities of daily living without falling did not always agree with the more objective measures indicating that fear of falling, falls, and postural stability are measures of different aspects of balance. People may reduce activities that would increase their risk of falls if they fear falling. Postural stability measures do not often reflect functional activities that often result in falls (Duncan *et. al.* 1992). The hypothesis that TCC training would decrease the fear of falling was not supported by the MFES data likely because TCC training challenged the functional issues (balance) most affected in IPD where as previous research with TCC assessed healthy and frail individuals.

The subjective rating of disease impact showed individual variability and TCC training did not appear to conclusively positively impact the perceived well-being in the individuals tested. The one individual that improved her PIMS scores once the treatment phase began was likely heavily influenced by the group activity more than TCC training specifically. The destabilizing effects of the dyskinesias experienced by the two individuals with IPD may have increased their risk of falling which may have negatively influenced their MFES scores.

The meditative effects of TCC training were probably not achieved in this study, since new movements were taught each class, which may have lessened the impact of TCC on subjective data. Individuals with IPD appear to learn slower and require information to be presented in a pre-sequenced order to ensure retention and retrieval of information therefore TCC training should be an achievable task for individuals with IPD. The meditative aspects of TCC training should assist in reducing the "noise" caused by BG dysfunction during information processing and motor output.

There was no indication that tremor was influenced by TCC training which likely reflected the confusion of subjects between resting or action tremor and dyskinesias.

## Limitations

The limitations of this study include: limited generalizability, absence of blinding, and absence of comparison exercise protocol. Randomization of subject selection would have allowed greater degree of generalizability. However, it might not have represented the different disease presentations. Single subject designs are more generalizable than case studies and the external validity of the SSD was improved through systematic replication of the exact protocol on multiple subjects representing different disease presentations. This study was a preliminary study and was designed to help identify the individual characteristics of people with IPD who would benefit from TCC training. As the individual disease presentation was highly variable, individual improvement might be masked in a larger study. The inclusion of only two stages of IPD weakens the external validity of results. However, people in the later stages of the disease may have difficulty remembering, or safely performing, the movements. Stage II and III show better reliability in measurements thereby enhanced the likelihood of determining statistical differences in outcomes measured. Also, people in stages II and III are still functioning within the community and are better able to attend scheduled testing and training sessions. In stage I symptoms are adequately controlled with medication and no alterations in the soft tissue and joint mobility are seen. The SSD can answer how TCC impacts an individual, it can not conclusively determine cause and effect and a randomized control trial would have to be performed to answer this question.

The lack of subject, instructor, and researcher blinding could have influenced subjective results. However, interaction effects were expected between the instructor and TCC students. This interaction was part of the social benefits of TCC group training. Researcher blinding was not possible due to funding limitations. Funding limitations also prohibited a second treatment phase using an alternative exercise to determine if changes were the result of exercise of any form.

The lack of control over prescribed medication, environmental conditions, and hormonal fluctuations associated with menopause may have confounded the results. It was not considered ethical to withhold medication changes that could help the subjects involved in this study. The available testing and exercise sites were not temperature or humidity controlled. The anecdotal reports of worsening symptoms with menstruation, and different phases of hormonal replacement therapies, was not expected and therefore information and controls were not implemented.

Finally, the SSD allowed only limited very broad statistical analysis. However, this study helped determine whether TCC training impacted the disease trends in the outcomes measured in the four individuals by showing non-significant improvements in trends for subjects with shorter disease duration.

## Research Recommendations

1. Multiple SSD may be useful in determining differential effects of training methods on subjects who suffer from diseases with great individual variability.

2. In SSD equal phase lengths are necessary to allow complete comparison between phase data.

3. A larger randomized control trial is necessary to determine definitive cause and effect relationship between TCC training and improvements in selected motor measurements.

4. Treatment and testing should be performed in a climate controlled environment whenever possible.

5. Further investigation needs to be made into the effects of menopause, hormonal fluctuations, partner and subject stress management, and sexuality in women with IPD.

6. Video and written information does not appear to be sufficient support to ensure compliance with home TCC programs. Individual variability in motivation and compliance should be addressed with frequent reinforcement of the necessity for daily practice. Structure should be implemented to promote compliance and it should be investigated if females react differently to this type of exercise program than males since the compliance with the TCC classes was less than expected based on previous research in males.

7. Home safety and emotional support issues need to be addressed prior to study commencement to decrease adverse effects on results.
8. Newly diagnosed people may not seek alternative information sources like the Parkinson's Foundation due to anxiety over interaction with individuals with longer disease duration therefore adequate information needs to be provided to subjects to enhance compliance and result reliability.
9. Partner's well being and reactions to the diagnosis need further investigation.
10. Although FR decreases with increased disease duration, it may not be predictive of falls once individuals with IPD develop dyskinesias. Further investigation is required into the predictive ability of FR once dyskinesias begin.
11. Development of the FR to assess backward and lateral balance may improve the usefulness as a clinical assessment tool for individuals with IPD.
12. For research in the balance capabilities of individuals in Stage II and III IPD, balance measures with greater sensitivity than the FR should be used.
13. Tight adherence and monitoring of medication dosage and schedules should be maintained since medications are not only adjusted by the physicians, but also by the patients to achieve optimal functional performance so that social or routine activities obligations may be met.
14. Careful consideration should be given to the timing of exercise classes since both employed and unemployed individuals with IPD suffer from increased fatigue levels.

15. Transportation should be provided to participants with IPD to improve attendance in exercise classes since this was identified as a major factor that limited attendance.

16. Previous research has shown cardiovascular (CV) disease is the main cause of death in people with IPD and TCC has been shown to help maintain CV fitness in other clinical populations. There is a need to evaluate the CV and respiratory benefits of TCC training in individuals with IPD since the deep breathing and movement should help maintain chest expansion thereby preventing the occurrence of pneumonia, the second leading cause of death in people with IPD.

17. Previous research used only a limited number of TCC movements (<10). The necessity of the subjects in this study to constantly be learning new movements each class may have exceeded their learning capacity, increased stress levels and negated the meditative effects of TCC. The optimal number of movements for a specified training period needs to be investigated.

## Clinical Recommendations

1. Variability of dominant symptoms and individual neural adaptations to dopamine insufficiency in people with IPD requires individual exercise program development. Physical and emotional issues should be considered when designing a personalized program. A detailed interview should be made to assess if exposure to other individuals further advanced in the disease would adversely affect the patient's attitude toward their disease. Since some people appear to be adversely affected emotionally by exposure to people in the later stages of IPD, group classes are more appropriate for certain individuals with IPD than others.

2. Different styles of TCC emphasize different muscle group training; therefore, additional maintenance exercises should also be performed to minimize flexed postures. This should be addressed when designing an exercise program for people with IPD.
3. Home TCC practice is likely necessary to gain TCC training benefits. People more advanced in the disease may benefit but require much more support from friends and family to allow safe practice of TCC. The earlier TCC training is begun the less home support is necessary.
4. Identification of previous exercise that individuals found enjoyable might increase the likelihood of compliance with home or structured exercise programs.
5. Employment of logbook data for a clinician may help identify factors limiting performance and issues that might interfere with the treatment program.
6. Females may react differently to the training or perhaps there are differences in home support between males and females that might adversely affect compliance.
7. The number of moves learned in this study did not allow the subjects to attain meditative gains. Limiting the number of new movements may be more appropriate to gain the meditative effects by reducing the stress associated with learning new movements every class.
8. The physical and mental well being of the caregiver should be addressed. As the physical symptoms worsen the caregiver will be required to perform increasingly more physical functions in transfers. Tai Chi Chuan is an activity that the two can perform together that is not solely rehabilitative in nature. Such community based TCC programs move a portion of the management of the disease from the health

care arena into the community thereby supplying social support and widening the individual's social circle.

9. Employment is a great concern for people when newly diagnosed with IPD as well as though further advanced in the disease so adaptation of work environment or tasks might extend the duration of employment. Also, counseling should be provided to reduce anxiety over potential job loss or lack of promotion.

10. Since many issues arise beyond purely physical problems in individuals with IPD, a team approach to treatment is suggested.

11. Based on my research, there was some indication that TCC training may assist people with IPD of shorter disease duration. The earlier individuals start TCC the more likely they are to benefit. The longer form is more difficult for people to learn but increases CV benefit. To achieve meditative effects, fewer TCC movements should be taught per class. If the full 108 movements are to be learned several things would have to occur: daily home practice, longer training period with fewer forms taught per class, and individual and group practice during class time.

Appendix A.

Partial Fhan Tremor Scale Pilot Work

**Pilot Study: The validity of the Partial Fahn Tremor Scale.**

By Linda MacLaggan

**Purpose**: To establish the validity of the Partial Fahn Tremor Scale compared to the total Fahn Tremor Scale.
**Subjects:** Five right-handed subjects, post deep brain stimulation, between the ages of 50-75.
**Methods:** Retrospective chart analysis of the Partial Fahn Scale scores compared to the Total Fahn Temor Scale scores.
**Analysis:** Spearman's Rho and Wilcoxon Rank Sum tests.
**Results**: Right hand partial Fahn scores were not significantly different from ($p > 0.05$) and were highly correlated to ($r = .93$) the overall Fahn scale values.
**Conclusion:** This portion of Fahn tremor scale was valid for the dominant hand only.

**Introduction**

Tremor is one of the cardinal signs of Parkinson's disease, however clinical measurement of this sign is difficult. Tremor tends not to be consistent and may vary from minute to minute. Many different methods have been developed to attempt to accurately represent tremor. Clinical rating scales have been useful in determining the impact the tremor has on a person's function. One popular scale is the Fahn tremor scale. Unfortunately, this scale takes approximately 20 minutes to administer. This may not be practical for clinical assessments due to time constraints. Much of this scale is ordinal in nature however certain components are quantitative. The drawing of spirals and marking between the lines allows an opportunity for quantitative analysis (see Figure 1). This part of the scale was chosen since it closely represents the functional task of writing. The purpose of this study was to determine if the assessment of the spiral and lines portion correlates to the overall Fahn tremor scale score. The objective was to determine if counting the number of times a person touches the lines during this drawing task correlates with the overall Fahn tremor scale. Also, to determine if each hand correlates equally to the overall Fahn tremor scale.

**Methods**

A retrospective chart analysis of five Parkinsonian subjects, post deep brain stimulation, who had been assessed using the Fahn tremor scale was performed. Subjects ranged from 50 to 77 years of age and all were right hand dominant. Four subjects were left hand tremor dominant and one was right hand tremor dominant.

Each time the subject was assessed post deep brain stimulation (DBS) the scales were rated according to the number of times the lines were touched during the drawing task (see figure 1). Some of the spiral and line results were not used due to inability to determine the results. The majority of the scores were assessed while subject was on DBS. A total of 15 scales were assessed. The total Fahn score was also recorded. One rater scored all spiral & line tests and a second rater scored the overall Fahn tremor scale. In the line & spiral test, freezing made some results uninterpretable. Any time the drawn line remained on the outline it was given a score of one.

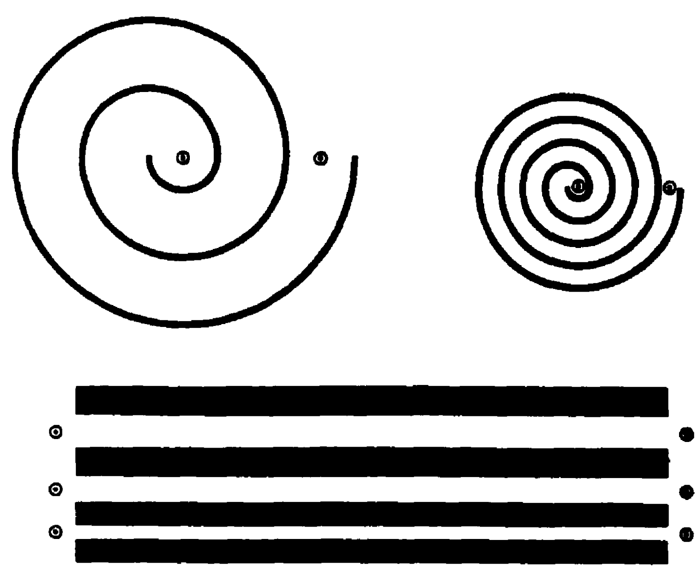


Figure 1. The spiral and line portion of the Fahn tremor scale.

