THE EFFECTS OF WEIGHTS ON THE AMPLITUDE AND FREQUENCY OF POSTURAL HAND TREMOR IN PEOPLE WITH PARKINSON'S DISEASE

by

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Abstract

Objectives: Parkinson's disease (PD) is a disabling condition characterized by rigidity, bradykinesia and tremor. The occupational therapy management of tremor has included use of weights to alleviate tremor and improve activities of daily living. However, there is no published evidence that weights do, indeed, help PD tremor. The objective of this study was to compare the effects of weights (a weighted spoon and a weighted wrist cuff) on postural hand tremor in subjects with PD. Methods: Fifteen men and three women with PD and hand tremor participated (mean age 67.5 ± 6.2 years, mean duration of PD since diagnosis 5.1 ± 4.1 years). Each subject's postural hand tremor was recorded using laser displacement sensors. In a single session, tremor was recorded in three conditions presented in random order: a built-up spoon (108g), a weighted spoon (248g) and a weighted wrist cuff (470g) along with a built-up spoon. The built-up spoon was used as a control condition. The effects of the three conditions on tremor amplitude and frequency were compared. Results: Analysis using repeated measures ANOVA revealed no significant differences in the amplitude of tremor in any of the three conditions. Analysis using Kruskal-Wallis test revealed no significant differences in the peak frequency of tremor in the three conditions. Correlation analysis revealed that the age of the subjects, the duration of PD and the duration of tremor in the hand tested did not show any relationship with the effects of weights. Conclusions: This study showed that a weighted spoon or a weighted wrist cuff do not affect the amplitude or peak frequency of postural hand tremor in PD. The results suggest that weights as they are often clinically applied may not be beneficial for PD
patients with postural hand tremor. The results of this study may influence rehabilitation management of tremor in Parkinson’s disease.
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1. Introduction

Parkinson's disease (PD) is a slowly progressive, degenerative disorder of the basal ganglia of unknown etiology. Degeneration of the dopaminergic cells of the substantia nigra is the principal pathologic feature of PD. PD is characterized clinically by bradykinesia, rigidity and tremor. The age of onset is typically around 50 years. Tremor is a rhythmical, involuntary oscillatory movement of a body part. Tremor is a common symptom in PD, and is found in approximately 75% of patients with PD during the course of their illness.

Various types of tremor, such as rest tremor, postural tremor and/or kinetic tremor are seen in PD patients. Postural tremor occurs while voluntarily holding the limb in an antigravity position, while kinetic tremor occurs during movement. These tremors usually occur in the distal upper extremities and can interfere with the patients' ability to perform their activities of daily living. Studies to date indicate that PD tremor has a central origin, although it can be modified by peripheral input. The parameters that are used to study tremor include the amplitude, frequency and waveform analysis of tremor.

Various types of treatment have been used to alleviate the symptoms of PD. These methods include pharmacological and surgical methods and rehabilitation therapy. Various physical methods have been shown to be effective in reducing tremor and include stretching exercises and upper body karate exercises. The occupational therapy (OT) evaluation consists of a complete assessment of the manifestations of tremor. The goals of OT are to maintain maximum functional independence and to prevent limitations from tremor. These are achieved by adaptive techniques such as
stabilizing proximal limb segments and weighting distal segments. Weights are used in the form of weighted utensils, weighted cups and weighted wrist cuffs. The reasons for the use of weights appear to be the recommendations in some of the standard OT textbooks. The clinical use of weights to manage PD tremor may have arisen either from these recommendations or possibly from benefits seen in clinical practice. Further, it is possible that this clinical practice of using weights to control PD tremor was stated in textbooks as a recommendation for the use of weights to manage PD tremor, in spite of the lack of evidence that weights do, indeed, help subjects with PD tremor. Thus a cyclical process appears to have been set up, with the OT textbooks recommending weights because of their use in clinical practice, and weights being used in clinical practice because of the recommendations in the OT textbooks. Although weights are used by occupational therapists in clinical practice for PD tremor management, several scientific studies suggest that weights may not have a beneficial effect on PD tremor.

Because of the contradiction between the OT textbooks and the scientific literature on tremor, the effects of weights on PD tremor were examined in this study. Specifically, this study examined the effects of weights (a weighted spoon or a weighted wrist cuff) on the frequency and amplitude of postural hand tremor in subjects with PD during the act of holding a spoon.

This study was a single visit, within-subjects design. Eighteen subjects who were clinically diagnosed with PD and had hand tremor were recruited for this study. There were three recording conditions: a built-up spoon, a weighted spoon and a weighted wrist cuff along with the built-up spoon. The built-up spoon was the control
condition. Postural hand tremor was recorded using two laser displacement sensors while the subject was holding a spoon in a seated position. The subjects’ tremor was recorded for thirty seconds each with the built-up spoon, the weighted spoon and the weighted wrist cuff along with the built-up spoon. Three trials were recorded for each condition, resulting in a total of nine trials per subject. Tremor amplitude and frequency were the outcome variables for this study.

As will be seen in the presentation of the results, it was found that weights did not alter the amplitude or the peak frequency of postural hand tremor in PD. Further, correlation analysis revealed that the age of the subjects, the duration of PD and the duration of tremor in the hand tested did not show any relationship with the effects of weights.

This study supports the findings of other comparable studies, that weights do not alter the characteristics of PD tremor. Possible reasons for these findings are discussed. In addition, the clinical significance of these findings are presented along with recommendations for further research.
2. Background Literature Review

2.1. Parkinson’s disease

Parkinson’s disease (PD), formerly called paralysis agitans, was first described by James Parkinson in 1817. PD is a slowly progressive degenerative disorder of the basal ganglia. Pathological findings of PD include degeneration and neuronal loss in the substantia nigra (SN). Because the degenerating cells in the SN normally synthesize dopamine, the pathophysiological hallmark of PD is dopaminergic underactivity in the striatum (caudate nucleus and putamen). Dopamine acts as a precursor to the inhibitory neurotransmitter norepinephrine, and is responsible for balancing the excitatory action of acetylcholine. Depletion of dopamine in the extrapyramidal system results in the transmission of uncontrolled excitatory impulses (Oertel and Hartmann, 1999).

Primary Parkinson’s disease is idiopathic. Another category called secondary or acquired Parkinson’s disease is due to other causes such as infectious diseases resulting in encephalitis, or exposure to the intoxicant 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP; Langston et al., 1984). The prevalence of idiopathic PD is 0.1% - 0.162% in the general population (Tanner, 1992), although the prevalence has been estimated to be 1% in the population over the age 60 (Barbeau and Boucher, 1982). PD does not appear to be restricted to a particular race, geographic region, or either sex.

PD is characterized by akinesia (difficulty initiating movement) and bradykinesia (slowness and difficulty maintaining movement), rigidity (increased tone in both agonist
and antagonist muscles), tremor, and disorders of posture and gait. PD patients may also exhibit diminished righting and balance reactions causing them to fall frequently. Festinating, or slow shuffling, gait is another problem associated with mobility. Some patients with PD appear to have a masked facial appearance (Gilroy, 1990).

2.2. Medical management of Parkinson’s disease

The purpose of pharmacological treatment in PD is to restore dopamine to the basal ganglia, stimulate intact dopamine receptors, block central acetylcholine in order to produce a favorable balance between the dopaminergic and cholinergic systems, and to reduce the degree of nigrostriatal degeneration.

The most effective treatment for the symptoms of PD is levodopa (Metman and Mouradian, 1999), which is a precursor of dopamine, the neurotransmitter depleted in patients with PD. Levodopa is administered orally and is absorbed in the small intestine. It is then converted to dopamine by an enzyme called dopa-decarboxylase. Conversion to dopamine outside the blood-brain barrier can result in a lower level of dopamine within the CNS, and can also be responsible for some of the early side effects of levodopa, particularly nausea and vomiting. The addition of dopa-decarboxylase inhibitors that do not cross the blood-brain barrier (e.g., carbidopa) minimizes dopamine formation in the periphery and greatly improves patient tolerance to therapy. It also results in higher levels of dopamine in the CNS. This is the concept behind the use of the carbidopa-levodopa combination (e.g., Sinemet). Levodopa has been shown to be effective in improving all individual symptoms of PD, and in improving overall disability (Fahn and Calne, 1978; Boshes, 1981).
The chronic use of levodopa is complicated by the development of two motor problems, namely, fluctuations, which are unpredictable irregular responses to medications, and dyskinesias, which are drug-induced involuntary movements. In some patients, prolonged levodopa therapy can result in complex and less predictable ("on-off") motor fluctuations. These patients may change from relatively normal function to a frozen akinetic state in as little as a few seconds (sudden on-off), or they may develop severe dyskinesia at both the peak effect of the levodopa dose and at the end of the dose (biphasic dyskinesia).

One of the principal pathologic features in PD is that the cholinergic system is spared, while the dopaminergic system is affected. Thus, the dopaminergic-cholinergic balance in the striatum is tilted in favor of the cholinergic pathways in PD. Therefore, anticholinergic therapy has been used to improve PD symptoms. Anticholinergic drugs effectively suppress the symptoms of tremor, but have minimal effect on rigidity and bradykinesia (Ebling, 1971; Obeso and Martinez-Lage, 1987). In fact, anticholinergic drugs have been recommended as the drugs of choice if tremor is the predominant symptom (Waters, 1999).

Inhibition of the enzyme monoamine oxidase (MAO), which exists in two forms, MAO-A, and MAO-B, has been thought to be beneficial for PD patients. This is because of neuroprotective effects seen with inhibition of both forms of MAO (Carrillo et al., 1994; Lai et al., 1994). The requirement of MAO-B activity for MPTP neurotoxicity (Snyder and D’Amato, 1986) suggests that if any toxic substances are responsible for PD, then MAO-B inhibition may be beneficial. Moreover, inhibition of MAO-A can result in a life-threatening hypertensive crisis. Therefore, for practical
considerations, MAO-B has been inhibited using pharmacological agents (e.g., selegiline) to treat the symptoms of PD, and this strategy has been shown to delay the clinical progression of PD (The Parkinson Study Group, 1993). While selegiline appears to be effective within one year of starting selegiline treatment, it appears to hasten PD progression over a longer period of five years (Brannan and Yahr, 1995).

Finally, agents such as bromocriptine and pramipexole that stimulate dopamine receptors (dopamine agonists) have been used to treat PD patients. Dopamine agonists have been shown to be effective in improving PD symptoms, including tremor (Obeso et al., 1986).