**Analysis:**

The data were analyzed using Statview program version 4 with non-parametric statistics (Wicoxon Signed Rank test for differences & the Spearman Rank correlation for relationships).

**Results**

The correlations and significance of the correlations are shown in Table 1. The Spearman's rho correlation was significant for the left and right hand compared to the overall Fahn tremor score but the total of both hands was not significant. The Wilcoxon test for differences results are seen in Table 2. The right hand and total from both hands were not statistically different than the overall Fahn tremor score. The left hand compared to the Fahn tremor score was statistically different.

Table 1. Correlation values for the overall Fahn tremor scale to the bilateral, right, and left-hand ratings for the line & spiral portion of the scale

| | Bilateral total | right | left |
|---|---|---|---|
| rho | .600 | .929 | .755 |
| significant | .2301 | .0229 | .0236 |

Table 2. The Wilcoxon signed rank test scores of the overall Fahn tremor scale to the bilateral, right, and left hand ratings for the line & spiral portion of the scale.

| | Bilateral total | right | left |
|---|---|---|---|
| Z value | -2.023 | -0.169 | -2.803 |
| P value | .0431 | .8658 | .0051 |

**Discussion**

The results indicate that the dominant hand correlates strongly with the overall Fahn tremor scale and was not significantly different from the overall Fahn score. Although the left hand had a significant correlation value the data showed the score was significantly different from the overall Fahn tremor score. The systematic error associated with the left-hand score was likely the cause of the low correlation of the bilateral total with the overall score. These results indicated that performing the dominant hand line & spiral test may be a fast alternative to performing the overall scale in indicating severity of the tremor.

The major limitation was that this was pilot work and the sample size was very small which weakened the generalizability of the results. Also, the reliability, and responsiveness to change has not been established for this portion of the scale. The overall Fahn scale has been shown to be reliable and valid.

It should be noted however that the total scale gives a better indication of how the tremor might affect other areas of function and might be more appropriate to lead rehabilitation intervention.

**Conclusion**

The line & spiral portion of the Fahn tremor scale may be a useful tool for in-term tremor assessments as a fast method to determine overall score although the overall Fahn scale would provide more information as to nature and functional issues associated with the tremor.

Appendix B.

Pilot work for FR

The reliability of functional reach measures of two dyskinetic subjects with Idiopathic Parkinson's "on" and "off" medication.

By Linda MacLaggan

**Subjects**: Two females in stage II or III of ideopathic Parkinson's disease (IPD) suffering from dyskinesias.
**Design.** Single subject designs.
**Method:** Subject 1; Functional reach (FR) was measured 60 minutes post medication ("on") every three minutes for ten measures for the first set of measures, then FR was measured just prior to medication, 270 minutes post medication ("off"), three months later using the same protocol. Subject two; FR was measured first just prior to medication, 225 minutes after medication ("off"), first and then 60 minutes after medication ("on") three months later using the same protocol.
**Analysis:** The maximum percent error of mean of any three sequential trials was calculated. Descriptive statistics of mean FR distance in cm and standard deviation for each subject were determined.
**Results:** Subject 1: mean FR "on" medication = 22.4cm, "off" medication = 16.3cm, Maximal % error "on"<9% and maximal % error "off" < 5%.
Subject 2: mean FR "on" medication = 29.3cm, "off" medication=165.9cm. Maximal % error "on" <10%, and maximal % error "off" < 16 %.
**Conclusion:** Subject 1 FR scores were more reliable "off" medication but the distance reached was less. Subject 2 was more reliable and reached farther "on" medication.

**Introduction**

In older individuals, more than 200,000 fractures are directly attributable to falls and the one year mortality rate is greater than 15% (Kenzora *et. al.* 1984, Duncan *et. al.* 1992). Chronic conditions like Parkinson's disease, a degenerative neurological condition, can impair balance abilities as people age (Rajput & Birdie 1997). Many different tools have been developed to identify people at risk of falling and monitor the ability to control balance. Functional reach (FR) is a popular balance measure among clinicians because it is inexpensive, portable, and easy to use. This tool has been shown to be reliable, valid, predictive of falls, and sensitive to change in populations that included people with PD (Duncan *et. al.* 1990 & 1992, Weiner *et. al.* 1992 & 1993). These studies involved a small number of subjects with PD (<13%) and as such may have masked the measurement variability seen in people with PD. Variability in motor performance secondary to medication effects have been reported (MacKay Lyonns 1998). The purpose of this pilot study was to determine the test retest reliability of FR measurements in two women with moderate idiopathic Parkinson's disease (IPD) just prior to medication ("off") and one hour after medication ("on").

Assessing balance in people with IPD is difficult due to the variability in the disease and medication side effects. Once people have been on L-dopa medication more than 5 years they often develop what is termed "on-off" phases (Eriksson et. al. 1984). The "on" phase is when the medication is working as expected and the "off" phase is when the medication is not working well resulting in reemergence of IPD symptoms. The timing of these phases becomes unpredictable as the disease progresses. Dyskinesias, unwanted choreic movements, and dytonias, involuntary sustained muscular contractions, occur the longer people are on medications. These dyskinesias can occur at peak dose, end of dose, or during the transition from "on" to "off" periods. Traditionally, measurements have been taken one-hour post medication ingestion ( 25% of the medication cycle). The medication cycle of most people with PD is 4-6 hours and represents the time between L-dopa medications. A previous study has shown less variability in standard measurements when they were taken between 40-60 % of the medication cycle (MacKay-Lyons, 1998) however this does not necessarily reflect the time of their best motor performance. The post medication window in which reliable measurements can be obtained has only begun to be examined.

The procedure usually employed for FR requires the person to stand barefoot beside a meter-stick adjusted to the height of the acromion (shoulder level). The person is asked to raise the arm closest to the meter stick to shoulder height (90 degreees) and "reach forward as far as possible without taking a step" (Duncan et al 1990). The mean value (of three trials) of the difference between the start and stop positions as measured from the position of the third metacarpal of the extended arm is considered the reach distance. The FR relies on the rater's ability to determine the position of the metacarpals relative to the meterstick and are subject to paralax error. Dyskinesias and tremors often present in people with PD make the readings more difficult affecting the reliability of results. Previous studies have used handles to adapt FR, however, handles may encourage some weight to be transferred to the handle therefore the push-bar was employed in this study (Duncan et. al. 1990).

Functional tasks like reaching require control of the center of mass within the base of support. The FR is a functional goal oriented task that is thought to represent the usual manner in which a person controls their balance in a double weight bearing position. It is unlikely that FR reflects dynamic postural stability required during ambulation.

The criterion validity of FR was established by Duncan et al 1990 through concurrent measurement of the reach distance of 134 healthy elderly subjects using a force plate to give center of pressure excursion measures (COPE), electronic push handle system (ES) using a potentiometer readings, and a yard stick (YS). The population tested did not include people with PD. Subjects stood on a force-plate during the YS measure only. Reach distances from the YS and the ES correlated well to the COPE (PPMC YS & CPOE r=.71, YS & ES r= .69). Test retest reliability ICC (1,3) for the three measures was highest for the FR (FR=.92, COPE = .52, ES = .81). Anthropometric measures, particularly height, were highly associated with the distance reached (r>.81). Age was also negatively correlated with reach distance with all three measures (COPE = -.37, ES= -.54, FR=-.45) such that if age increased 10 years the FR decreased an average of 7 inches. After stating that height was an important determinant of FR, Duncan et. al. 1990 published the normative values based on gender only.

Weiner et. al. 1992 further extended their previous research by evaluating FR as an indicator of physical frailty in elderly. The same protocol was used for 45 elderly (unknown if any suffered from IPD) and the reach differences were compared to several indices of mobility and ADLs (Physical and instrumental activities of daily living [PADL], life space social mobility scale, mobility skills, walking speed, one leg stance time, tandem walking). The FR correlated well with all the scales(r>.50) except for the PADL (r=.48). The results suggested that the FR was able to discriminate levels of physical frailty and further strengthened the concurrent validity of this tool.

The predictive validity of the FR was established by Duncan et. al. 1992 using a population that consisted of 13% subjects with PD. The same FR protocol was used as employed by Duncan et. al. 1990 and self-report falls were analyzed. The results indicated that reach distances less than 6 inches predicted recurrent falls and physical frailty. There was sufficient evidence that FR was predictive of recurrent falls in the 217 elderly male veterans studied. Age, depression and Mini Mental State exam score were also associated with shorter FR distances (Duncan et. a.l 1992). Disease stability was assumed over the 6 month study which is unlikely with subjects with IPD.

Weiner et al 1993 explored the FR ability to detect change over time. Twenty eight male veterans (unknown if any had IPD) were compared using a responsiveness index (RI, exact calculation not stated) where a lower number indicated better responsiveness. As baseline variability increased the change over time needed to be larger to detect a difference. The mean baseline variability was 2 inches. FR and other measures of physical performance assessed showed sensitivity to change (RI FR=0.97, other measures 4.63-11.26). These results would be expected since FR was a continuous measure and the scales were ordinal measures.

Although FR has been tested using subjects with many varied conditions (largest number of subjects from the following diagnostic groups: Parkinson's, stoke, myelopathy, sensorimotor peripheral neuropathies, amputations, inflammatory arthritis, and joint replacement) it is not appropriate for all populations. Light et al 1996 found that FR was not able to differentiate between elderly individuals with vestibular disequalibrium and without. Reach strategies were assessed and found to be similar between groups. These results agreed with later research by Robinson et. al. 1999.

One limitation of the FR test is that it assesses balance only in the anterior direction and control of balance is necessary in all directions. Newton 1997 developed a four direction FR screening tool for inner city adults, however, the reliability and validity of this tool has yet to be established.

In the original Duncan et. al. 1990 paper the FR was described as a measure of dynamic balance. It would be more correct to state it as a measure of self perturbed anterior postural stability with the feet together. In every day function lifting with the feet in this position may not occur. A stride step is the more usual position however the bilateral stance allows easy standardization of foot position. Robinson et. al. 1999 studied FR as dynamic balance measure and found FR correlated with anterior-posterior sway only (r=.69 to .84 ). The mean moment arm during the FR was less than that of free gait. The difference in moment arm length would be expected since free gait requires the body's center of mass (COM) to be displaced beyond the base of support. The COM movement allows forward progression of the body as the back leg is quickly brought ahead to "capture" the COM within the base of support and prevent a fall. Although FR is correlated but does not directly reflect dynamic balance needed for gait, it does reflect the control of balance necessary for standing mobility and transfers.

**Subjects**

The specifics of each subjects may be seen in Table 1. Subjects were recruited by poster and referral from local neurologists. Subjects were included if they were in Hoehn & Yahr stage II or III IPD, suffering from dyskinesias, and able to ambulate independently. Subjects were excluded if they were legally blind or had other physical ailments, other than IPD, that might limit balance. Six subjects were recruited but only two met the inclusion / exclusion criteria.

Table 1. Subject details

| subject | Height (cm) | Age | Duration since diagnosis | Stage | Medications |
|---|---|---|---|---|---|
| 1 | 156 | 52 | 10 years | 3 on<br>3 off | Levodopa 100/25mg tid<br>Ropinirole 0.75mg tid<br>Neuronton 400mg tid<br>Elavil 50mg<br>Novotriamzide 50mg bid<br>Eldypril 5mg bid |
| 2 | 160 | 61 | 12 years | 2 on<br>2.5 off | Levodopa100/25mg tid<br>Ranitidine 150mg bid<br>Symmetrel 100mg tid<br>Ropinirole II 4mg tid<br>Novotriamzide 50mg bid<br>Eldypril 5mg bid |

Abbreviations: bid = twice a day, tid = three times a day

**Material and methods**

For this study "on" medication will refer to the time one hour post medication ingestion, a time which the plasma levels of L-dopa are considered to be greatest resulting in best motor functioning, and "off" medication will refer to just prior to medication. The exact timing of "off" measures differed because the subjects had different medication intervals

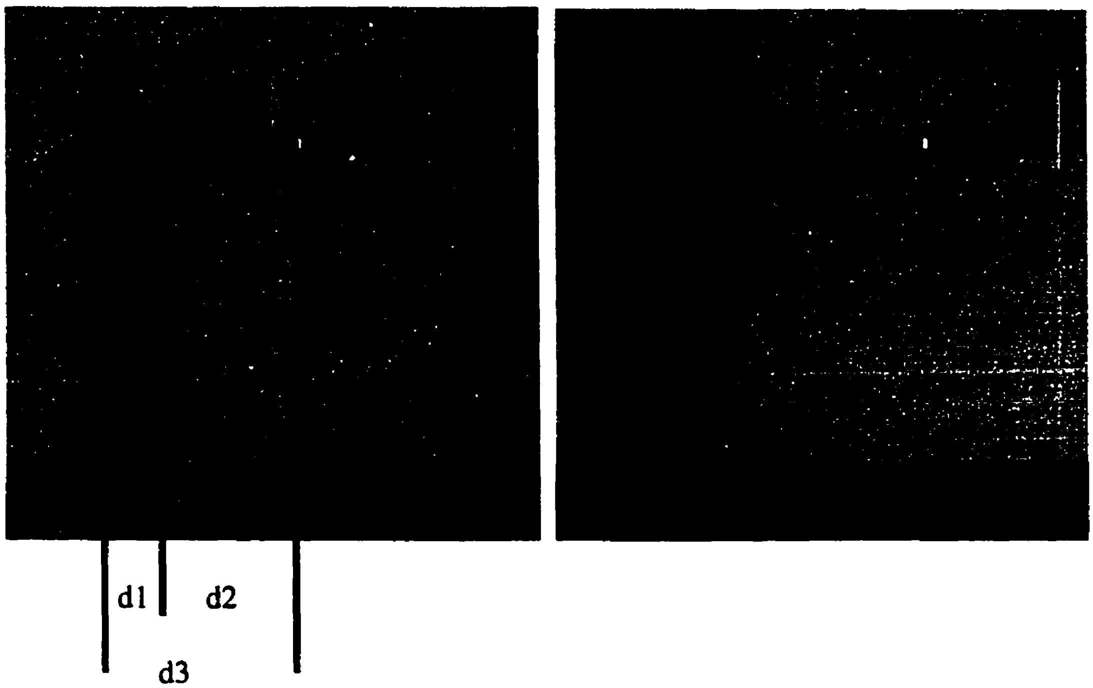



Figure 1. Modified FR. d3 = length of arm from acrominion to tip of middle finger. d1 = distance from medial malleolus to tip of great toe. d2 = the difference in between the arm and the partial foot measurement. d2 = d3 – d1 and represents the distance from the meter stick 10 cm mark that the footplate was placed.

The subject's ability to control balance during forward reaching was assessed using FR. For the purposes of this study, FR was considered a measure of static (feet not moved) balance. The subject stood with their feet together, arm flexed to 90 degrees, and the change in fingertip position was measured using a meter stick placed at shoulder level (level of acromion) as the subject reached forward. Due to the high degree of motor variability in IPD, the foot position was standardized to improve the reliability of measures. A foot-plate was placed so that the toe position equaled the difference between the arm (tip of acromion process to tip of third finger) and foot length (distance from medial malleolus and tip of great toe) from 10 cm mark of the meter stick. See Figure 1. The meter stick was also modified with a push bar to reduce the error introduced by paralax, rater reliability of the metacarpal head or fingertip position, and subject dyskinesia or tremor. Standardized FR instructions were as follows: "stand with your toes against the foot-plate, raise your left arm to shoulder level and push the bar slowly forward as far as you can without lifting your heels off the ground." The average of three consecutive FR measures was calculated and used to improve reliability. Measures were discarded if the subject pushed the bar too quickly resulting in movement beyond the ends of the fingers or if the heels left the ground. A rest of at least 90 seconds was provided between each reach.

At each testing session the subjects had ten FR measurements taken three minutes apart. Subject 1 was first measured "on" medication and three months later the testing was repeated "off" medication. Subject two was measured using the same protocol however measured "off" first and then three months later measured "on" medication. Subject 2 experienced dyskinesias throughout both tests but they were more pronounced during the "off" testing. Fatigue was monitored subjectively during the testing and neither subject stated fatigue was an issue during testing.

## Results

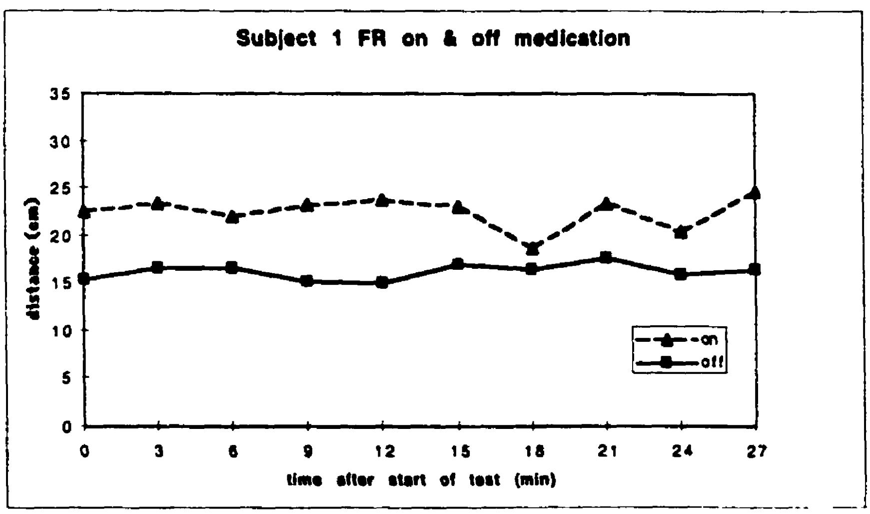


Figure 2. Subject 1 FR distances "on" and "off" medication

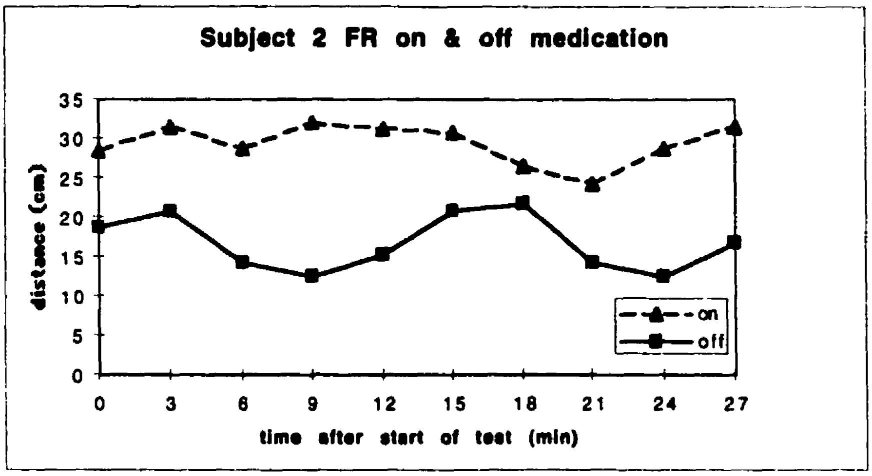



Figure 3. Subject 2 FR distances "on" and "off" medication

Figure 2 shows the actual reach distances for subject 1 "on" and "off" medication. The mean reach distance "on" medication was 22.5+/- 1.8 cm and "off" medication was 16.3 +/- 0.8 cm. There was a 28 % reduction in mean reach distance between "on" and "off" measurements. At 72 minutes after medication, subject 1 reported the onset of dyskinesias during the "on" testing. Subject 1 was also participating in another study which indicated that on the same day the "off" measurements were taken, the mean value of three "on" reaches was 21.4 cm.

Figure 3 shows the actual reach distances for subject 2 "on" and "off" medication. The mean reach distance "on" medication was 29.4 +/- 2.5 cm and "off" was 16.7 +/- 3.5 cm. The mean reach distance was reduced 44% as the medications wore off. Note the rhythmical variability predominant in the "off" reach distances for subject 2. The pattern was not as noticeable in the "on" measures.

Table 2. The mean FR distance for any three reaches and the percent error. Percent error was calculated by subtracting the average for three reaches from the overall average divided by overall average and multiplied by 100 ((avg 3 FR – overall mean / overall mean ) * 100).

| | Subject 1 | | Subject 2 | |
|---|---|---|---|---|
| tests | % Error ON | % Error OFF | % Error ON | % Error OFF |
| 1,2,3 | 0.4 | 0.2 | 0.9 | 7.0 |
| 2,3,4 | 1.6 | 0.4 | 4.7 | 5.2 |
| 3,4,5 | 2.2 | 3.6 | 4.3 | 16.3 |
| 4,5,6 | 3.8 | 2.8 | 6.4 | 3.4 |
| 5,6,7 | 3.0 | 0.6 | 0.2 | 14.8 |
| 6,7,8 | 3.6 | 4.6 | 7.6 | 13.0 |
| 7,8,9 | 7.4 | 2.5 | 9.8 | 3.6 |
| 8,9,10 | 1.4 | 2.7 | 3.9 | 13.5 |

The maximal % error for the mean of any three reach distances "on" medication for subject 1 are shown in Table 2 and occurred at 18 minutes after test commencement (78 minutes post medication) and was 7.4 %. All other means had less than 5% error. The maximal percent error for the "off" phase occurred at 15 minutes after the start of testing (285 minutes) and was less than 5%.

The maximal percent error associated with the "on" testing for subject 2 is also shown in Table 2 and occurred at 24 minutes post testing (84 minutes post medication) and was 9.8%. Percent errors were only less than 5% for the first six minutes after testing commencement. Six of the eight measures were greater than 5% error for the mean reach distance of three consecutive reaches. The smaller errors occurred interspersed among the other measures at time 9 minutes and 24 minutes after test commencement. Also note the increased variability in the "off" scores of subject 2.

**Discussion**

Subject 1 was more reliable (max % error <5%) during the "off" testing however her mean reach distance was reduced by 27% (6.2 cm). Even though the maximal error occurred during the "on" phase, it happened after the self-report onset of dyskinesias. Since this subject was able to accurately report the time at which dyskinesias occurred, subjective report may be useful way to monitor motor performance of "best on". For subject 1 FR was reliable for the mean of any three measures "on" or "off" medication, however the reliability was better "off" the medication. This did not necessarily reflect the best motor performance.

As with subject one the mean reach distances "off" for subject 2 were less compared to the "on" measures (12.7 cm less, a 44% reduction). Unlike subject 1, the reliability was worse "off" (max % error <16%) than on (max % error <10%). With subject 2 the maximal percent error "on" occurred at 84 minutes post medication. For subject 2 the reliability was poor for both "on" and "off" the medication. The reliability became worse as the dykinesias worsened and medication wore off. The rhythmical pattern in the "off" medication FR may represent the dyskinesias or the on/off effect of the medication as it wears off.

The differences in the reliability of the two subjects highlights the individual variability in motor performance seen in IPD. Subject 1 may have had peak dose dyskinesias while subject 2 may have had end of dose dyskinesias. Clinicians will only know when patients suffer from dyskinesias by performing careful interviews with their clients. Even though the dyskinesias appear to interfere with the reliability of FR measurements, they still likely reflect the COPE described by Duncan et. al. (1990). FR may only reliable for a narrow time frame post medication and may be less reliable for subjects who suffer from severe dyskinesias.