2.3. Surgical management of Parkinson's disease

Surgical treatment for PD is reserved for PD patients in whom standard medical therapies have failed to produce adequate control of symptoms. Restoration of striatal function has been attempted by neural grafting, which involves the implantation of fetal tissue into the basal ganglia of subjects with PD. This has been reported to show promising results in clinical trials (Fahn, 1992; Olanow et al., 1996).

Other surgical methods to treat PD have included the use of lesions or stimulators. Attempts have been made to reduce basal ganglia outflow by lesioning cells in the globus pallidus (pallidotomies). Pallidotomies, which are speculated to terminate the effect of abnormal globus pallidus activity on normal human movement, have been beneficial in akinesia, rigidity and motor fluctuations (Baron et al., 1996). Alternatively, high-frequency (>120 Hz) deep brain stimulators have been implanted into the globus pallidus. Activity of these stimulators can act as functional lesions by desynchronizing neuronal activity. They have been reported to be effective in
controlling rigidity, bradykinesia, tremor and gait abnormalities (Siegfried and Lippitz, 1994).

Lesions of the subthalamic nucleus and implantation of subthalamic nucleus stimulators have been shown to be effective in controlling motor signs of PD (Limousin et al., 1995; 1998).

Neurosurgical lesioning has been performed on the nuclei in ventral and lateral thalamus (thalamotomies). Severe tremor is reduced or even disappears with thalamotomies (Lozano et al., 1995; Lang et al., 1997). Also, high-frequency stimulation of the nucleus intermedius ventralis has been found to be effective in reducing tremor (Benabid et al., 1991).

2.4. Tremor in Parkinson’s disease

Tremor has been defined as a rhythmical, involuntary oscillatory movement of a body part (Deuschl et al., 1998). Seventy percent of PD patients present with tremor as a dominant and best developed feature, especially in the early stages of the disease (Deuschl, 1999). Approximately 75% of patients with PD will have tremor during the course of their illness (Lance et al., 1963). The tremor occurs most often in the distal extremities but can also involve the lips, the chin and the tongue (Fahn et al., 1993) and can impede activities of daily living (Foti et al., 1996). Tremor in PD is asymmetric, usually begins in the upper extremities, and involves the fingers and thumb to result in a characteristic “pill-rolling” tremor. Parkinsonian tremor occurs at a uniform frequency between 4-8 Hz in different body parts of the same patient (Dubinsky, 1995). Although the most common tremor in PD is resting tremor, various types of tremor such as postural tremor and/or kinetic tremor occur in patients with PD. Postural tremor in PD
is present while voluntarily maintaining a position against gravity (Deuschl et al., 1998). Recent studies indicate that the amplitude of postural tremor may be as high as that of rest tremor in patients with PD (Rajaraman et al., 2000) and that there is a positive correlation between the amplitudes of the two types of tremor (Foerster and Smeja, 1999). The mechanism that produces the sudden and extreme amplitude fluctuations seen in PD tremor is not understood (Cleeves et al., 1986). Tremor activity is usually suppressed during sleep, and complete relaxation of the axial postural muscles. The amplitude of tremor increases with stress and anxiety (Delwaide and Gonce, 1993).

2.5.  Physiological tremor

Physiological tremor occurs when the outstretched limb is maintained in an antigravity position and is characterized by periodic involuntary oscillations in the limb (Marsden, 1984; Elble and Koller, 1990). Physiological tremor occurs in healthy subjects and is not normally evident to the naked eye. Physiological tremor is a result of the mechanical properties of the limb responding to internal or external oscillations, and thus has a purely peripheral origin. The frequency of physiological tremor in the upper limb varies with the site of measurement. It has been shown that, in the upper limb, the more distal the measurement site, the higher the frequency of the tremor (Bain, 1995). Various studies have shown that physiological tremor recorded at the fingertips has a peak frequency in acceleration of 8-12 Hz (Elble and Randall, 1976; Elble, 1986), while that recorded at the upper arm has a peak frequency of 2-4 Hz (Morrison and Newell, 1996; 1999).
2.6. **Origin of tremor in Parkinson’s disease**

The experimental data summarized below indicate that PD tremor has a central origin, with peripheral inputs modifying the tremor.

Evidence that points towards a central mechanism of PD tremor includes the following:

1. Rhythmic electrical activity has been recorded in the thalamus during intraoperative microelectrode recordings in association with contralateral limb tremor (Jasper and Bertrand, 1964; Albe-Fessard et al., 1966; Narabayashi and Ohye, 1983). While the possibility exists that some of this activity is driven by the movements of the muscle or by afferent activity, it is also clear that a part of the rhythmic thalamic activity was present before the tremor, and may represent the activity of the movement’s pacemaker.

2. PD tremor is abolished by lesions in the nucleus ventralis intermedius of the thalamus, and high-frequency electrical stimulation of the nucleus ventralis intermedius suppressed rest tremor (Benabid et al., 1991).

3. Rhythmical activity has been tracked from the thalamus and is said to follow a path to the motor cortex and then down to the spinal motor neuron pool via the pyramidal tract. Tremor is abolished on the paretic side in a PD patient who develops hemiplegia, and surgical section of the pyramidal tract abolishes tremor (Bucy, 1951; Walker, 1955).

Evidence for a peripheral influence on tremor includes studies that have shown the following:
1. Electrical stimulation of the median nerve resets the tremor in PD patients (Britton et al., 1993). This study, and other similar studies, show that while supramaximal electrical stimulation of a mixed peripheral nerve is unable to abolish tremor, it can reset tremor rhythm (Rondot, 1977; Rondot and Bathien, 1981).

2. Brief mechanical perturbations of the wrist using a torque motor can reset tremor, although tremor is not abolished by these perturbations (Britton et al., 1992).

3. Dorsal rhizotomy, while unable to abolish rest tremor in PD, alters the tremor characteristics (Pollock and Davis, 1930).

4. Nerve trunk anesthesia or ischemia makes tremor irregular (Ekbom et al., 1952).

5. External loading of the limb does not abolish or alter PD postural wrist tremor (Homberg et al., 1987) or kinetic tremor (Morgan, 1975; Morgan et al., 1975; Hewer et al., 1972; Forssberg et al., 2000). This evidence will be discussed further in Section 2.10.

2.7. Methods used to study tremor

A number of parameters have been examined to study and describe tremor. The kinematic measures of tremor include displacement, velocity, acceleration and jerk. The other measurements of tremor include force and electrical activity of muscles. Based on these measurements the parameters that are used to analyze tremor are frequency, amplitude and waveform of tremor (Gresty and Findley, 1984). The frequency of tremor bears an important relationship to the nature of the underlying mechanism. In PD the tremor frequency is quite stable (Delwaide and Gonce, 1993) and, in fact, frequency of tremor has been widely used to make pathophysiological diagnoses (Deuschl, 1999). Waveform reflects the specific distribution and timing
sequence of muscular activity involved in tremor. Amplitude of tremor sheds little light on the mechanism of tremor, but from a therapeutic point of view it can play an important role in the inability of the patient to carry out his or her activities of daily living. For example, Bain et al. (1993) showed that in subjects with essential tremor, the extent of impairment during functional tasks such as holding a cup of water, drawing a spiral and a tracking task positively correlated with the amplitude of tremor.

Various devices can be used to measure the various parameters of tremor. Force can be measured with force transducers, and muscle activity can be measured with electromyography equipment (Shahani and Young, 1976; Deuschl et al., 1996; Norman et al., 1999). The kinematics of tremor can be measured with different techniques employing mechanical, optical or magnetic principles. Accelerometry has been widely used, and has been shown to be highly sensitive (Deuschl et al., 1996; Deuschl, 1999). Digitizing tablets have also been used to record tremor based on the movement of a pencil (Elble and Koller, 1990). Other devices are available that can record three-dimensional movements based on video recordings with light-dark contrast, infrared, or ultrasound technology (Deuschl, 1999). The latter systems are limited principally by their temporal resolution. A novel method of using simple laser systems to record and analyze tremor has been shown to be accurate and easy to use, with the additional advantages that it eliminates physical contact between the subject and the sensor (Beuter et al., 1994), and that it has good spatial and temporal resolution.
2.8. **Physical methods for management of Parkinson’s disease tremor**

Several studies have established the benefits of physical therapy for patients with PD (Formisano et al., 1992; Dam et al., 1996). While these studies have mostly focused on the other aspects of PD such as bradykinesia and abnormal posture and gait, a few studies have examined the benefits of exercise on tremor. Palmer et al. (1986) compared the effect of a physical exercise program developed by the United Parkinson Foundation and compared it with a program of upper body karate training for twelve weeks. This study found that arm tremor as measured by measurement of torque changes at the elbow and by a questionnaire improved with both methods, whereas some other signs of PD such as rigidity and pronation-supination rate did not improve. However, this study did not examine hand tremor, and the improvement in arm tremor may not be accompanied by an improvement in hand tremor. The rationale behind why arm tremor would improve with this method is unclear. Bergenhouse and colleagues developed an external damping device for the upper extremity to manage tremor in PD. The device was designed to damp intention tremor and therefore improve the patient’s ability to perform fine motor tasks (Bergenhouse et al., 1989).

2.9. **Occupational therapy management of Parkinson’s disease tremor**

Tremor in subjects with PD can impact the patient’s life both from a physical and a psychological perspective. For example, the loss of ability to complete feeding can result in a lower self-esteem and a deep sense of dependence. Moreover, since feeding is a social activity, problems with feeding can result in the client preferring isolation from the rest of his or her community during eating.
The role of occupational therapy (OT) is to assess a client's status with respect to activities of daily living (ADLs) and to determine problems that interfere with independence. This is followed by a determination of treatment objectives, with the goals of providing training and/or equipment to enable the achievement of a higher level of independence.

The OT evaluation consists of complete assessment of the manifestations of tremor (Foti et al., 1996). The degree of involvement (presence and characteristics of tremor) is noted, as is the extent of impact on functional activities. The functional evaluation includes recording the time involved and manner of performance of selected activities of daily living such as feeding and grooming.

The goals of occupational therapy are to maintain maximum independence in functional activities by preventing limitations from tremor and by providing adaptive or assistive devices. The adaptive techniques used in OT include stabilizing proximal limb segments and weighting distal segments to help compensate for the lack of fine motor skills. The adaptive equipment used during feeding to improve function are aimed at reducing tremor itself and reducing the consequences of tremor. Weighted utensils, weighted cups or a weighted wrist cuffs are used to reduce tremor. Non-skid placemats, covered glass with an inserted straw, use of plate guards or scoop dishes to prevent pushing food off the plate are used to reduce consequences of tremor.

The use of weights may arise from the recommendations in standard occupational therapy textbooks (Foti et al, 1996; Trombly, 1995; Turner et al., 1996). Some occupational therapists feel that the use of heavy dinnerware and weighted
utensils and wrist weights are beneficial for patients with PD tremor (Foti et al., 1996; Turner et al., 1996). Accordingly, such equipment is being marketed by a number of rehabilitation equipment suppliers to meet the needs of patients with tremor. Others feel that activities like hammering and leather punching which involve resisted grasp, provide distal stability and reduce tremor can improve the ADLs in PD patients (Newman et al., 1995).

Thus, weights have played a key role in the management of PD tremor, and continue to do so. The obvious expectation is that the use of weights in PD tremor is based on scientific studies and theoretical considerations. As the following discussion shows, it is based on neither.

2.10. Studies on the effect of weights on Parkinson's disease tremor

Hewer et al. (1972) investigated the effects of weights (240g-720g) on tremor in 50 subjects with essential tremor, multiple sclerosis, Friedreich's ataxia, cerebellar degeneration, cerebrovascular accident and Parkinson's disease (five subjects). The weights were used in the form of wrist bands and tremor was recorded either by accelerometry or by a photographic method. The subjects were instructed to move their hands in the horizontal plane two feet from side to side, with the arm pronated and extended in front of them. The severity of tremor was also assessed during writing and drawing spirals. Thirty-six percent of the subjects showed improvement, including subjects with cerebellar tremor, although the authors did not report the performance of subjects with Parkinsonian tremor.
Morgan (1975) investigated the effect of weights on tremor in 58 subjects with multiple sclerosis, essential tremor, cerebellar degeneration, Friedreich's ataxia or PD (five subjects). The effect of weights on arm movement towards a target was measured using accelerometry. Weights (480g - 720g) were used in the form of wrist bands or upper arm bands. The authors reported, but did not present data, that weighted wrist bands did not improve tremor in PD subjects, whereas tremor in cerebellar patients showed improvement.

Morgan et al. (1975) also examined the effect of weights in 31 subjects with intention tremor resulting from multiple sclerosis, essential tremor, cerebellar degeneration, Friedreich's ataxia or PD (four subjects). Weights (480-960g) were used in the form of wrist bands. The effect of weights during arm movement towards a target was measured using accelerometry. They reported that 65% of the subjects showed a significant reduction of tremor with weights. This study does not report the performance of the individual subjects, so it is not possible to differentiate the effect of weights in PD. They also reported that PD tremor in an antigravity position did not show improvement.

Homberg et al. (1987) investigated the effects of weights on postural wrist tremor in healthy controls (physiological and enhanced physiological tremor) and subjects with PD (five subjects) and essential tremor. Weights (100g-1500g) were attached to the dorsum of the hand at a distance of 8 cm from the wrist joint. Tremor was recorded using accelerometry. They found that the peak frequency of physiological and enhanced physiological tremor reduced with weights, whereas the peak frequency and amplitude of postural tremor in PD and essential tremor did not
change with addition of a 1000g load. The authors speculated that the differential response to loading might have been due to different origins of tremor in these conditions.

Deuschl et al. (1996) reported that no subjects with Parkinsonian tremor and essential tremor show reduction in tremor frequency with external loading. On the other hand, in subjects with physiological tremor the addition of one kilogram of external load reduced hand tremor frequency by more than 1Hz. The EMG peak frequency in normal subjects was reduced with the addition of the weight, whereas the EMG peak remained constant in PD tremor and essential tremor.

Forssberg et al. (2000) examined the effect of weights on tremor in ten PD subjects and twenty healthy controls. Weights were used in the form of a weighted cube (300g or 900g). The weighted cube was held between the tips of the thumb and the index finger. Tremor was recorded as an infrared signal emitted by the object and captured by a camera, while the subject was picking up the weighted cube. They found that weights did not alter the amplitude or peak frequency of PD tremor.

The evidence presented above suggests that weights may have no effect on Parkinsonian tremor. While it is difficult to compare these studies because of the variations in the weights used, these studies suggest that a wide range of weights (100 -1500 g) may not have an effect on PD tremor.

2.11. Reasons for the use of weights in the occupational therapy management of Parkinson’s disease tremor

As described above, weights have been recommended by occupational therapists for PD tremor, in the form of weighted utensils and weighted wrist cuffs.
The exact reasons for the use of weights, and for the recommendations described above, are not clear. One possible reason can be the influence of studies during the 1970s (as discussed in Section 2.10) that showed a beneficial effect of weights in cerebellar intention tremor (Hewer et al., 1972; Morgan, 1975; Morgan et al., 1975). Although these studies did not show an effect of weights in PD tremor, it is possible that the effect of weights seen in cerebellar tremor in these studies led to a generalization that weights help all forms of tremor.

There is a possible explanation for the effect of weights on cerebellar tremor, but not on PD tremor, seen in the above studies. Both PD tremor and cerebellar tremor are believed to have a central origin, with a modulatory influence by the periphery. The ability to respond to weights is a measure of the relative magnitude of the peripheral influence (Homberg et al, 1987; Deuschl, 1999). The results imply a stronger modification of tremor by peripheral input in cerebellar tremor, but not in PD tremor.

Another explanation for use of weights by therapists in the absence of any scientific evidence indicating a beneficial effect could be that the therapists have seen beneficial effects of weighting in day-to-day practice on PD patients.

Thus, it appears that weighting has been recommended by occupational therapy textbooks for PD patients to reduce tremor and improve their ADLs in the absence of any published evidence that weights do help these patients. Moreover, very few studies have examined the effects of loading on tremor from a therapeutic point of view, possibly leading to the continuation of the early recommendations.

Further, these studies focused on trying to understand the mechanism of tremor. It is not clear how these weights would have affected basic activities of daily living such
as feeding. To understand the mechanism of PD tremor and to devise better tools for the practice of rehabilitation therapy for Parkinson’s disease we examined the effects of weighted utensils and wrist weights on the frequency and amplitude of postural hand tremor in PD subjects during the act of holding a spoon. It is important to determine the effects of weighted utensils and weighted wrist cuffs on tremor in order to guide occupational therapists in evaluating whether a client would benefit from such equipment.

2.12. Summary of background and purpose of study

The use of weighted utensils or weighted wrist cuffs may alter hand tremor frequency, amplitude or both, although the available evidence suggests that tremor frequency in Parkinson’s Disease (PD) is unlikely to be altered. The extent to which tremor may be altered will have implications for whether occupational therapists should recommend weighted eating utensils or weighted wrist cuffs for clients with PD. This study’s purpose was to analyze the effects of weighted spoons and weighted wrist cuffs on the amplitude and frequency of tremor. The results of this study will help determine whether weighted spoons or weighted wrist cuffs are beneficial for postural tremor during eating in PD patients.
3. Methodology

3.1. Objective

The objective of this study was to study the effects of external loading on frequency and amplitude of tremor in patients with Parkinson’s disease.

3.2. Research Hypotheses

a. Weighted wrist cuffs and weighted utensils will have no effect on the frequency of postural hand tremor in PD patients during the act of holding a spoon.

b. Weighted wrist cuffs and weighted utensils will reduce the amplitude of postural hand tremor in PD patients during the act of holding a spoon.

3.3. Research Design

This study was a single visit, within-subjects design. The three recording conditions were: a built-up spoon that weighed 108 g, a weighted spoon that weighed 248 g, and a weighted wrist cuff that weighed 470 g, which was used along with the built-up spoon. The built-up spoon was used as a control condition in this study. Postural hand tremor was recorded using two laser displacement sensors, one in the horizontal and the other in the vertical direction. The variables that were calculated included amplitude and frequency of postural hand tremor. The effects of the three conditions on tremor amplitude and frequency were compared.
3.4. Sample Selection

3.4.1. Nature of selection

Human subjects who gave informed consent were included in this study. The inclusion criteria were:

a. subjects who were clinically diagnosed with Parkinson's Disease.
b. subjects who had postural tremor in at least one upper extremity.

The exclusion criteria were:

a. subjects who had coexisting neurological conditions.
b. subjects who had coexisting musculoskeletal conditions that could result in an altered grasp of the extremity tested.

The subjects were recruited from the Movement Disorders clinic at Kingston General Hospital and the Kingston Chapter of the Parkinson Foundation of Canada. Potential subjects were informed of the study by the research nurse at the Movement Disorders clinic, and by verbal announcements by the investigators at the Kingston Chapter of the Parkinson Foundation of Canada. The subjects for the study contacted the investigators and informed them of their willingness to participate in the study. The subjects were a sample of convenience because they were recruited from the Movement Disorders clinic or from the Kingston Chapter of the Parkinson Foundation of Canada.

3.4.2. Number of subjects

Because this study was a pilot study and this experiment had not been done before, it was not possible to estimate the number of subjects based on the corresponding power of the study. Based on the impressions of variability of tremor from clinical practice and relevant literature (Morgan, 1972; Homberg et al., 1987;
Forssberg et al., 2000) a sample size of 18 was used. This sample size was larger than the sample sizes of PD subjects used in other comparable studies (Hewer et al., 1972; Morgan, 1975; Morgan et al., 1975, Homberg et al., 1987; Forssberg et al., 2000). This sample consisted of all available subjects at the Movement Disorders clinic who consented to participate in the study over a seven month period, and all volunteers from the Kingston Chapter of the Parkinson Foundation of Canada during the same time period.

3.5. Weights used in this study

For this study weights were used in the form of a weighted spoon and a weighted wrist cuff. The weighted wrist cuff, the weighted spoon, and the built-up spoon used in this study are shown in Figure 3.1. The weighted wrist cuff was borrowed from the Physical Therapy Clinic at Queen’s University. The built-up spoon and the weighted spoon were purchased from Sammons Preston Inc. The amount and location of weights were selected based on literature review (Hewer et al., 1972; Morgan, 1972; Homberg et al., 1987; Forssberg et al., 2000) and discussion with practicing therapists about the weights used to reduce tremor in clinical practice. The weight of the wrist band falls within the range of weights used in previous studies on effects of weighting on tremor (Hewer et al., 1972; Homberg et al., 1987). The 8-ounce spoon was selected because it is commercially available and marketed to reduce tremor. The built-up spoon was used in this study because it had a built-up handle but added negligible weight to the utensil. The handles of the built-up spoon and the weighted spoon provided similar grasp, so that any effects seen could be attributable to the weight itself, and not to the shape or size of grasp. A spoon was chosen for this
study because spoons are recommended by OT textbooks for use in PD patients because of lower possibility of injury (Hill, 1993). A fork can spear food, tremor has greater consequences when using the spoon in terms of spilling the food. Also, the bowl of the spoon is shallow compared to a cup, so tremor has more consequences in terms of spilling the food while using a spoon compared to while using a cup.