Subject 1 results support the findings of Mackay Lyonns (1998) which showed that measures taken 1 hour post medication may not provide the most reliable results. However, both subject's results support the idea that the one hour post medication may reflect the time of best functioning. These results support the results described by Duncan et. al. 1990 that the "on" medication mean reach distances for the taller subject (subject 2) were greater than for subject 1 (30% greater, 6.9 cm)

The validity of the FR to predict falls may be questionable given the variability in motor performance once dyskinesias appear. The dyskinesias may create a destabilizing effect causing pertubations in balance which are difficult to anticipate or correct. Also, the validity of detecting physical frailty in subjects with IPD is questionable. Previous studies only used small number of people with IPD and medication timing were not discussed. The small numbers of subjects with IPD may have masked the performance variability in the IPD subjects. Clinicians should be cognisant of the effects of medication timing and dyskinesias on FR test scores. Efforts should be made to improve the reliability of the scores by standardizing the test time after medication ingestion as well as foot and start positions. Otherwise the value of the test score is questionable.

**Conclusion**

Medication induced dyskinesias may severely influence the FR reliability. FR measure is fairly reliable prior to the onset of dyskinesias. As self-report dyskinesias worsen the reliability of FR measurements also worsens. The dyskinensias occur at different medication phases for different people and must be considered when assessing motor performance.

Appendix C.

Ethical Approval

DALHOUSIE
*University*

FACULTY OF
GRADUATE STUDIES

March 18, 1999

Ms. Linda MacLaggan
1263 Queen Street, Apt. #802
Halifax, Nova Scotia
B3J 3L4

Dear Ms. MacLaggan:

The Human Ethics Review Committee of the Faculty of Graduate Studies has examined the ethical aspects of your research proposal entitled "The Effectiveness of Tai Chi Chuan training on the balance, gait, tremor, fear of falling, and quality of life in four people in stage II or III Parkinson's", and have agreed that your proposal is acceptable from an ethical point of view.

I wish you every success with your project.

Yours sincerely,

Daniel Woolf
Associate Dean
Faculty of Graduate Studies

DW/lrs

cc: Dr. George Turnbull

Room 314, Arts & Administration Building
6299 South Street
Halifax NS B3H 4H6
Canada

Tel: 902.494.2485
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Appendix D.

Interview Questions

**Initial Interview Questions**
Have you trained Tai Chi in the last three months?
Are you currently being treated for heart problems?
Do you have hip or knee arthritis?
Have you had low back problems in the last two years?
Can you walk four blocks without assistance?
What other exercise and sports have you done or are doing?
Which hand do you write with?
Which hand did your first Parkinson's symptoms begin?
When were you first diagnosed with Parkinson's?
Why do you want to learn Tai Chi Chuan?
What do you expect to gain from this training?
What medications are you currently taking?

**Final Interview Questions**
What benefit did you gain from the Tai Chi training?
What negative things came from your Tai Chi training?
What issues made you miss Tai Chi Class?
What issues kept you from training Tai Chi at home?
What benefit did you gain from participating in the testing?
What negative things resulted from participating in the testing?
What things could have been done better the next time?

**Support Person's Questionnaire**
Describe your experience (both positive and/or negative) of the Tai Chi training.
What issues would you like to see researched in regards to Parkinson's?

Appendix E.

## Informed Consent

Dalhousie University School of Physiotherapy

This study is being conducted by Linda MacLaggan, a licensed physiotherapist and master's student, to examine how Tai Chi Chuan exercise training affects people with Parkinson's. We are recruiting volunteers to participate in this study. The description below tells what is involved in participating in the study. The benefits, risks, inconvenience, or discomfort that might occur will also be mentioned.

People with Parkinson's have difficulty with moving which can lead to permanent loss of arm, leg, and body movement. The loss of balance and shuffling walk seen in people with Parkinson's is partially due to the other problems, often severely affect a person's lifestyle. The ancient Chinese art of Tai Chi is thought to reduce the movement problems in people with Parkinson's. Research indicates that Tai Chi may improve balance, strength, quality of life and reduce the fear of falling in healthy elderly people. Tai Chi is expected to reduce the risk of falls and delay postural problems associated with Parkinson's. Tai Chi is inexpensive, requires no special equipment, is offered in most communities and is available on video. Since Tai Chi is available within the community, participants will have the opportunity to continue training after the completion of the study.

This study will require repeated testing sessions before, during and after the training period. Four people with stage II or III Parkinson's will be chosen from all who meet the preset criteria. Participation in this study requires the participant to have a previous diagnosis of idiopathic Parkinson's, no serious medical problems (like heart disease), no serious joint problems (like severe knee arthritis), the ability to walk unassisted, and a willingness to participate three times a week for 26 weeks.

Participants will be asked to take a two-hour interview and videotaped assessment to determine their stage of disease at the Dalhousie school of Physiotherapy. Also, two, five minute screening questionnaires will be used to determine if the participant meets the preset criteria (for example no dementia, no Tai Chi training in the last three months). The participant's physician will be contacted and given a questionnaire to determine if there are any medical reasons why moderate exercise might be harmful.

During the first phase, measurements will be taken at the Dalhousie School of Physiotherapy for one hour three times a week for three weeks. Measurements include standing with feet together and reaching forward three times which will take less than five minutes. The participant will be videotaped to observe how they maintain their balance. Participants will also be videotaped walking six times down a 10-meter walkway accompanied by a safety supervisor to prevent falls. Subjects will be asked to draw spirals and lines while being videotaped for a one-minute period. Two 10-minute questionnaires will be filled out by the participant.

One-hour Tai Chi classes will be held at the Studley dance studio twice a week for 20 weeks. During this period measurements will be taken once every two weeks. Participants will be provided with a video and written instructions of the Tai Chi form for home practice and will be allowed to keep this material after completing the study. Participants will also be asked to keep track of the number of falls, home Tai Chi practice sessions, and a journal of personal thoughts regarding training effects on their life in a log book. The fourth and the final Tai Chi classes will be videotaped and scored to see how well participants learned the exercises.

Another three weeks of measurements will be taken at the Dalhousie School of Physiotherapy three times a week after completion of the Tai Chi training. Participants will be asked to sign an agreement not to do Tai Chi within the three-week period. A final two-hour interview and videotaped assessment will be made at the end of the study.

During the first week of Tai Chi, most people experience some thigh muscle soreness that should go away within the first week. Extra warm up and cool down time and a five-minute break will be included in the first week of classes to reduce muscle soreness. Since people in stage II and III of Parkinson's d are functioning independently in the community, the risk of falls is small. Safety supervisors will be present during all classes and testing sessions to minimize the risk of falls or assist with first aid should it be required. The Tai Chi classes will be held in an area that has a waist high bar firmly attached to the wall. This will allow support if required and will further minimize the risk of I falls. If the Tai Chi movements are repeated incorrectly, some joint soreness may result. For this reason attendance in the class is suggested to allow for corrections to be made. Participants will be responsible for their own travel expenses to and from testing and training sessions.

In any research project risks nit yet identified may occur. Therefore, ANY DISCOMFORT SHOULD ALWAYS BE REPORTED TO THE INSTRUCTOR OR TESTER to prevent any harm. Time will be allotted for discussion about concerns participants have after completion of each testing session.

Once the initial information has been documented, for data analysis, participants will be only identified by number. All data will be kept on a university computer that can only be accessed by study investigators. In the Tai Chi classes and at testing sessions participants will be identified by name. All volunteers who accompany participants during testing and training sessions will be required to sign a confidentiality form. Upon completion of this study a copy of the report will be given to the Parkinson's Foundation and various journals. Participants may receive a copy if requested. In these papers the participants will be identified by case number only. Videotaped material may be used in some conference presentations. The videotapes will be stored in a locked cabinet and any segments not used for presentation will be destroyed after a five-year period.

Your participation is voluntary and the quality of health care will not be affected by not participating. Participation in this study might not result in any benefits but it will increase the understanding of how Tai Chi training will impact people with Parkinson's.

If you have any questions or concerns at any point during the study please contact: **Linda MacLaggan at 494-1446 or 420-0778**
**Or George Turnbull at 494-2043**

I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I understand that I am a volunteer and **may withdraw at any time, even after the study has started, without penalty.** I understand that I may ask questions of the contact people at any time during the study. **I hereby consent to take part in this study**

signature of participant | date | signature of investigator | date

signature of witness | date

**I hereby consent for researcher to contact my physician to obtain approval for my participation in the study.**

signature of participant | date | signature of investigator | date

signature of witness | date

**I hereby agree not to do any Tai Chi during the second baseline measure.**

signature of participant | date | signature of investigator | date

signature of witness | date

Appendix F.

Physician Health Questionnaire

Physician's name_______________ Patient's name ____________________

1) Does the patient suffer from significant heart disease including angina, MI, CABG, PTCA, CHF, severe valvar disease, valve surgery, heart transplant, cardiomyopathy, pacemaker, or LBBB? yes no

2) Within the past twelve weeks has this patient had an episode of systemic or pulmonary embolism? yes no

3) Does the patient suffer from any major orthopaedic problems like moderate to severe knee or hip arthritis, LBP? yes no

4) Does this patient have uncontrolled hypertension? yes no

5) Does the patient have any other medical problems which might affect their ability to perform moderate exercise? yes no

6) Do you feel the patient is safe to participate in a community based moderate (about 4.1 METS) exercise program? yes no

7) Please list all medications and dosages the patient is currently taking ______________________________________

8) Tai Chi is an ancient Chinese exercise. It is composed of a series of slow rhythmical movements, deep breathing, and meditation. There is no impact to any joints and the average mean peak heart rate achieved in Tai Chi by older adults is between 104 to 130 +or- 14 beats per minute representing 70 % of their maximal heart rate (Zhou *et. al.* 1988, Brown *et. al* .1989). The Tai Chi movements resembled walking and moving arms from waist to shoulder height. The training location has waist high bar attached to the wall which may be used to help with balance. Also several volunteers will be present to help prevent falls.

   Do you feel the patient will be able to safely participate in Tai Chi exercise program? yes no

   Physician's signature____________________
   Professional credentials ______________________Date________________

Appendix G.