The spoons were subjected to a few modifications after purchase, as follows: one plastic box with lightweight cards was attached to the bowl of each spoon to provide reflective surfaces for the two laser beams. Markings were made on the handles of the two spoons to provide uniform distance between the subject’s fingers and the bowl of the spoon. The handle of the weighted spoon was modified so that both spoons provided similar grasp.

Figure 3.1. Weights used in this study. (a) weighted wrist cuff which weighed 470 g. (b) weighted spoon which weighed 248 g. (c) built-up spoon which weighed 108 g.
3. 6. Instrumentation

3. 6. 1. Laser displacement sensors

Two laser measurement systems (Aromat LM10-ANR12151, Matsushita Electric Works, Osaka, Japan) were used in this study. The laser measurement systems use optical triangulation to measure displacement. The use of laser systems to accurately record the characteristics of tremor has already been characterized and validated (Beuter et al., 1994) by comparing their performance with that of an accelerometer. Laser systems were used in this study because they yield displacement information, and the magnitude of displacement could directly impact feeding using a spoon. The laser system consisted of a laser source and a laser detection sensor as parts of a single unit. The unit was placed at a fixed distance from the moving surface. The laser beam emitted by the light-emitting element was reflected by a lightweight card, which was attached to the moving surface (i.e., the spoon). The beam was reflected onto a spot on the position sensitive device within the laser unit. The change in the output currents from the position sensitive device was used to measure displacement. The distance between the starting point of recording and each of these units was approximately 130 mm. The recording range of each unit was ± 50 mm and their spatial and temporal resolution were 0.2 mm and 1000 Hz, respectively. Because these were displacement sensors they were calibrated by measuring a fixed known distance of 31.52 mm and calculating the calibration constants.
3.6.2. Analog to digital (A/D) Converter

The A/D system (A-Tech Instruments Limited) had a bit size of 12, an input range of ± 10 V and resolution of 0.0049 V (corresponding to 0.049 mm).

3.7. Procedure

Informed consent was obtained from the subjects prior to the recordings. The subjects were interviewed by the investigator and asked about their age, the duration of PD, duration of tremor, coexisting diagnoses, medication usage, hand dominance, use of nicotine or caffeine, time of last meal, history of hand injury or hand surgery, current participation in physiotherapy and/or occupational therapy, current participation in any exercise programs, use of adaptive devices for fine motor ADLs and functional status. Their responses were recorded in a questionnaire by the investigator. Tremor was recorded from the hand with tremor or from the dominant hand in subjects who had tremor in both hands, except in one case where the tremor in the dominant hand was too large for the laser sensor's range. For recording, the subjects were seated. Then the recording position was finalized, with the subject leaning forward in a sitting position while holding the built-up spoon, to simulate normal feeding posture. The upper extremity from which tremor was recorded was maintained in the position shown in Figure 3.2. The shoulder was maintained in slight abduction and flexion sufficient to keep the upper arm away from the trunk. The elbow was maintained in approximately 90° flexion. The forearm was held in a position between pronation and supination such that the spoon was held in a horizontal position. The wrist was in a slightly extended
position. The spoon was held between the thumb, the index finger and the middle finger. This position of the limb during part of feeding was chosen because postural tremor must be recorded with the limb in an antigravity position and the consequences of tremor in this position could impede feeding. The starting position of the hand holding the spoon was approximately at the midpoint of the recording range of both laser units (130 mm). The laser beams were directed perpendicularly on to the two lightweight cards attached to the bowl of the spoon. The subjects' tremor was recorded for 30 seconds, each with the built-up spoon, the weighted spoon and the weighted wrist cuff along with the built-up spoon. Three trials were recorded for each condition, resulting in a total of nine trials per subject. The order of the nine trials was randomized.
Figure 3.2. Recording setup. This figure shows the position of the upper extremity holding the spoon. The subject was seated in the position shown here. Postural hand tremor was recorded while the subject was holding the spoon with a laser unit recording tremor in the vertical direction (a), and another recording tremor in the horizontal direction (b).
3.8. Data recording, processing and analysis

Signals were sampled at 1000 Hz per channel and recorded directly onto a personal computer. Data processing was done offline using Matlab software (V 5.3, The Mathworks, Inc). This study consisted of nine 30-second 2-channel recordings and resulted in a total of eighteen time series per subject. The signals were filtered offline using 4th order double-pass Butterworth filters (high-pass at 2 Hz and low-pass at 20 Hz). Then the signals were multiplied by appropriate calibration constants (10.0315 mm/V and 10.1154 mm/V for the horizontal and vertical directions, respectively).

The first step was to obtain measures of amplitude and frequency in both horizontal and vertical directions. The standard deviation of the calibrated, filtered time series was used as a measure of amplitude for the following reasons. First, root mean square is a commonly used measure of tremor amplitude. The mean of the filtered kinematic time series is zero, and the standard deviation and root mean square are identical when the mean of the time series is zero. This measure is less susceptible than other measures of amplitude, such as range, to variations from outlying values. Second, sudden transient fluctuations in amplitude can alter the range, thereby falsely implying a change in the amplitude of tremor with weights, whereas standard deviation is only affected by a sustained change, which is more important for function. The mean value of amplitude of the three trials was taken to represent the amplitude for that condition. Because the sampling rate was 1000 Hz and each trial was recorded for 30 seconds, there were 30,000 points per trial. Power spectral analysis was performed
with a window of 10,000 points resulting in a frequency resolution of 0.1 Hz. The average peak frequency over a ninety second time series (which consisted of three thirty-second trials) was taken to represent the peak frequency for that condition. This is in accordance with a number of studies of tremor that have used peak frequency as a sensitive measure to examine tremor frequency (Homberg et al., 1987; Norman et al., 1999; Forssberg et al., 2000). The peak frequency between 4 Hz and 8 Hz was taken to represent Parkinsonian peak frequency (Dubinsky, 1995). The peak frequency between 2 Hz and 3.9 Hz was taken to represent physiological tremor (Morrison and Newell, 1996; 1999).

The next step was to choose one direction of recording, either the horizontal or the vertical for further analysis. The amplitude recorded from the lasers in each direction was compared, and the direction in which there was a greater amplitude was considered for subsequent data analysis except in two subjects in whom the horizontal direction alone was considered due to technical difficulties in recording the vertical direction. The frequency in the direction in which greater amplitude was found was considered for further analysis. One subject had such erratic tremor that all 30-second trials contained sections in which the tremor was too large for the laser sensor’s recording range. For this subject, all trials were calibrated and filtered. Then sections of two to twelve seconds’ duration that contained no saturation were spliced together to form one 30 second time series for each condition. The measures of amplitude and peak frequency were calculated from these time series.

The calculations of amplitude and peak frequency were imported into Excel ’97, SPSS 10.0, and GraphPad Prism 3.0 software and further statistical analyses were
performed. A repeated measures ANOVA was calculated with the tremor amplitude as the dependent variable and the conditions (built-up spoon, weighted spoon and the weighted wrist cuff) as the independent variables. The amplitudes obtained with the weighted spoon and the weighted wrist cuff were normalized to the amplitude obtained with the built-up spoon for each subject. A second repeated measures ANOVA was performed for this set of data.

Pearson correlation coefficients were calculated for the amplitude of tremor with the built-up spoon and the relative amplitude of tremor with the weighted spoon and the weighted wrist cuff. Pearson correlation coefficients were also calculated for the relative amplitude of tremor and the following variables:

a. age of the subjects
b. duration of PD since diagnosis
c. duration of tremor in the hand tested

The subjects were divided into two groups based on intake of each type of medication (levodopa, dopamine agonists, anticholinergics and MAO-B inhibitors). The effects of medications on the amplitude of tremor in the three conditions were compared using t tests. Because tremor frequency does not have a normal distribution (the PD tremor frequency has a narrow range of 4-8 Hz), the effect of weights on peak frequency was analyzed by a non-parametric (Kruskal–Wallis) test.
4. Results

4.1. Subjects

Eighteen subjects, three female and fifteen male, were recruited for the study. All the subjects had been clinically diagnosed with Parkinson's disease. Twelve of the subjects were recruited from the Movement Disorders Clinic and six from the Kingston Chapter of the Parkinson Foundation of Canada. Based on their responses to questions during the interview process, it was concluded that none of the subjects in this study had coexisting neurological conditions, or coexisting musculoskeletal conditions that could result in an altered grasp of the extremity tested. Further, all the subjects had or reported tremor in at least one upper extremity.

The age, gender and duration of disease of the subjects as determined from the questionnaire are listed in Table 4.1. The age of the subjects ranged from 56 to 81 years, and the mean age was 67.5 years, and a standard deviation of 6.2 years. The duration of PD since diagnosis ranged from 5 months to 15.5 years, with a mean duration of 5.1 years, and a standard deviation of 4.1 years. All subjects had tremor in at least one extremity as one of the presenting symptoms at the time of diagnosis according to self-report. The method of selection of upper extremity for tremor recording has been described in Section 3.7. Based on the selection procedure, in some subjects the upper extremity selected for tremor recording was different from the upper extremity that presented with tremor at the time of diagnosis of PD. The duration of tremor symptoms in the hand tested ranged from 3 weeks to 11.5 years, with a mean duration of 4.5 years, and a standard deviation of 2.8 years. Tremor was recorded from
the dominant hand in eleven of the subjects. Tremor in other parts of the body, including the other upper extremity, the jaw or the lower extremities was noticed for six subjects during recordings.

The anti-Parkinson medications used by the subjects are listed in Table 4.1. Thirteen subjects were taking levodopa, ten were taking at least one dopamine agonist, five were taking an anticholinergic, and four were taking a MAO-B inhibitor. The recording session for each subject was scheduled about an hour before his or her usual medication intake. Five subjects had hypertension and were taking anti-hypertensive medication. One subject had asthma and was taking anti-asthma medication. Two subjects had diabetes and were taking anti-diabetic medication. Three subjects had hypothyroidism and were taking medications for hypothyroidism. Four subjects were taking anti-depressants or sedative medications. Further, two subjects had rheumatoid arthritis, two subjects had sleep apnea, and one subject had Gilbert’s syndrome. The coexisting conditions mentioned above were not severe and their type and severity unlikely to have affected the outcome measures. One of the subjects (subject P15) had a high frequency stimulator in the right thalamus implanted to treat PD as described in Section 2.3. The stimulator in the right thalamus reduces tremor in the left upper extremity. Therefore, tremor was recorded from the right hand for this subject. This subject had the highest tremor amplitude compared to the other subjects. One subject who had surgery for carpal tunnel syndrome in both hands three years prior to the recording complained of pain and discomfort in the lateral aspect of the wrist during all trials but his performance on the recordings was similar to that of the other subjects.
All subjects recruited for this study were living at home and functioning independently. Except for one subject (P15) who used a buttonhook, none of the subjects used assistive/adaptive devices for activities of daily living. None of the subjects was receiving occupational or physical therapy for PD at the time of their participation in the study. Eleven of the subjects were involved in exercise activities.

None of the participants in this study was a smoker. Twelve of the subjects used caffeine-containing beverages or chocolate, and the mean duration since last intake of the caffeine before recordings was 4 hours. The mean duration since intake of the meal prior to the recordings was 3.75 hours.

Two of the subjects who participated in this study felt that weights reduced their tremor. This information was not solicited, but was spontaneously volunteered by the two subjects. One of the two subjects (P07) stated, before the recording session, that holding heavy dinnerware reduced tremor. The other subject (P09) stated, during the recording session, that tremor was reduced while using the weighted spoon or the wrist cuff. As will be described in the following sections, weights did not have any effect on the tremor in both subjects.
Table 4.1: Subject Characteristics. m = male, f = female

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Anti-Parkinson medications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Duration of PD (yrs)</td>
</tr>
<tr>
<td>P01</td>
<td>65</td>
<td>m</td>
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</tr>
<tr>
<td>P02</td>
<td>62</td>
<td>m</td>
<td>3.0</td>
</tr>
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<td>P03</td>
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<td>m</td>
<td>4.2</td>
</tr>
<tr>
<td>P04</td>
<td>73</td>
<td>m</td>
<td>5.0</td>
</tr>
<tr>
<td>P05</td>
<td>57</td>
<td>m</td>
<td>2.6</td>
</tr>
<tr>
<td>P06</td>
<td>65</td>
<td>m</td>
<td>0.5</td>
</tr>
<tr>
<td>P07</td>
<td>74</td>
<td>m</td>
<td>11.5</td>
</tr>
<tr>
<td>P08</td>
<td>56</td>
<td>m</td>
<td>2.2</td>
</tr>
<tr>
<td>P09</td>
<td>68</td>
<td>f</td>
<td>5.5</td>
</tr>
<tr>
<td>P10</td>
<td>73</td>
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</tr>
<tr>
<td>P11</td>
<td>63</td>
<td>m</td>
<td>5.0</td>
</tr>
<tr>
<td>P12</td>
<td>66</td>
<td>f</td>
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<tr>
<td>P13</td>
<td>64</td>
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<tr>
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</tbody>
</table>

Mean ± SD: 67.5 ± 6.2

Duration of PD: 5.1 ± 4.1

Levodopa: 13 (72%) ± 4.1

Dopamine agonists: 10 (55%) ± 4.1

MAO-B inhibitors: 4 (22%) ± 4.1

Anti-cholinergics: 5 (27%) ± 4.1
4.2. **Effect of weights on tremor**

The following description illustrates some of the data recorded. The subsequent sections provide a summary analysis.

On observation the tremor was mostly distal, occurring mainly at the wrist joint and appearing to be in the 4-8 Hz range, which is the typical Parkinsonian tremor frequency. Thus tremor was seen while the subjects maintained the posture described in Section 3.7. In all subjects the tremor was rotational in nature. In most subjects the tremor was observed to occur mainly in either the horizontal or the vertical plane, although in some other subjects the tremor did not appear to be predominant in either the horizontal or the vertical directions. Parkinsonian tremor in the subjects appeared to have a range of patterns. The subjects with relatively large tremor amplitude, for example subject P01, were found to have tremor that was elliptical in nature. In contrast, the tremor in subjects with relatively low amplitude tremor, for example subject P05, was of an irregular nature, with no clearly distinguishable elliptical pattern. Data from these two subjects are shown in more detail to illustrate the characteristics of the tremor recordings.

The tremor in P01 had a clearly large amplitude in the vertical direction as shown by the calibrated filtered time series (Figures 4.1.A. and 4.1.B). On further examination of a representative three-second recording from the thirty-second trials, it can be seen that the vertical component was indeed the predominant component in this subject’s tremor (Figures 4.2.A. and 4.2.B). Plotting the vertical displacement against the horizontal displacement for this three-second period revealed the ellipsoidal nature of this subject’s tremor, predominantly in the vertical direction (Figure 4.3). The peak
frequency as determined by power spectral analyses was 5.2 Hz for both directions (Figures 4.4.A and 4.4.B). Thus, the tremor in P01 was of an ellipsoidal nature with greater amplitude in the vertical direction than in the horizontal direction, but with a peak frequency that was independent of the direction examined.

The tremor in P05 had a similar amplitude in the horizontal and the vertical directions as shown by the calibrated filtered time series (Figures 4.5.A. and 4.5.B). However, over all trials there was a slightly greater amplitude in the vertical direction and the amplitude and the peak frequency from the vertical direction were selected for further analysis. On further examination of a representative three-second recording from the thirty-second trials, it can be seen that this subject’s tremor had similar amplitude in both directions for this brief period (Figures 4.6.A. and 4.6.B). Plotting the vertical displacement against the horizontal displacement for this three-second period revealed the irregular nature of this subject’s tremor (Figure 4.7). The peak frequency as determined by power spectral analyses was similar for both directions (Figures 4.8.A and 4.8.B). The peak frequency from the vertical direction (6.5 Hz) was chosen for further analysis.

As described in detail in the methods section (Section 3.7), this study consisted of three trials per each condition of a built-up spoon, a weighted spoon, and a weighted wrist cuff along with the built-up spoon. The standard deviation was used as a measure of the amplitude, and the peak frequency was used as a measure of frequency. The mean values of the three trials for each condition were calculated (Table 4.2).
Figure 4.1.A. Thirty-second time series of vertical displacement during tremor recording from a subject with relatively large tremor (P01). Calibrated filtered time series in the vertical direction for P01 while holding the built-up spoon. This is the entire thirty-second time series from trial 1 for this subject in this condition. This subject's tremor had a larger amplitude in the vertical direction when compared to the horizontal direction (shown in Figure 4.1.B). The standard deviation for this trial was 1.21 mm. The area enclosed by the solid lines was selected for further viewing in Figure 4.2.A.
Figure 4.1.B. Thirty-second time series of horizontal displacement during tremor recording from P01. Calibrated filtered time series in the horizontal direction for P01 while holding the built-up spoon. This is the entire thirty-second time series from trial 1 for this subject in this condition. This subject’s tremor had a larger amplitude in the vertical direction (shown in Figure 4.1.A) when compared to the horizontal direction, shown here. The standard deviation for this trial was 0.36 mm. The area enclosed by the solid lines was selected for further viewing in Figure 4.2.B.
Figure 4.2.A. Three-second time series of vertical displacement during tremor recording from P01. This figure shows the calibrated filtered time series for the three-second period enclosed by the solid lines in Figure 4.1.A, and represents tremor in the vertical direction while holding a built-up spoon. Please note the larger amplitude in the vertical direction, shown here, when compared with the horizontal direction, shown in Figure 4.2.B.
Figure 4.2.B. Three-second time series of horizontal displacement during tremor recording from P01. This figure shows the calibrated filtered time series for the three-second period enclosed by the solid lines in Figure 4.2.A, and represents tremor in the horizontal direction while holding a built-up spoon. Please note the larger amplitude in the vertical direction, shown in Figure 4.2.A, when compared with the horizontal direction, shown here.
Figure 4.3. Vertical versus horizontal displacement from three-second time series during tremor recording from P01. This graph shows the tremor in P01 for the three-second period shown in Figures 4.2.A and 4.2.B. The displacement in the vertical direction has been plotted against the corresponding displacement in the horizontal direction. As described in the text, the tremor in this subject was elliptical, with a clearly larger vertical component.
Figure 4.4.A. Power spectrum of vertical direction of tremor in P01. This graph shows the power spectral analysis of tremor in the vertical direction for P01 while holding a built-up spoon. The thirty-second trial examined in this analysis is the same as that shown in Figure 4.1.A. Please note the peak frequency of tremor at 5.2 Hz. This peak frequency was identical to that in the horizontal direction, shown in Figure 4.4.B.

Note also that the y-axis is ten times the value of the y-axis in Figure 4.4.B.
Figure 4.4.B. Power spectrum of horizontal direction of tremor in PO1. This graph shows the power spectral analysis of tremor in the horizontal direction for PO1 while holding a built-up spoon. The thirty-second trial examined in this analysis is the same as that shown in Figure 4.1.B. Please note the peak frequency of tremor at 5.2 Hz. This peak frequency was identical to that in the vertical direction, shown in Figure 4.4.A. Note also that the y-axis is only one-tenth of the value of the y-axis in Figure 4.4.A.
Figure 4.5. A. Thirty-second time series of vertical displacement during tremor recording from a subject with relatively small tremor (P05). Calibrated filtered time series in the vertical direction for P05 while holding the built-up spoon and wearing the weighted wrist cuff. This is the entire thirty-second time series from trial 2 for this subject in this condition. The tremor in P05 was similar in the horizontal and vertical directions for this trial as shown by this calibrated filtered time series (compare Figure 4.5.B). The standard deviation for this trial was 0.27 mm. The area enclosed by the solid lines was selected for further viewing in Figure 4.6.A. Note that vertical scale is smaller than in Figures 4.1.A and 4.1.B.
Figure 4.6 B. Note that vertical scale is smaller than in Figures 4.1 A and 4.1 B.