**Mini-Mental State Exam**

| *Maximum Score* | *Score* | |
|---|---|---|
| 5 | ( ) | What is the (year) (season) (date) (day) (month)? |
| 5 | ( ) | Where are we: (state) (country) (town) (hospital) (floor)? |
| 3 | ( ) | Name 3 objects: 1 second to say each. Then ask the person to repeat them after you have said then three times. |
| 5 | ( ) | Spell WORLD backwards |
| 3 | ( ) | Ask for the 3 objects repeated above. |
| 9 | ( ) | Name a pencil and a watch<br>Repeat the following, "No if ands or buts."<br>Follow a three-stage command.<br>Read and obey the following: "Close your eyes."<br>Write a sentence.<br>Copy a design. |
| 30 | ( ) | TOTAL SCORE |

A selection of questions from Folstein (1986)

**Appendix H.**

**Beck's Depression Inventory**

**Beck's Depression Inventory**

| | | | |
|---|---|---|---|
| **Name** | | **Patient's number** | |
| **Date** | | **Rater's initials** | |

**1. Mood**

- ☐ I do not feel sad
- ☐ I feel blue or sad
- ☐ I am blue or sad all the time and I can't snap out of it
- ☐ I am so sad or unhappy that it is very painful
- ☐ I am so sad or unhappy that I can't stand it

**2. Pessimism**

- ☐ I am not particularly pessimistic or discouraged about the future
- ☐ I feel discouraged about the future
- ☐ I feel I have nothing to look forward to
- ☐ I feel that I won't ever get over my troubles
- ☐ I feel that the future is hopeless and that things cannot improve

**3. Sense of future**

- ☐ I do not feel like a failure
- ☐ I feel that I have failed more than the average person
- ☐ I feel I have accomplished very little that is worthwhile of that means anything
- ☐ As I look back on my life all I can see is a lot of failure
- ☐ I feel I am a complete failure as a person (parent, husband / wife)

**4. Lack of satisfaction**

- ☐ I am not particularly dissatisfied
- ☐ I feel bored most of the time
- ☐ I don't enjoy things the way I used to
- ☐ I don't get satisfaction out of anything any more
- ☐ I am dissatisfied with everything

**5. Guilty feeling**

- ☐ I don't feel particularly guilty
- ☐ I feel bad or unworthy a good part of the time
- ☐ I feel quite guilty
- ☐ I feel bad or unworthy practically all the time now
- ☐ I feel as though I am very bad or worthless

**6. Sense of punishment**

- ☐ I don't feel I am being punished
- ☐ I have a feeling that something bad may happen to me
- ☐ I feel I am being punished or will be punished
- ☐ I feel I deserve to be punished
- ☐ I want to be punished

**7. Self hate**

- ☐ I don't feel disappointed in myself
- ☐ I am disappointed in myself
- ☐ I don't like myself
- ☐ I am disgusted with myself
- ☐ I hate myself

**8. Self accusation**

- ☐ I don't feel I am any worse than anybody else
- ☐ I am very critical of myself for my weaknesses or mistakes
- ☐ I blame myself for everything that goes wrong
- ☐ I feel I have many bad faults

**9. Self-punitive wishes**

- ☐ I don't have any thoughts of harming myself
- ☐ I have thoughts of harming myself but I would not carry them out
- ☐ I feel I would be better off dead
- ☐ I have definite plans about committing suicide
- ☐ I would kill myself if I could

**10. Crying spells**

- ☐ I don't cry any more than usual
- ☐ I cry more now than usual
- ☐ I cry all the time now. I can't stop it
- ☐ I used to be able to cry but now I can't cry at all even though I want to

**11. Irritability**

- ☐ I am no more irritated now than I ever am
- ☐ I get annoyed or irritated more easily than I used to
- ☐ I feel irritated all the time
- ☐ I don't get irritated at all thethings that used to irritate me

**12. Social withdrawal**

- ☐ I have not lost interest in other people
- ☐ I am less interested in other people now than I used to be
- ☐ I have lost most of my interest in other people and have little feeling for them
- ☐ I have lost all interest in other people and don't care about them at all

**13. Indecisiveness**

- ☐ I make decisions about as well as ever
- ☐ I am less sure of myself now and try to put off making decisions
- ☐ I can't make decisions any more without help
- ☐ I can't make any decisions at all any more

**14. Body image**

- ☐ I don't feel I look any worse than I used to
- ☐ I am worried that I am looking old or unattractive
- ☐ I feel that there are permanent changes in my appearance and they make me look unattractive
- ☐ I feel that I am ugly or repulsive looking

**15. Work inhibition**

- ☐ I can work about as well as before
- ☐ It takes extra effort to get started at doing something
- ☐ I don't work as well as I used to
- ☐ I have to push myself very hard to do something
- ☐ I can't do any work at all

**16. Sleep disturbance**

- ☐ I can sleep as well as usual
- ☐ I wake up more tired in the morning than I used to
- ☐ I wake up 1-2 hours earlier than usual and find it hard to get back to sleep
- ☐ I wake up early every day and can't get more than 5 hour sleep

**17. Fatigability**

- ☐ I don't get any more tired than usual
- ☐ I get tired more easily than I used to
- ☐ I get tired from doing anything
- ☐ I get too tired to do anything

**18. Loss of appetite**

- ☐ My appetite is no worse than usual
- ☐ My appetite is not as good as usual
- ☐ My appetite is much worse now
- ☐ I have no appetite at all any more

**19. Weight loss**

- ☐ I haven't lost much weight, if any, lately
- ☐ I have lost more than 5 pounds
- ☐ I have lost more than 10 pounds
- ☐ I have lost more than 15 pounds

**20. Somatic preoccupation**

- ☐ I am no more concerned about my health than usual
- ☐ I am concerned about aches and pains or upset stomach or constipation or other unpleasant feelings in my body
- ☐ I am so concerned with how I feel or what I feel that it's hard to think of much else
- ☐ I am completely absorbed in what I feel

**21. Loss of libido**

- ☐ I have not noticed any recent change in my interest in sex
- ☐ I am less interested in sex than I used to be
- ☐ I am much less interested in sex now
- ☐ I have lost interest in sex completely

Appendix I

Unified Parkinson's Disease Rating Scale

UPDRS protocol

**Questions**

**Hoehn and Yahr section plus motor questions**
**20:** videotape subject lying, ten second close up of face, each hand, and each foot.
**22:** videotape as PT assesses neck, elbow, and knee rigidity. Use contralateral arm movement only to confirm if rigidity barely detectable. PT states findings.
**27**: videotape subject rising from chair, side view.
**30:** videotape side on for retropulsion test.
**31**:lying to standing

**1 – 17b** are subjective and to be completed by the subject.
**18:** Have subject read the rainbow passage while videotape with close up.
**19**: Facial expression: video tape facing subject for 10 seconds, close up on face.
**21:** videotape subject from front in sitting.
**23:** close up each hand during the finger tapping movements.
**24:** videotape close-up of each hand with supination and pronation.
**25:** Close-up of fingertip to nose test. PT states if tremor present.
**26:** Close-up for heel tapping. Heel touch to knee straight, repetitive.
**28:** videotape side-view for ten seconds.
**29:** videotape side view as subject walks 7 meters.
**32-42**: patient report
**Dyskinesia section** rated from other previous videotaped section
**S&E:** ask the following questions. How long does it take you to do your chores when "on"? When "off"? Do you require assistance with your chores when "on"? When "off"?
**Modified H&Y**: From previous videotape protocol.

# U.P.D.R.S. PHASE II

NAME ☐ PATIENT INITIALS ☐

DATE ☐ EVALUATION ☐ DRUG HOLIDAY ☐ FULL

MEDS TIME ☐

MEDS. ☐

"ON" TIME ☐ "OFF" TIME ☐

"ON" VIDEO NO. ☐ "OFF" VIDEO NO. ☐

Rater's Initials ☐

**1. Intellectual impairment:**
- ☐ 0 = None
- ☐ 1 = Mild
- ☐ 2 = Moderate memory loss
- ☐ 3 = Severe memory loss. Impariment in handling problems
- ☐ 4 = Severe memory loss. Unable to make judgements or solve problems

**2. Thought disorder:**
- ☐ 0 = None
- ☐ 1 = Vivid dreaming
- ☐ 2 = 'Benign' hallucinations with insight retained
- ☐ 3 = Occasional to frequent hallucinations or delusion, without insight
- ☐ 4 = Persistent hallucination, delusions or florid psychosis

**3. Depression:**
- ☐ 0 = Not present
- ☐ 1 = Periods of sadness or guilt greater than normal, never sustained for days or weeks
- ☐ 2 = Sustained depression (1 week or more)
- ☐ 3 = Sustained depression with vegetative symptoms
- ☐ 4 = Sustained depression with vegetative symptoms and suicidal thoughts or intent

**4. Motivation/Initiative:**
- ☐ 0 = Normal
- ☐ 1 = Less assertive than normal, more passive
- ☐ 2 = Loss of initiative or disinterest in nonroutine activities
- ☐ 3 = Loss of initiative or disinterest in routine activites
- ☐ 4 = Withdrawn, complete loss of motivation

**5a. Speech "ON":**
- ☐ 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

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# U.P.D.R.S. PHASE II

| | | | |
|---|---|---|---|
| PATIENT INITIALS | | DATE | |

| | |
|---|---|
| 5b: Speech "OFF" | ☐ 0 = Normal<br>☐ 1 = Mildly affected<br>☐ 2 = Moderately affected, sometimes asked to repeat statements<br>☐ 3 = Severely affected, frequently asked to repeat statements<br>☐ 4 = Unintelligible most of the time |
| 6a. Salivation "ON": | ☐ 0 = Normal<br>☐ 1 = Slight but definite excess of saliva in mouth<br>☐ 2 = Moderately excessive saliva<br>☐ 3 = Marked excess of saliva with some drooling<br>☐ 4 = Marked drooling |
| 6b. Salivation "OFF": | ☐ 0 = Normal<br>☐ 1 = Slight but definite excess of saliva in mouth<br>☐ 2 = Moderately excessive saliva, may have minimal drooling<br>☐ 3 = Marked excess of saliva with some drooling<br>☐ 4 = Marked drooling |
| 7a. Swallowing "ON" : | ☐ 0 = Normal<br>☐ 1 = Rare choking<br>☐ 2 = Occasional choking<br>☐ 3 = Requires soft food<br>☐ 4 = Requires NG tube or gastrotomy feeding |
| 7b. Swallowing "OFF" : | ☐ 0 = Normal<br>☐ 1 = Rare choking<br>☐ 2 = Occasional choking<br>☐ 3 = Requires soft food<br>☐ 4 = Requires NG tube or gastrotomy feeding |
| 8a. Handwriting "ON": | ☐ 0 = Normal<br>☐ 1 = Slightly slow or small<br>☐ 2 = Moderately slow or small, all words legible<br>☐ 3 = Severely affected, not all words legible<br>☐ 4 = The majority of words are not legible |
| 8b. Handwriting "OFF": | ☐ 0 = Normal<br>☐ 1 = Slightly slow and small<br>☐ 2 = Moderately slow or small, all words legible<br>☐ 3 = Severely affected, not all words legible<br>☐ 4 = The majority of words are not legible |
| 9a . Cutting food and handling utensils "ON" : | ☐ 0 = Normal<br>☐ 1 = Somewhat slow and clumsy, but no help needed<br>☐ 2 = Can cut most foods, although slow and clumsy, some help needed<br>☐ 3 = Food must be cut by someone, but can still feed slowly<br>☐ 4 = Needs to be fed |
| 9b . Cutting food and handling utensils "OFF" : | ☐ 0 = Normal<br>☐ 1 = Somewhat slow and clumsy, but no help needed<br>☐ 2 = Can cut most foods, although clumsy and slow, some help needed<br>☐ 3 = Food must be cut by someone, but can still feed slowly<br>☐ 4 = Needs to be fed |