The area enclosed by the solid lines was selected for further viewing in Figure 4.5 A. The standard deviation for this trial was 0.30 mm (compare Figure 4.5 A). The calibrated fibre optic time series vertical directions for this trial are shown by the calibrated fibre optic time series subject in this condition. The trial in Figure 4.5 was similar to the horizontal and vertical time series of Figure 4.5 B. Thirty-second time series of horizontal displacement during

[Diagram showing a graph with time (seconds) on the x-axis and horizontal displacement (mm) on the y-axis.]
Figure 4.6 A. Three-second time series of vertical displacement during tremor recording from P05. This figure shows calibrated filtered time series for the three-second period enclosed by the solid lines in Figure 4.5 A, and represents tremor in the vertical direction while holding a built-up spoon and wearing a weighted wrist cuff.
Figure 4.6.B. Three-second time series of horizontal displacement during tremor recording from P05. This figure shows calibrated filtered time series for the three-second period enclosed by the solid lines in Figure 4.5.B, and represents tremor in the horizontal direction while holding a built-up spoon and wearing a weighted wrist cuff.
Figure 4.7. Vertical versus horizontal displacement from three-second time series during tremor recording from P05. This graph shows the tremor in P05 for the three-second period shown in Figures 4.6.A and 4.6.B. The displacement in the vertical direction has been plotted against the corresponding displacement in the horizontal direction. As described in the text, plotting the horizontal displacement against the vertical displacement for this three-second period revealed the irregular nature of this subject's tremor.
Figure 4.8.A. Power spectrum of vertical direction of tremor in P05. This graph shows the power spectral analysis of tremor in the vertical direction for P05 while holding the built-up spoon and wearing the weighted wrist cuff. The thirty-second trial examined in this analysis is the same as that shown in Figure 4.5.A. Please note the peak frequency of tremor at 6.5 Hz. This peak frequency was similar to that in the horizontal direction, shown in Figure 4.8.B. Note that the vertical scale is smaller than in Figure 4.4.A.
Figure 4.8.B. Power spectrum of horizontal direction of tremor in P05. This graph shows the power spectral analysis of tremor in the horizontal direction for P05 while holding the built-up spoon and wearing the weighted wrist cuff. The thirty-second trial examined in this analysis is the same as that shown in Figure 4.5.B. Please note the peak frequency of tremor at 6.4 Hz. This peak frequency was similar to that in the vertical direction, shown in Figure 4.8.A. Note that the vertical scale is smaller than in Figure 4.4.B.
4.2.1. **Effect of weights on tremor amplitude for individual subjects**

The average tremor amplitude values for individual subjects in the three recording conditions can be seen in Table 4.2 and Figure 4.9. To determine the effect of weights on tremor amplitude for individual subjects, the tremor amplitude values obtained for the three conditions were compared (Figure 4.9).
Table 4.2. Amplitude values for individual subjects in the three recording conditions.

<table>
<thead>
<tr>
<th>Subject number</th>
<th>Tremor Amplitude * (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Built-up Spoon</td>
</tr>
<tr>
<td>P01</td>
<td>0.77</td>
</tr>
<tr>
<td>P02</td>
<td>0.78</td>
</tr>
<tr>
<td>P03</td>
<td>0.17</td>
</tr>
<tr>
<td>P04</td>
<td>0.30</td>
</tr>
<tr>
<td>P05</td>
<td>0.29</td>
</tr>
<tr>
<td>P06</td>
<td>1.60</td>
</tr>
<tr>
<td>P07</td>
<td>0.38</td>
</tr>
<tr>
<td>P08</td>
<td>0.24</td>
</tr>
<tr>
<td>P09</td>
<td>0.25</td>
</tr>
<tr>
<td>P10</td>
<td>0.17</td>
</tr>
<tr>
<td>P11</td>
<td>0.38</td>
</tr>
<tr>
<td>P12</td>
<td>0.93</td>
</tr>
<tr>
<td>P13</td>
<td>0.63</td>
</tr>
<tr>
<td>P14</td>
<td>0.49</td>
</tr>
<tr>
<td>P15</td>
<td>12.42</td>
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<tr>
<td>P16</td>
<td>0.42</td>
</tr>
<tr>
<td>P17</td>
<td>0.19</td>
</tr>
<tr>
<td>P18</td>
<td>0.19</td>
</tr>
</tbody>
</table>

| Mean ± Standard deviation | 1.14 ± 2.83 | 1.09 ± 2.30 | 1.00 ± 2.07 |

* The standard deviation of the calibrated, filtered time series was used as a measure of tremor amplitude. The mean value of the three trials for each condition was taken to represent the tremor amplitude for that condition.
Figure 4.9. Mean amplitude of the three trials for each condition for individual subjects. P01 to P18 refer to subject number.
4.2.2. Effects of weights on tremor amplitude for the entire group

To determine the effect of weights on tremor amplitude for the entire group, the tremor amplitude values obtained for the three conditions were compared for the group (Figure 4.10). A repeated measures ANOVA was performed and the results showed no significant differences between the three conditions (F statistic = 0.569, p = 0.571).

Figure 4.10 Group mean amplitude (± standard deviation) with the built-up spoon, the weighted spoon and the weighted wrist cuff.
4.2.3. Effects of weights on relative tremor amplitude for individual subjects

To determine the effects of weights on relative tremor amplitude, the ratios of the weighted spoon amplitude and weighted wrist cuff amplitude to built-up spoon amplitude were calculated for individual subjects (Figure 4.11). A within-subjects ANOVA was performed on the ratios and the results revealed no significant differences between the three conditions (F statistic = 1.060; p value = 0.357).
Figure 4.11. Ratio of the weighted spoon and weighted wrist cuff amplitudes relative to the built-up spoon amplitude for individual subjects. A ratio of 1 indicates that the only the built-up spoon amplitude with weighted wrist cuff (spoon or wrist cuff) is exactly the same as the amplitude with weighted spoon/built-up spoon.
4.2.4. Effects of weights on relative tremor amplitude for the group

To determine the effects of weights on the relative tremor amplitude for the entire group of subjects, the ratios of the weighted spoon amplitude and weighted wrist cuff amplitude to built-up spoon amplitude were calculated for the group (Figure 4.12). No significant differences were observed between the three conditions.

![Graph showing the ratio of weighted spoon and weighted wrist cuff amplitudes relative to the built-up spoon amplitude. A ratio of 1 indicates that the amplitude with weight (spoon or wrist cuff) is exactly the same as the amplitude with only the built-up spoon.]

Figure 4.12. Group mean ratio of the weighted spoon and weighted wrist cuff amplitudes relative to the built-up spoon amplitude. A ratio of 1 indicates that the amplitude with weight (spoon or wrist cuff) is exactly the same as the amplitude with only the built-up spoon.
4.2.5. Effects of weights on peak frequency of tremor

As described in Section 3.7, this study consisted of three 30-second trials per condition of built-up spoon, weighted spoon, and weighted wrist cuff along with the built-up spoon. The average peak frequency over the 90-second time series was taken to represent the frequency for that condition. The peak frequency between 4.0 and 8.0 Hz was taken to represent the Parkinsonian tremor peak frequency (Table 4.3), while the peak frequency between 2.0 and 3.9 Hz was taken to represent the physiological tremor peak frequency (Table 4.4).

To determine the effect of weights on tremor frequency, the average peak frequencies for the three conditions were compared for Parkinsonian tremor (4.0–8.0 Hz). A similar analysis was also performed for physiological tremor frequency (2.0-3.9 Hz). The group mean peak frequency for the three conditions are shown in Figure 4.13 (4-8 Hz) and Figure 4.14 (2-3.9 Hz). Kruskal-Wallis test performed on Parkinsonian tremor peak frequencies for the three conditions revealed no significant differences between the conditions (H statistic = -135). Kruskal-Wallis test was also performed on the mean physiological peak frequencies for the three conditions. The analysis revealed no significant differences between the conditions (H statistic = -149).
Table 4.3. Peak Parkinsonian tremor frequency in the 4.0-8.0 Hz range for individual subjects for the three recording conditions

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Peak tremor frequency (4 to 8 Hz)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Built-up Spoon</td>
<td>Weighted Spoon</td>
<td></td>
<td>Weighted wrist cuff</td>
</tr>
<tr>
<td>P01</td>
<td>5.2</td>
<td>5.4</td>
<td></td>
<td>5.2</td>
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<tr>
<td>P02</td>
<td>5.7</td>
<td>5.6</td>
<td></td>
<td>5.7</td>
</tr>
<tr>
<td>P03</td>
<td>4.9</td>
<td>4.1</td>
<td></td>
<td>4.2</td>
</tr>
<tr>
<td>P04</td>
<td>4.2</td>
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<td></td>
<td>4.8</td>
</tr>
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<td>6.3</td>
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</tr>
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<td>6.2</td>
<td></td>
<td>5.1</td>
</tr>
<tr>
<td>P08</td>
<td>5.9</td>
<td>4.0</td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td>P09</td>
<td>6.5</td>
<td>6.2</td>
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<td>5.7</td>
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<td>P10</td>
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<td>P18</td>
<td>4.0</td>
<td>4.0</td>
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| Mean ± standard deviation | 5.5 ± 0.71 | 5.3 ± 0.79 | 5.2 ± 0.77 |
Table 4.4. Peak physiological tremor frequency in the 2.0-3.9 Hz range for individual subjects for the three recording conditions

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Peak tremor frequency (2.0 to 3.9 Hz)</th>
<th>Built-up Spoon</th>
<th>Weighted spoon</th>
<th>Weighted wrist cuff</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>3.6</td>
<td>3.8</td>
<td>3.8</td>
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<td>P02</td>
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<td>2.4</td>
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<tr>
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<td>2.3</td>
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<tr>
<td>P18</td>
<td>3.9</td>
<td>2.5</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>

Mean ± standard deviation

<p>| | | | |</p>
<table>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.0 ± 0.64</td>
<td>2.9 ± 0.54</td>
<td>2.8 ± 0.58</td>
</tr>
</tbody>
</table>
Figure 4.13. Group mean Parkinsonian tremor peak frequencies (4.0-8.0 Hz) for the three conditions.
Figure 4.14. Group mean physiological tremor peak frequencies (2.0-3.9 Hz) for the three conditions.
4.3. Relationships of tremor amplitude with other variables

4.3.1. Relationship between effects of weights and tremor amplitude with built-up spoon

In order to assess the possible effect of the amplitude of tremor and the effects of weights on tremor, the subjects' data were divided into two groups based on the amplitude while holding the built-up spoon. Group 1 consisted of subjects who had ≤ 0.5 mm tremor amplitude while holding the built-up spoon (n =12), and group 2 consisted of subjects who had > 0.5 mm tremor amplitude while holding the built-up spoon (n = 6). Within-subjects ANOVA was performed on the group mean amplitudes of group 1. Results revealed no significant differences between the three conditions (F-statistic = 0.1252; p value = 0.8827) Within-subjects ANOVA was performed on the group mean amplitudes of group 2. Results revealed no significant differences between the three conditions (F-statistic = 0.1177; p value = 0.9824).