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## U.P.D.R.S. PHASE II

| | | | |
|---|---|---|---|
| PATIENT INITIALS | | DATE | |

| | |
|---|---|
| 10a. Dressing "ON": | ☐ 0 = Normal<br>☐ 1 = Somewhat slow<br>☐ 2 = Occasional assistance with buttoning, getting arms in sleeves<br>☐ 3 = Considerable help required, but can do some things alone<br>☐ 4 = Helpless |
| 10b. Dressing "OFF": | ☐ 0 = Normal<br>☐ 1 = Somewhat slow, but no help needed<br>☐ 2 = Occasional assistance with buttoning, getting arms in sleeves<br>☐ 3 = Considerable help required, but can do some things alone<br>☐ 4 = Helpless |
| 11a. Hygiene "ON" : | ☐ 0 = Normal<br>☐ 1 = Somewhat slow, but no help needed<br>☐ 2 = Needs help to shower or bathe, or very slow in hygienic care<br>☐ 3 = Requires assisstance for washing, brushing teeth, combing hair, going to bathroom<br>☐ 4 = Foley catheter or other mechanical aids |
| 11b. Hygiene "OFF" : | ☐ 0 = Normal<br>☐ 1 = Somewhat slow, but no help needed<br>☐ 2 = Needs help to shower or bathe, or very slow in hygienic care<br>☐ 3 = Requires assistance for washing, brushing teeth, combing hair, going to bathroom<br>☐ 4 = Foley catheter or other mechanical aids |
| 12a. Turning in bed and adjusting bedclothes "ON": | ☐ 0 = Normal<br>☐ 1 = Somewhat slow and clumsy, but no help needed<br>☐ 2 = Can turn alone or adjust sheets, but with great difficulty<br>☐ 3 = Can initiate, but not turn or adjust sheets alone<br>☐ 4 = Helpless |
| 12b. Turning in bed and adjusting bedclothes "OFF": | ☐ 0 = Normal<br>☐ 1 = Somewhat slow and clumsy, but no help needed<br>☐ 2 = Can turn alone or adjust sheets, but with great difficulty<br>☐ 3 = Can initiate, but not turn or adjust sheets alone<br>☐ 4 = Helpless |
| 13a. Falling "ON": | ☐ 0 = None<br>☐ 1 = Rare falling<br>☐ 2 = Occasionally falls, less that once per day<br>☐ 3 = Falls an average of once daily<br>☐ 4 = Falls more than once daily |
| 13b. Falling "OFF": | ☐ 0 = None<br>☐ 1 = Rare falling<br>☐ 2 = Occasionally falls, less than once per day<br>☐ 3 = Falls an average of once daily<br>☐ 4 = Falls more than once daily |

continued on next page

# U.P.D.R.S. PHASE II

PATIENT INITIALS ☐ DATE ☐

**14a. Freezing when walking "ON":**

- ☐ 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

**14b. Freezing when walking "OFF":**

- ☐ 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

**15a. Walking "ON":**

- ☐ 0 = Normal
- ☐ 1 = Mild difficulty, may not swing arms or tend to drag leg
- ☐ 2 = Moderate difficulty, but requires little or no assistance
- ☐ 3 = Severe distrubance of walking, requires assistance
- ☐ 4 = Cannot walk at all, even with assistance

**15b. Walking "OFF":**

- ☐ 0 = Normal
- ☐ 1 = Mild difficulty, may not swing arms or tend to drag leg
- ☐ 2 = Moderate difficulty, but requires little or no assistance
- ☐ 3 = Severe disturbances of walking, requires assistance
- ☐ 4 = Cannot walk at all, even with assistance

**16a. Tremor "ON":**

- ☐ 0 = Absent
- ☐ 1 = Slight and infrequently present
- ☐ 2 = Moderate, bothersome to patient
- ☐ 3 = Severe, interferes with many activities
- ☐ 4 = Marked, interferes with most activities

**16b. Tremor "OFF":**

- ☐ 0 = Absent
- ☐ 1 = Slight and infrequently present
- ☐ 2 = Moderate, bothersome to patient
- ☐ 3 = Severe, interferes with many acitvites
- ☐ 4 = Marked, interferes with most activites

**17a. Sensory complaints related to parkinsonism "ON":**

- ☐ 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

**17b. Sensory complaints related to parkinsonism "OFF":**

- ☐ 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

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# U.P.D.R.S. PHASE II

PATIENT INITIALS ☐ DATE ☐

OFF ON

**18. Speech:**

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

**19. Facial expression:**

- ☐ ☐ 0 = Normal
- ☐ ☐ 1 = Minimal hypomimia, could be normal "Poker Face"
- ☐ ☐ 2 = Slight but definitely abnormal diminution of facial expression
- ☐ ☐ 3 = Moderated hypomimia, lips parted some of the time
- ☐ ☐ 4 = Masked or fixed facies with severe or complete loss of facial expression

**20. Tremor at rest: Face**

- ☐ ☐ 0 = Absent
- ☐ ☐ 1 = Slight and infrequently present
- ☐ ☐ 2 = Mild in amplitude and persistent, or moderate in amplitude, intermittent
- ☐ ☐ 3 = Moderate in amplitude and present all the time
- ☐ ☐ 4 = Marked in amplitude and present most of the time

**20. Tremor at rest: Left hand**

- ☐ ☐ 0 = Absent
- ☐ ☐ 1 = Slight and infrequently present
- ☐ ☐ 2 = Mild in amplitude and persistent, or moderate in amplitude intermittent
- ☐ ☐ 3 = Moderate in amplitude and present all the time
- ☐ ☐ 4 = Marked in amplitude and present most of the time

**20. Tremor at rest: Right hand**

- ☐ ☐ 0 = Absent
- ☐ ☐ 1 = Slight and infrequently present
- ☐ ☐ 2 = Mild in amplitude and persistent, or moderate in amplitude intermittent
- ☐ ☐ 3 = Moderate in amplitude and present all the time
- ☐ ☐ 4 = Marked in amplitude and present most of the time

**20. Tremor at rest: Left foot**

- ☐ ☐ 0 = Absent
- ☐ ☐ 1 = Slight and infrequently present
- ☐ ☐ 2 = Mild in amplitude and persistent, or moderate in amplitude ,intermittent
- ☐ ☐ 3 = Moderate in amplitude and present all the time
- ☐ ☐ 4 = Marked in amplitude and present most of the time

**20. Tremor at rest: Right foot**

- ☐ ☐ 0 = Absent
- ☐ ☐ 1 = Slight and infrequently present
- ☐ ☐ 2 = Mild in amplitude and persistent, or moderate in amplitude, intermittent
- ☐ ☐ 3 = Moderate in amplitude and present all the time
- ☐ ☐ 4 = Marked in amplitude and present most of the time

continued on next page

# U.P.D.R.S. PHASE II

PATIENT INITIALS [ ] DATE [ ]

| | OFF | ON |
|---|---|---|
| **21. Action or postural tremor of hands: Left** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight, present with action<br>☐ 2 = Moderate in amplitude, present with action<br>☐ 3 = Moderate in amplitude, with posture holding as well as action<br>☐ 4 = Marked in amplitude, interferes with feeding |
| **21. Action or postural tremor of hands: Right** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight, present with action<br>☐ 2 = Moderate in amplitude, present with action<br>☐ 3 = Moderate in amplitude, with posture holding as well as action<br>☐ 4 = Marked in amplitude, interferes with feeding |
| **22. Rigidity: Neck** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight or detectable only when activated by mirror or other movements<br>☐ 2 = Mild to moderate<br>☐ 3 = Marked, but full range of motion easily achieved<br>☐ 4 = Severe, range of motion achieved with difficulty |
| **22. Rigidity: LUE** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight or detectable only when activated by mirror or other movements<br>☐ 2 = Mild to moderate<br>☐ 3 = Marked , but full range of motion easily achieved<br>☐ 4 = Severe, range of motion achieved with difficulty |
| **22. Rigidity: RUE** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight or detectable only when activated by mirror or other movements<br>☐ 2 = Mild to moderate<br>☐ 3 = Marked, but full range of motion easily achieved<br>☐ 4 = Severe, range of motion achieved with difficulty |
| **22. Rigidity: LLE** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight or detectable only when achieved by mirror or other movements<br>☐ 2 = mild to moderate<br>☐ 3 = Marked, but full range of motion easily achieved<br>☐ 4 = Severe, range of motion achieved with difficulty |
| **22. Rigidity: RLE** | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Absent<br>☐ 1 = Slight or detectable only when activated by mirror or other movements<br>☐ 2 = Mild to moderate<br>☐ 3 = Marked, but with full range of motion easily achieved<br>☐ 4 = Severe, range of motion achieved with difficulty |

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# U.P.D.R.S. PHASE II

PATIENT INITIALS ☐ DATE ☐

| | OFF | ON |
|---|---|---|
| 23. Finger taps: Left | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and or reduction in amplitude<br>☐ 2 = Moderately impaired, definite and early fatiguing<br>☐ 3 = Severely impaired, frequent hesitation<br>☐ 4 = Can barely perform the task |
| 23. Finger taps: Right | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and or reducion in amplitude<br>☐ 2 = Moderately impaired, definite and early fatiguing<br>☐ 3 = Severely impaired, frequent hesitation<br>☐ 4 = Can barely perform the task |
| 24. Hand movements: Left | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and/or reduction in amplitude<br>☐ 2 = Moderately impaired, definite and early fatiguing<br>☐ 3 = Severely impaired, frequent hesitation<br>☐ 4 = Can barely perform the task |
| 24. Hand movements: Right | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and/or reduction in amplitude<br>☐ 2 = Moderately impaired, definite and early fatiguing<br>☐ 3 = Severely impaired, frequent hesitation<br>☐ 4 = Can barely perform the task |
| 25. Rapid alternating movements of hands: Left | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and /or reduction in amplitude<br>☐ 2 = Moderately impaired, definite and early fatiguing<br>☐ 3 = Severely impaired, frequent hesitaiton<br>☐ 4 = Can barely perform the task |
| 25. Rapid alternating movements of hands: Right | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and/or reduction in amplitude<br>☐ 2 = Moderately impaired, definite and early fatiguing<br>☐ 3 = Severely impaired, frequent hesitaion<br>☐ 4 = Can barely perform the task |
| 26. Leg agility : Left | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and /or reduction in amplitude<br>☐ 2 = Moderately impaired, definite early fatiguing<br>☐ 3 = Severely impaired, frequent hesitaion<br>☐ 4 = Can barely perform the task |
| 26. Leg agility : Right | ☐ ☐ ☐ ☐ ☐ | ☐ 0 = Normal<br>☐ 1 = Mild slowing and/or reduction in amplitude<br>☐ 2 = Moderately impaired, definite early fatigue<br>☐ 3 = Severely impaired, frequent hesitation<br>☐ 4 = Can barely perform the task |

continued on next page

## U.P.D.R.S. PHASE II

**PATIENT INITIALS** ☐ **DATE** ☐

**OFF ON**

**27. Arising from chair:**

☐ ☐ 0 = Normal
☐ ☐ 1 = Slow, or may need more than one attempt
☐ ☐ 2 = Pushes self up from arms of seat
☐ ☐ 3 = Tends to fall back and may have to try more than one time, gets up without help
☐ ☐ 4 = Unable to arise without help

**28. Posture:**

☐ ☐ 0 = Normal
☐ ☐ 1 = Not quite erect, slightly stooped posture
☐ ☐ 2 = Moderately stooped posture, definitely abnormal
☐ ☐ 3 = Severely stooped posture with kyphosis
☐ ☐ 4 = Marked flexion with extreme abnormality of posture

**29. Gait:**

☐ ☐ 0 = Normal
☐ ☐ 1 = Walks slowly, may suffle with short steps, but no festination or propulsion
☐ ☐ 2 = Walks with difficulty, but requires little or no assistance, some festination
☐ ☐ 3 = Severe distrubance of gait, requiring assistance
☐ ☐ 4 = Cannot walk at all, even with assistance

**30. Postural stability**

☐ ☐ 0 = Normal
☐ ☐ 1 = Retropulsion, but recovers unaided
☐ ☐ 2 = Absence of postural response, would fall if not cought by examiner
☐ ☐ 3 = Very unstable, tends to lose balance spontaneously
☐ ☐ 4 = Unable to stand without assistance

**31. Body bradykinesia and hypokinesia:**

☐ ☐ 0 = None
☐ ☐ 1 = Minimal slowness, giving movement a deliberate character
☐ ☐ 2 = Mild degree of slowness and poverty of movement
☐ ☐ 3 = Moderate slowness, poverty or small amplitude of movement
☐ ☐ 4 = Marked slowness, poverty or small amplitude of movement

**32. Duration: Dyskinesias present**

☐ 0 = None
☐ 1 = 1-25% of day
☐ 2 = 26 -50% of day
☐ 3 = 51- 75% of day
☐ 4 = 76- 100% of day

**33. Disability: How disabling are dyskinesia?**

☐ 0 = Not disabling
☐ 1 = Mildly disabling
☐ 2 = Moderately disabling
☐ 3 = Severely disabling
☐ 4 = Completely disabling