In order to assess the possible effect of tremor amplitude with the built-up spoon and the amplitude of tremor with weights, a Pearson correlation analysis was performed. This analysis failed to reveal a correlation between the amplitude of tremor with the built-up spoon and the relative amplitude of tremor with the weighted spoon (r = -0.1692; p = 0.5021), or with the relative amplitude values calculated for the weighted wrist cuff (r = -0.2298; p = 0.3589).
4.3.2. Relationship between age and the effects of weights on tremor amplitude

In order to assess the possible impact of age on the amplitude of tremor, a Pearson correlation analysis was performed. This analysis failed to reveal a correlation between the age of the subject and the amplitude of tremor with the built-up spoon ($r = 0.1899; p = 0.4504$), with the relative amplitude values calculated for the weighted spoon ($r = 0.03; p = 0.905$), or with the relative amplitude values calculated for the weighted wrist cuff ($r = -0.037; p = 0.884$).

4.3.3. Relationship between duration of PD and the effects of weights on tremor amplitude

In order to assess the possible impact of duration of PD on the amplitude of tremor, a Pearson correlation analysis was performed. This analysis failed to reveal a correlation between the duration of PD and the amplitude of tremor with the built-up spoon ($r = 0.4096; p = 0.0914$), with the relative amplitude values calculated for the weighted spoon ($r = 0.018; p = 0.943$), or with the relative amplitude values calculated for the weighted wrist cuff ($r = 0.098; p = 0.698$).

4.3.4. Relationship between duration of tremor and the effects of weights on tremor amplitude

In order to assess the possible effect of duration of tremor on the amplitude of tremor, a Pearson correlation analysis was performed. This analysis failed to reveal a correlation between the duration of tremor and the amplitude of tremor with the built-up spoon ($r = 0.4388; p = 0.0781$), with the relative amplitude values calculated for the weighted spoon ($r = -0.1610; p = 0.5369$), or with the relative amplitude values calculated for the weighted wrist cuff ($r = -0.2893; p = 0.2601$).
4.3.5. **Effects of medication usage on tremor amplitude**

In order to assess the possible effect of the amplitude of tremor and the effects of weights on tremor, the subjects' data were divided into four groups based on the medication usage.

Group 1 consisted of subjects who were using levodopa \( (n=13) \). An unpaired t-test was used to compare the group using levodopa with the remaining subjects. No significant differences were found between levodopa users and non-users for built-up spoon amplitude \( (t = 0.6775; p = 0.5078) \), weighted spoon relative amplitude \( (t = 0.9103; p = 0.3762) \), and the weighted wrist cuff relative amplitude \( (t = 0.4219; p = 0.6787) \).

Group 2 consisted of subjects who were using dopamine agonists \( (n=10) \). An unpaired t-test was used to compare the group using dopamine agonists with the remaining subjects. No significant differences were found between dopamine agonist users and non-users for built-up spoon amplitude \( (t = 0.7981; p = 0.4365) \), weighted spoon relative amplitude \( (t = 0.6733; p = 0.5104) \), and the weighted wrist cuff relative amplitude \( (t = 0.1238; p = 0.9030) \).

Group 3 consisted of subjects who were using a MAO-B inhibitor \( (n=4) \). An unpaired t-test was used to compare the group using the MAO-B inhibitor with the remaining subjects. No significant differences were found between MAO-B inhibitor users and non-users for built-up spoon amplitude \( (t = 1.855; p = 0.0820) \), the weighted spoon relative amplitude \( (t = 0.6948; p = 0.4971) \), and the weighted wrist cuff relative amplitude \( (t = 2.229; p = 0.0405) \). Although this p value is less than 0.05, it has not
been corrected for the multiple comparisons being made, so this result is non-
significant.

Group 4 consisted of subjects who were using anticholinergic medications (n
= 5). An unpaired t- test was used to compare the group using anticholinergic
medications with the remaining subjects. No significant differences were found
between anticholinergic medication users and non-users for built-up spoon amplitude (t
= 1.669; p = 0.1147), weighted spoon relative amplitude (t = 0.0550; p = 0.9568), and
the weighted wrist cuff relative amplitude (t = 0.0269; p = 0.9789).
5. Discussion

5.1. Summary of findings

The effects of weights on postural hand tremor amplitude and peak frequency were examined in this study. Weights were used in the form of a weighted spoon and a weighted wrist cuff, the latter of which was used along with a built-up spoon. The built-up spoon alone was used as a control condition. Statistical analysis revealed no significant differences in the amplitude or the peak frequency of tremor for the three conditions. Further analysis revealed that the age of the subjects, the duration of PD, and the duration of tremor in the hand tested did not show any relationship to the effects of weights. Use of levodopa, dopamine agonists, a MAO-B inhibitor or anticholinergic drugs did not have an effect on the outcome measures.

These results indicate that weights as used in this study do not change the amplitude or the peak frequency of postural hand tremor in PD.

5.2. Post hoc power analysis

A power analysis could not be performed a priori because this study was a pilot study and studies of similar nature had not been conducted in the past. Therefore, a post hoc power analysis was performed to estimate the power of this study. For this purpose, the amplitude of tremor was used, because the amplitude was the more clinically relevant of the two outcome variables, amplitude and peak frequency, examined in this study. First, the effect size, omega, was calculated.

\[ \omega^2_A = \frac{(a-1)(F-1)}{(a-1)(F-1) + (a)(n)} \]
This study had three conditions (a=3) and a sample size of eighteen (n=18). The results of ANOVA for the effects of weights on tremor amplitude yielded an F value of 0.569.

The value of $\omega^2_A$ was calculated to be 0.016.

Then, $\phi^2_A$ was calculated using the formula:

$$\phi^2_A = \frac{n \cdot \omega^2_A}{1 - \omega^2_A}$$

The value of $\phi_A$ was calculated to be 0.537.

Therefore the power of this experiment can be estimated using the Pearson-Hartley power chart based on the values of $\phi_A = 0.537$, $df_{num} = 2$ and $df_{denom} = 51$.

The power of this study was found to be approximately 0.30, or thirty percent.

Based on this post hoc power calculation, the sample size for future studies needed to detect an effect of this small magnitude was estimated. For an alpha level of 0.05 and a power level of 80%, a sample size of 196 is needed in future studies to detect the effect (0.016) seen in this study. Since the effect size in this experiment is small, a relatively large sample size is needed to detect differences, if significant differences do exist. This finding leads to two key suggestions:

a. These calculations show that a relatively high sample size of 196 subjects is needed to detect any differences. The recruitment of such a high number of subjects is not feasible, considering the prevalence of PD (Tanner, 1992) and the population of Kingston.

b. These calculations also revealed the effect size of the weights to be 0.016, which is considered to be within the “small” magnitude category (Keppel, 1991). This low
effect has implications that go beyond this study into the clinical use of weights. This low-magnitude effect of weights suggests that weights in the clinical practice may not have a clinically relevant beneficial effect.

5.3. Assumptions and Limitations

Even though carryover effects and practice effects are the potential problems of within-subjects design, their effects in this study would have been negligible and are unlikely to have confounded the results. Because of the short duration of recordings there would have been minimal fatigue-induced variations in each subject. The effect of an experimental condition in our study was only expected to last while it was applied. The results of this study show that these assumptions are valid, as evidenced by the fact that the results were similar, irrespective of the order of the conditions.

Amplitude and frequency of tremor were used as the outcome variables. Amplitude determines the extent of functional impairment in patients with PD tremor, and conditions that improve PD tremor may affect the amplitude of tremor. The standard deviation of the calibrated, filtered time series was used as a measure of amplitude for the following reasons. First, root mean square is a commonly used measure of tremor amplitude. The mean of the filtered kinematic time series is zero, and the standard deviation and root mean square are essentially equivalent when the mean of the time series is zero. This measure is less susceptible than other measures of amplitude, such as range, to variations from outlying values. Second, sudden transient fluctuations in amplitude can alter the range, thereby falsely implying a change in the amplitude of tremor with weights, whereas standard deviation is less affected by transient fluctuations and more reflective of sustained changes, which is more important.
for function. The average peak frequency was taken to represent the peak frequency for that condition. This is in accordance with a number of studies of tremor that have used peak frequency as a sensitive measure to examine tremor frequency (Homberg et al., 1987; Norman et al., 1999; Forssberg et al., 2000). Peak frequency, especially with the resolution used in the power spectral analyses in this study, is inherently unstable and this contributed to high variability in the frequency measures. However, peak frequency was used because it is susceptible to change and is therefore more likely to change in response to intervention such as weights, whereas a measure such as median frequency is more stable and is less likely to show change in response to weights.

There are a few weaknesses of this research design:

1. Because of reasons as yet unknown, tremor fluctuates naturally and this fluctuation could have influenced the outcome measures. However, the lack of effects of weights on tremor seen consistently in this study argues against this possibility.

2. This study focused on changes in tremor only while holding a utensil, rather than during movement of the utensil from plate to mouth. This limitation was imposed by the laser systems, which have an excellent temporal and spatial resolution but have a limited recording range. Further, since this design studied tremor when the subject was trying to simulate one posture as a part of feeding behavior, the conclusions drawn from this study may not be applicable to the wide variety of postures held by people with PD during feeding.

3. Because the grasp of the subjects was maintained uniformly across subjects, the possible effects of weights for other types of grasp are not known.
4. Because the duration of recordings was short, this study did not record tremor in a natural situation, where factors such as fatigue can exert an influence on tremor. However, since this study found that weights do not help PD tremor, the cessation of use of weights implied by this study is expected to result in less, and not more, fatigue.

5. The method of sampling used for the study could have introduced bias into the study and the sample might not represent the entire population. For example, this sample only included subjects who volunteered and consented to participate in this study. Also, this sample consisted of community-dwelling PD subjects who were being treated as out-patients, and may not have represented the full spectrum of disability seen in PD.

5.4. Possible reasons why weights did not change amplitude or peak frequency of tremor in this study

As discussed in chapter 2, studies have shown that PD tremor has a central origin but peripheral inputs have a modulatory effect on PD tremor. The different peripheral stimuli that have been used to modify tremor characteristics are electrical stimulation of the median nerve (Britton et al., 1992) and mechanical perturbations of the wrist (Britton et al., 1993). Although PD tremor characteristics are altered by some types of peripheral modulation, weights may not be an appropriate stimulus to alter the tremor characteristics. In the studies discussed above, peripheral stimuli have been shown to alter PD tremor frequency and amplitude transiently (for less than one second).