**34. Painful dyskinesia: How painful?**

☐ 0 = No painful dyskinesias
☐ 1 = Slight
☐ 2 = Moderate
☐ 3 = Severe
☐ 4 = Marked

continued on next page

# U.P.D.R.S. PHASE II

PATIENT INITIALS [ ] DATE [ ]

35. Presence of early morning dystonia:
- ☐ 0 = No
- ☐ 1 = Yes

36. Off periods predictable after a dose of medication?:
- ☐ 0 = No
- ☐ 1 = Yes

37. 'Off" periods unpredictable after a dose of medication?:
- ☐ 0 = No
- ☐ 1 = Yes

38. Do 'off' periods come on suddenly, over a few seconds?:
- ☐ 0 = No
- ☐ 1 = Yes

39. Proportion of waking day 'off' on average?:
- ☐ 0 = None
- ☐ 1 = 1-25%of day
- ☐ 2 = 26-50% of day
- ☐ 3 = 51-75% of day
- ☐ 4 = 76-100% of day

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

If Yes Describe

41. Does the patient have any sleep disturbance?:
- ☐ 0= No
- ☐ 1 = Yes. Describe

Sleep description

# U.P.D.R.S. PHASE II

**PATIENT INITIALS** ☐ **DATE** ☐

**42. Does the patient have symptomatic orthostasis?:**

☐ 0 = No
☐ 1 = Yes. List symptoms

**Symptoms** ☐

**TIME OF EXAMINATION** ☐

**Intensity of dyskinesia during 'on' period: head**

☐ 0 = Normal
☐ 1 = Intermittent
☐ 2 = Generalized, mild but continuous, may not be obvious to untrained observer
☐ 3 = Moderate, generalized, definitely noticeable to untrained observer
☐ 4 = Incapacitating

**Intensity if dyskinesia during 'on' period: RUE**

☐ 0 = Normal
☐ 1 = Intermittent
☐ 2 = Generalized, mild but continous
☐ 3 = Moderate generalized, definitely noticeable
☐ 4 = Incapacitating

**Intensity if dyskinesia during 'on' period: LUE**

☐ 0 = Normal
☐ 1 = Intermittent
☐ 2 = Generalized, mild but continous
☐ 3 = Moderate, generalized, definitely noticeable
☐ 4 = Incapacitating

**Intensity if dyskinesia during 'on' period: RLE**

☐ 0 = Normal
☐ 1 = Intermittent
☐ 2 = Generalized, mild but continuous
☐ 3 = Moderate, generalized, definitely noticeable
☐ 4 = Incapacitating

**Intensity if dyskinesia during 'on' period: LLE**

☐ 0 = Normal
☐ 1 = Intermittent
☐ 2 = Generalized, mild but continuous
☐ 3 = Moderate, generalized, definitely noticeable
☐ 4 = Incapacitating

**Intensity if dyskinesia during 'on' period: Trunk**

☐ 0 = Normal
☐ 1 = Intermittent
☐ 2 = Generalized, mild but continuous
☐ 3 = Moderate, generalized, definitely noticeable
☐ 4 = Incapacitating

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# U.P.D.R.S. PHASE II

PATIENT INITIALS [ ] DATE [ ]

**Modified Schwab-England Disability Scale "ON"**

- ☐ 100% Completely independent
- ☐ 90% Completely independent, able to do all chores with some degree of slowness
- ☐ 80% Completely independent in most chores, takes twice as long
- ☐ 70% Not completely independent, chores 3-4 times as long
- ☐ 60% Some dependency, can do most chores, exceedingly slowly
- ☐ 50% More dependent, help,with half, shower
- ☐ 40% Very dependent, can assist with all chores but few alone
- ☐ 30% With effort, now and then does a few chores alone, or begins alone
- ☐ 20% Nothing alone
- ☐ 10% Totally dependent, helpless, complete invalid
- ☐ 0% Vegetative functions such as swallowing, bladder, bowel not functioning

**Modified Schwab-England Disability Scale "OFF"**

- ☐ 100% Completely independent
- ☐ 90% Completely independent, able to do all chores with some degree of slowness
- ☐ 80% Completely independent in most chores, takes twice as long
- ☐ 70% Not completely independent, chores 3-4 times as long
- ☐ 60% Some independency, can do most chores, but exceedingly slowly
- ☐ 50% More dependent, help with half, shower
- ☐ 40% Very dependent, can assist with all chores but few alone
- ☐ 30% With effort, now and then does a few chores aloneor begins alone
- ☐ 20% Nothing alone
- ☐ 10% Totally dependent, helpless,complete invalid
- ☐ 0% Vegetative functions such as swallowing, bladder, bowel, not funtioning

**Modified Hoehn and Yahr Scale "ON":**

- ☐ 0 = No signs of disease
- ☐ 1 = Unilateral disease
- ☐ 1.5 = Unilateral disease, without inpairment of balance
- ☐ 2 = Bilateral disease, without impairment of balance
- ☐ 2.5 = Mild bilateral disease, with recovery on pull test
- ☐ 3 = Mild to moderate bilateral disease, some postural instability
- ☐ 4 = Severe disability, still able to walk or stand unassissted
- ☐ 5 = Wheelchair bound or bedridden unless aided

**Modified Hoehn and Yahr Scale "OFF":**

- ☐ 0 = No signs of disease
- ☐ 1 = Unilateral disease
- ☐ 1.5 = Unilateral disease, without impairment of balance
- ☐ 2 = Bilateral disease, without impairment of balance
- ☐ 2.5 = Mild bilateral disase, with recovery on pull test
- ☐ 3 = Mild to moderate bilateral disease, some postural instability
- ☐ 4 = Severe disability, still able to walk or stand unassisted
- ☐ 5 = Wheelchair bound or bedridden unless aided

**Changes in Drugs**

- ☐ Yes
- ☐ No

continued on the next page

# U.P.D.R.S. PHASE II

PATIENT INITIALS

DATE

If Yes Describe

Daily Drugs

Comments

Appendix J.
Parkinson's Impact Measurement Scale

**Parkinson's Impact Scale**

Name: Date:

Year symptoms began: Date of Birth:

- Please indicate by a number (0_4) what impact Parkinsons has had on your life.
  0 = no change 1 = slight 2 = moderate 3 = moderately severe 4 = severe
- Use the definitions below to help you to measure impact

| | |
|---|---|
| Self: (positive) | refers to how positive you feel about yourself (self-worth, happiness, optimism) |
| Self:(negative) | refers to how negative you feel about yourself (level of stress, anxiety,or depression) |
| Family Relationships: | refers to your spouse, partner, children and relatives that you consider part of your immediate family |
| Community Relationships: | refers to your neighbours, friends, people you work with and those who provide you with services (store clerk, doctor, pastor, etc.) |
| Work: | refers to your job and / or the running of your home and your ability to support yourself and your family |
| Leisure: | refers to your ability to continue enjoyable activities (hobbies, sports, volunteering) |
| Travel: | refers to your ability to reach your destination, i.e.: work and/or social |
| Safety: | refers to your ability to do what you want without injuring yourself or others (driving, being outdoors, in the kitchen, in the bathroom, etc.) |
| Financial Security: | refers to your ability to support yourself and your family and pay your medical treatment. |
| Sexuality: | refers to your ability to maintain a satisfactory sexual relationship. |

- If your symptoms are stable complete column 1
- If your symptoms fluctuate complete columns 2a and 2b (best and worst)

| | 1 (Stable) | 2a (Best) | 2b (Worst) |
|---|---|---|---|
| Self: (positive) | | | |
| Self: (negative) | | | |
| Family Relationships | | | |
| Community Relationships | | | |
| Safety | | | |
| Leisure | | | |
| Travel | | | |
| Work | | | |
| Finanical Security | | | |
| Sexuality | | | |

Appendix K

**Modified Fall Efficacy Scale** Date (d/m) ______ subject number ______

**How confident are you that you can do each of the following activities without falling?**

| | Not confident | fairly confident | completely confident |
|---|---|---|---|
| 1. Dressing | | | |
| 2. Prepare a simple meal | | | |
| 3. Take a shower or bath | | | |
| 4. Get in or out of chair | | | |
| 5. Get in or out of bed | | | |
| 6. Answer the door or telephone | | | |
| 7. Walk around inside your home | | | |
| 8. Reaching into cabinets or closets | | | |
| 9. Light housekeeping | | | |
| 10. Simple shopping | | | |
| 11. Using public transit | | | |
| 12. Crossing roads | | | |
| 13. Light gardening or hanging out the wash* | | | |
| 14. Using the front or rear steps at home | | | |

Appendix L.

Health Questionnaire

Subject number_____
Time ________ subject number ____________

PLEASE CIRCLE APPROPRIATE ANSWER

| | |
|---|---|
| 1) Have you been sick of injured this week? | Yes no |
| 2) Did you take your medication as prescribed? | yes sometimes no |
| 3) Have your medications been changed? If yes, give details (dosages) ____________ ____________ | yes no |
| 4) Have you had any coffee to drink today? | yes no |
| 5) Are you under more stress than usual today? | yes no |
| 6) What time did you take your last medication? | yes no |
| 7) Please rate your level of fatigue on a scale from 1 to 10, 1 being no fatigue, 10 representing extreme fatigue. /10 | |

Appendix M.

<u>Movements of the Wu Style Tai Chi Chuan</u>

1. Beginning of the Tai Chi Chuan
2. Raise Hands
3. Play Guitar
4. Grasp Bird's Tail
5. Single Whip
6. Slant Flying
7. Raise Hands
8. White Crane Spreads Wings
9. Brush Knee and Push (Left & Right, 4 times)
10. Playing Guitar
11. Step Forward and Push
12. Push Forward
13. Carry Tiger to Mountain
14. Cross Hands
15. Slant Brush Knee
16. Turn Body, Brush Knee & Push
17. Grasp Bird's Tail
18. Single Whip
19. Fist Under Elbow
20. Step Back, Repulse Monkey (Left & Right, 3 times)
21. Slant Flying
22. Raise Hands
23. White Crane Spreads Wings
24. Brush Knee and Push
25. Needle at Sea Bottom
26. Play Arms Like Fan
27. Turn Body and Strike Fist to Back
28. Step Back and Punch
29. Step Forward and Grasp Bird's Tail
30. Single Whip
31. Wave Hands Like Cloud
32. Single Whip
33. Left High Pat on Horse
34. Right Foot Kick (separate)
35. Right High Pat on Horse
36. Left Foot Kick (separate)
37. Turn Body, Kick with Heel
38. Brush Knee and Push (Right & Left)
39. Step Forward and Punch Down
40. Grasp the birds tail
41. Single whip
42. End of Chuan

Appendix N.

<u>Log Book</u>

**date:________**

Number of falls today. ______

If you fell, what caused the fall?

Minutes Tai Chi Chuan training today ______
Did you use the video or written instruction today?
Please comment on your feelings and daily life
experience as a result of participation in this study.

Appendix O.

C statistic formula, and Z scores for all measures.

Let x = a datum, n = number of data in a phase, and let $x_i$ = adjacent scores (next score).

$x_m = \Sigma x / n.$

$SS(x) = \Sigma (x - x_m)^2$

$D2 = \Sigma(x - x_i)^2$

$C = 1 - [D2 / 2SS(x)]$

$SE = (n - 2)/ (n + 1)(n - 1)$

$Z = C / SE$ = Z statistic for normal curve.

Table 1. Subject 1 Z statistic values calculated from the C statistic for all measures. For significance Z>1.67.

| stats/s | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.14 | 0.27 | 0.01 |
| phase B | 0.13 | -0.05 | 0.07 |
| phase A2 | 0.01 | 0.03 | 0.12 |
| phase A1 vs B | 0.13 | 0.15 | 0.04 |
| phase B vs A2 | 0.09 | -0.01 | 0.06 |
| phase A2 vs A1 | 0.12 | 0.15 | 0.03 |

| RSL | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.32 | 0.25 | 0.02 |
| phase B | 0.17 | 0.03 | 0.22 |
| phase A2 | 0.34 | 0.06 | 0.17 |
| phase A1 vs B | 0.07 | 0.14 | 0.07 |
| phase B vs A2 | 0.12 | 0.04 | 0.04 |
| phase A2 vs A1 | 0.05 | 0.14 | 0.09 |

| RST | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.22 | 0.27 | -0.02 |
| phase B | 0.07 | -0.12 | -0.15 |
| phase A2 | 0.30 | 0.19 | 0.02 |
| phase A1 vs B | 0.16 | -0.13 | 0.01 |
| phase B vs A2 | 0.12 | -0.03 | 0.02 |
| phase A2 vs A1 | 0.19 | 0.14 | -0.00 |

| cadence | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.21 | 0.27 | 0.01 |
| phase B | 0.09 | -0.11 | -0.16 |
| phase A2 | 0.32 | 0.21 | -0.00 |
| phase A1 vs B | 0.17 | 0.13 | 0.01 |
| phase B vs A2 | 0.12 | -0.04 | 0.12 |
| phase A2 vs A1 | 0.18 | 0.15 | 0.01 |

| SST% | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.11 | 0.21 | 0.09 |
| phase B | 0.14 | -0.07 | 0.17 |
| phase A2 | 0.29 | -0.05 | 0.33 |
| phase A1 vs B | 0.12 | 0.11 | 0.23 |
| phase B vs A2 | 0.14 | 0.09 | 0.14 |
| phase A2 vs A1 | 0.12 | 0.09 | 0.034 |

| | Range of WS | FR | FES | TREMOR | | PIMS | |
|---|---|---|---|---|---|---|---|
| | | | | Right | Left | best | worst |
| phase A1 | 0.14 | 0.010 | 0.15 | -0.04 | 0.26 | 0.083 | 0.075 |
| phase B | -0.01 | 0.005 | 0.16 | 0.27 | 0.34 | 0.211 | 0.276 |
| phase A2 | 0.04 | 0.221 | 0.33 | 0.29 | 0.34 | 0.245 | 0.333 |
| phase A1 vs B | 0.09 | 0.033 | 0.17 | 0.07 | 0.05 | 0.147 | 0.189 |
| phase B vs A2 | 0.07 | 0.028 | 0.13 | 0.17 | 0.23 | 0.200 | 0.181 |
| phase A2 vs A1 | 0.06 | 0.084 | 0.22 | 0.18 | 0.22 | 0.140 | 0.200 |

Table 2. Subject 2 Z statistic values calculated from the C statistic for measures

| stats/s | slow | free | fast |
|---|---|---|---|
| phase A1 | -0.04 | -0.03 | -0.05 |
| phase B | 0.14 | 0.27 | 0.22 |
| phase A2 | 0.16 | -0.02 | 0.10 |
| phase A1 vs B | 0.02 | 0.13 | 0.08 |
| phase B vs A2 | 0.16 | 0.12 | 0.13 |
| phase A2 vs A1 | 0.14 | 0.15 | 0.14 |

| RSL | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.33 | -0.18 | -0.17 |
| phase B | 0.30 | 0.19 | 0.17 |
| phase A2 | 0.32 | 0.20 | 0.09 |
| phase A1 vs B | 0.23 | 0.05 | 0.06 |
| phase B vs A2 | 0.15 | 0.06 | 0.02 |
| phase A2 vs A1 | 0.18 | 0.08 | 0.03 |

| RST | slow | free | fast |
|---|---|---|---|
| phase A1 | -0.11 | 0.06 | 0.02 |
| phase B | -0.04 | 0.19 | 0.25 |
| phase A2 | 0.21 | 0.21 | 0.25 |
| phase A1 vs B | -0.08 | 0.07 | 0.07 |
| phase B vs A2 | 0.09 | 0.07 | 0.15 |
| phase A2 vs A1 | 0.11 | 0.10 | 0.12 |

| cadence | slow | free | fast |
|---|---|---|---|
| phase A1 | -0.11 | 0.04 | 0.02 |
| phase B | 0.00 | 0.22 | 0.26 |
| phase A2 | 0.24 | 0.24 | 0.26 |
| phase A1 vs B | -0.07 | 0.08 | 0.08 |
| phase B vs A2 | 0.10 | 0.09 | 0.15 |
| phase A2 vs A1 | 0.11 | 0.11 | 0.12 |

| SST% | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.02 | -0.18 | 0.34 |
| phase B | 0.11 | 0.28 | 0.34 |
| phase A2 | 0.15 | 0.14 | 0.34 |
| phase A1 vs B | 0.04 | 0.10 | 0.11 |
| phase B vs A2 | 0.03 | 0.09 | 0.08 |
| phase A2 vs A1 | 0.05 | 0.07 | 0.12 |

| | Range of WS | FR | FES | Tremor | | PIMS | |
|---|---|---|---|---|---|---|---|
| | | | | Right | Left | best | worst |
| phase A1 | 0.13 | 0.09 | 0.00 | 0.06 | 0.04 | 0.21 | 0.13 |
| phase B | 0.27 | -0.04 | 0.25 | 0.05 | -0.03 | 0.30 | 0.22 |
| phase A2 | 0.29 | 0.18 | 0.33 | 0.15 | 0.00 | 0.33 | 0.27 |
| phase A1 vs B | 0.16 | 0.00 | 0.16 | 0.04 | 0.00 | 0.20 | 0.12 |
| phase B vs A2 | 0.20 | 0.06 | 0.20 | 0.06 | -0.01 | 0.21 | 0.12 |
| phase A2 vs A1 | 0.17 | 0.09 | 0.27 | 0.07 | 0.03 | 0.23 | 0.11 |

Table 3. Subject 3 Z statistic values calculated from the C statistic for measures

| stats/s | slow | free | fast | RSL | slow | free | fast |
|---|---|---|---|---|---|---|---|
| phase A1 | 0.14 | 0.25 | 0.25 | phase A1 | 0.33 | 0.27 | 0.16 |
| phase B | 0.13 | 0.14 | 0.16 | phase B | 0.09 | 0.10 | 0.17 |
| phase A2 | 0.19 | 0.23 | -0.14 | phase A2 | 0.34 | 0.14 | -0.11 |
| phase A1 vs B | 0.10 | 0.17 | 0.17 | phase A1 vs B | 0.08 | 0.17 | 0.10 |
| phase B vs A2 | 0.13 | 0.15 | 0.06 | phase B vs A2 | 0.12 | 0.10 | 0.02 |
| phase A2 vs A1 | 0.12 | 0.17 | 0.11 | phase A2 vs A1 | 0.10 | 0.17 | 0.10 |

| RST | slow | free | fast | cadence | slow | free | fast |
|---|---|---|---|---|---|---|---|
| phase A1 | 0.12 | 0.24 | 0.14 | phase A1 | 0.15 | 0.26 | 0.15 |
| phase B | 0.12 | 0.15 | 0.10 | phase B | 0.12 | 0.16 | 0.11 |
| phase A2 | -0.05 | 0.00 | -0.20 | phase A2 | -0.04 | 0.01 | -0.20 |
| phase A1 vs B | 0.10 | 0.17 | 0.15 | phase A1 vs B | 0.10 | 0.18 | 0.15 |
| phase B vs A2 | 0.14 | 0.16 | 0.07 | phase B vs A2 | 0.13 | 0.16 | 0.06 |
| phase A2 vs A1 | 0.13 | 0.15 | 0.04 | phase A2 vs A1 | 0.14 | 0.16 | 0.05 |

| SST% | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.09 | 0.15 | 0.34 |
| phase B | 0.07 | -0.01 | 0.10 |
| phase A2 | 0.12 | 0.07 | -0.02 |
| phase A1 vs B | 0.07 | 0.08 | 0.15 |
| phase B vs A2 | 0.12 | 0.07 | 0.20 |
| phase A2 vs A1 | 0.12 | 0.09 | 0.04 |

| | Range of WS | FR | FES | TREMOR | | PIMS |
|---|---|---|---|---|---|---|
| | | | | Right | | Left |
| phase A1 | 0.33 | -0.10 | -0.10 | 0.13 | -0.02 | 0.06 |
| phase B | 0.31 | -0.11 | 0.21 | 0.09 | 0.00 | 0.03 |
| phase A2 | 0.19 | 0.13 | 0.15 | -0.10 | 0.00 | 0.05 |
| phase A1 vs B | 0.23 | -0.08 | -0.02 | 0.02 | 0.14 | 0.11 |
| phase B vs A2 | 0.23 | 0.14 | 0.11 | -0.02 | 0.05 | 0.10 |
| phase A2 vs A1 | 0.23 | 0.10 | -0.03 | 0.09 | 0.15 | 0.05 |

Table 4. Subject 4 Z statistic values calculated from the C statistic for measures

| Stats/s | slow | free | fast | RSL | slow | free | fast |
|---|---|---|---|---|---|---|---|
| phase A1 | 0.08 | 0.15 | 0.06 | phase A1 | 0.30 | 0.15 | 0.01 |
| phase B | 0.27 | 0.12 | 0.19 | phase B | 0.30 | 0.29 | 0.26 |
| phase A2 | -0.08 | 0.08 | 0.19 | phase A2 | -0.07 | -0.01 | 0.15 |
| phase A1 vs B | 0.15 | 0.10 | 0.10 | phase A1 vs B | 0.19 | 0.11 | 0.12 |
| phase B vs A2 | 0.18 | 0.18 | 0.18 | phase B vs A2 | 0.21 | 0.21 | 0.21 |
| phase A2 vs A1 | 0.10 | 0.12 | 0.17 | phase A2 vs A1 | 0.19 | 0.13 | 0.20 |

| RST | slow | free | fast | cadence | slow | free | fast |
|---|---|---|---|---|---|---|---|
| phase A1 | 0.01 | 0.18 | 0.11 | phase A1 | 0.02 | 0.16 | 0.11 |
| phase B | 0.19 | 0.18 | 0.10 | phase B | 0.20 | 0.18 | 0.09 |
| phase A2 | 0.17 | 0.07 | 0.13 | phase A2 | -0.05 | 0.07 | 0.13 |
| phase A1 vs B | 0.09 | 0.13 | 0.07 | phase A1 vs B | 0.09 | 0.11 | 0.07 |
| phase B vs A2 | 0.12 | 0.13 | 0.08 | phase B vs A2 | 0.11 | 0.13 | 0.08 |
| phase A2 vs A1 | 0.12 | 0.12 | 0.10 | phase A2 vs A1 | 0.02 | 0.11 | 0.10 |

| SST% | slow | free | fast |
|---|---|---|---|
| phase A1 | 0.10 | 0.16 | 0.34 |
| phase B | 0.04 | -0.02 | -0.12 |
| phase A2 | -0.08 | -0.02 | -0.02 |
| phase A1 vs B | 0.06 | 0.12 | 0.01 |
| phase B vs A2 | 0.03 | 0.00 | -0.04 |
| phase A2 vs A1 | 0.10 | 0.04 | 0.05 |

| | Range of WS | FR | FES | Tremor | | PIMS | |
|---|---|---|---|---|---|---|---|
| | | | | Right | Left | best | worst |
| phase A1 | 0.31 | 0.22 | -0.08 | 0.10 | 0.18 | 0.08 | 0.23 |
| phase B | 0.33 | -0.06 | 0.25 | -0.07 | -0.08 | 0.07 | 0.33 |
| phase A2 | 0.33 | 0.10 | 0.08 | 0.00 | 0.12 | 0.15 | 0.15 |
| phase A1 vs B | 0.22 | 0.07 | 0.08 | 0.10 | -0.01 | 0.17 | 0.19 |
| phase B vs A2 | 0.23 | 0.11 | 0.17 | -0.03 | 0.01 | 0.12 | 0.23 |
| phase A2 vs A1 | 0.22 | 0.20 | 0.12 | 0.10 | 0.01 | 0.14 | 0.02 |

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