This study supports findings of other studies (Hewer et al., 1972; Morgan, 1975; Morgan et al., 1975; Homberg et al., 1987; Forssberg et al., 2000) that weights do not alter characteristics of PD tremor. While some studies (Hewer et al., 1972;
Mo~gm-,
[170x723]1975; Morgan et al., 1975; Homberg et al., 1987) have reported that weights do not affect PD tremor frequency, they did not examine the amplitude of tremor, which may be more important for function. The report of a study that examined the amplitude (Forssberg et al., 2000) indicates that weights do not change PD tremor amplitude. However, these studies examined a low number of PD subjects (4-10), and a larger sample was expected to detect any changes missed because of the low sample size, although as discussed in Section 5.2, it appears that the sample would have to be .

Moreover, the earlier reports had several weaknesses as described in Section 2.10. For example, some of these reports (Hewer et al., 1972; Morgan, 1975; Morgan et al., 1975) summarized their findings but did not present data. Some studies (Hewer et al., 1972; Morgan et al., 1975) reported the performance of all subjects without separately describing the performances by diagnosis. Based on the information presented in these reports it is impossible to determine the response of PD tremor to weights (Hewer et al., 1972; Morgan et al., 1975), or the magnitude of change in PD tremor (Morgan, 1975).

It is possible that the amount of weights used (248g and 470g for the weighted spoon and the weighted wrist cuff, respectively) were not sufficient to alter the tremor characteristics. However, these weights were chosen because they are clinically relevant, being marketed and prescribed for PD tremor in OT practice. Therefore, an increase of weights may not be feasible in a clinical setting.

Considering the possibilities that the weights used in this study were insufficient to have an effect on PD tremor, and that it may not be feasible to increase the weight of the weighted spoon, future studies done using a combination of the weights used in this

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study may demonstrate effects not seen in this study. However, it is unlikely that any effects will be detected in the combined condition, considering the fact that previous studies that used as much as 1000g (Homberg et al., 1987) failed to see any effect of weights on PD tremor. Furthermore, the possibilities that fatigue can confound the results and also make the use of heavy weights impractical in day-to-day life should be borne in mind while interpreting the results of such a study. For instance, a bowl of approximately 300 ml of soup will require about twenty feeding cycles from the bowl to the mouth and back to the bowl, with a tablespoon (15 ml).

The control condition in this study was a built-up spoon, which weighed 108g, compared to the experimental conditions of weighted spoon (248g) or a weighted wrist cuff with a built-up spoon (total 578g). It is possible that the difference in weights between the control and the experimental conditions was not sufficient to exert a detectable effect on the amplitude of tremor. The built-up spoon was used for two reasons in this study – to represent a regular spoon that patients use during feeding, and to provide uniform grasp in this study.

While some studies have examined the effect of weights applied over or proximal to the wrist joint (Hewer et al., 1972; Morgan, 1972; Morgan et al., 1972), other studies have examined weights applied distal to the wrist joint (Homberg et al., 1987; Forssberg et al., 2000). The studies that have used weights over or proximal to the wrist joint have shown beneficial effects in subjects with cerebellar tremor, whereas there is no evidence that weighted utensils change tremor characteristics in any condition. It is also possible that relatively fewer studies have examined distal
application of weights because of anecdotal evidence that distal weights do not alter PD tremor characteristics.

While there is no evidence that weighted spoon is used more often than weighted wrist cuff, or vice versa, in PD patients, the results of this study, and previous studies discussed above, suggest that use of neither of them may be appropriate as a means to alleviate PD tremor.

5.5. Future research

The effects of weights on postural tremor were examined in this study. More specifically, the effect of weights on the act of holding a spoon were examined. Because postural tremor in PD has been well-studied compared to kinetic tremor (Rajaraman et al., 2000; Foerster and Smeja, 1999), this study focused on changes in postural tremor. The effect of weights on kinetic tremor need further investigation. Future studies designed to address this issue should reveal the effects of weights on tremor during the entire act of feeding.

The normal feeding cycle encompasses a range of motions including holding the spoon, bringing the spoon to the plate containing food, scooping the food into the spoon, and bringing the food to the mouth. The amplitude and frequency of tremor can affect each of these phases, and have an effect on the accuracy of the various movements. To know the effect of weights on all these stages, a study designed to examine all the stages would be more appropriate. The methodology of such a study would also be different, because of the need to examine many stages of the feeding cycle. An instrument such as the OPTOTRAK™, which can examine movement
through a larger volume than is captured by laser displacement sensors, would be better suited for such a study.

Another condition that usually coexists with tremor in PD, but has not been examined in this study, is incoordination. Incoordination can result in errors in various movements of the feeding cycle. Future studies designed to examine the effect of weights on incoordination, by examining the various parameters of incoordination such as errors during movement, could address questions as to whether weights have a beneficial effect in PD tremor by reducing incoordination.

5.6. Clinical relevance of this study

The goal of this study was to examine the effects of weights on PD tremor. The findings are relevant because they contribute to our understanding of whether it is appropriate to use weighted utensils and weighted wrist cuffs in patients with Parkinson's disease tremor as a way to improve their activities of daily living. Although there is no documented scientific evidence about the efficacy of weights on Parkinsonian tremor, weighted utensils and weighted wrist cuffs have been recommended by many occupational therapy textbooks as a way to alleviate Parkinsonian tremor. However, it is not specified whether weighted spoon or weighted wrist cuff is better suited to alleviate tremor. It is not even clear what is meant by alleviating tremor. Because the current OT practice includes the use of weighted utensils and wrist cuffs in the management of tremor, their effects were examined on postural hand tremor during the act of holding a spoon. This study was designed to allow quantification of effects for weighted spoon and weighted wrist cuff and to guide future use of weights in PD tremor.
This study found that the amplitude and the frequency of postural hand tremor were unaltered by weights in subjects with PD. This study examined the effect of weights on postural tremor during a specific part of the feeding cycle. Further studies are needed to examine the effect of weights during the other phases of the feeding cycle. Depending on the findings of such studies, the financial cost of equipment may represent economic resources that may be better used to treat the client. Moreover, the time spent by the OT prescribing and teaching the use of the weights and by the client learning and using the weights can be considerable and may also represent time and finances that may be better utilized.

The OT profession is based on sound scientific principles, and it is important to demonstrate the utility, or otherwise, of weights to reduce tremor. While the results of this study show that weights do not alleviate postural hand tremor in PD, the possibility that weights exert a beneficial effect in PD patients by alleviating incoordination remains open. Therefore the results of this study, which refute recommendations for the use of weights in postural PD tremor, may contribute to a scientific basis for the occupational therapy management of Parkinsonian tremor.
6. Conclusions

Weights in the form of a weighted spoon and a weighted wrist cuff do not change the amplitude of postural hand tremor in patients with Parkinson’s disease. Weights in the form of a weighted spoon and a weighted wrist cuff do not change the peak frequency of postural hand tremor in patients with Parkinson’s disease. There was no correlation between the effect of weights and the age of the subject, the duration of PD, the duration of tremor in the hand tested, the amplitude of tremor in the control condition, or with the types of medication used.

Weights, as used clinically in the form of weighted spoons and weighted wrist cuffs, are not beneficial for postural hand tremor in PD patients during the act of holding a spoon. This study does not support the recommendations in occupational therapy textbooks for the use of weights in the management of tremor in PD. This study supports the findings of previous scientific studies that found that weights do not alter PD tremor.
7. References


Appendix I: Consent Form
School of Rehabilitation Therapy, Queen's University.
Consent Form

Effects of Weights on Frequency and Amplitude of postural hand tremor in People with Parkinson's Disease.

Principal Investigator: Rubia P. Meshack
Graduate Student
School of Rehabilitation Therapy
Queen’s University
Tel: (613) 533-6000, Ext. 78005

Co-investigator: Dr. Kathleen E. Norman
Assistant Professor
School of Rehabilitation Therapy
Queen’s University
Tel: (613) 533-6104
(613) 533-6000, Ext. 78005

Background Information: The purpose of this research project is to determine the effects of weights on hand tremor in people with Parkinson’s Disease.

We invite you to participate in this research project if you have been diagnosed with Parkinson’s Disease for at least one year, have tremor in at least one hand, have no other disorders of the nervous system and no other major abnormalities of the hand that has tremor.

Description of Involvement: This research project will involve one visit to the School of Rehabilitation Therapy that will take about one hour. You will be asked questions to determine whether you are right-handed or left-handed. You will be also asked if you have recently smoked cigarettes or consumed anything with caffeine (coffee, tea, cola beverages etc.). You will be also asked about the duration of the disease and the tremor, and any medications which you have used or are using. On the day of the testing you will be asked to come to the laboratory shortly before a usual dose of your anti-Parkinsonian medication. You may bring your medication with you to take after the testing if that is your usual time. For the testing, you will be seated and you will be asked to hold a spoon that is either heavy or light and in combination with a wrist cuff that weighs 1-lb. A small plastic box with a lightweight card will be attached to the spoon. You will be asked to hold the spoon in a position between the table and the mouth with the arm unsupported. The tremor from your hand will be recorded with laser systems, which are devices that produce narrow red light beams and can measure small movements. The laser system works by measuring the reflection of its beam on the lightweight card that is attached to the spoon. The lasers are thus not attached to your hand but are positioned near your hand.
**Risks:** Temporary fatigue or discomfort may arise in the muscles that are responsible for holding the spoon and for maintaining the arm in the required position. The discomfort, if any, will disappear in a few hours.

The laser beams will always be pointed away from your face and they do not pose a risk to your health as long as you do not try to look directly into the source of the laser beam (the laser system is of a class and power that is similar to, or less powerful than, most laser pointers that are used in classrooms and auditoriums).

**Benefits:** You will probably not directly benefit from participating in this research project. However, if you have been prescribed weights to reduce tremor, you may benefit from the understanding of whether weights have a beneficial effect. The results of this research project may help guide therapy of hand tremor in future Parkinson’s Disease patients.

**Confidentiality:** All information obtained during this research project will be strictly confidential and your anonymity will be protected at all times. A participant identification number will be assigned to the data of each participant and this information will be kept in a secure location. Only the principal investigator and her academic advisor will have access to the data. When the results are reported, your identity will not be revealed because we will only be revealing the general characteristics of the group such as average age, range of ages, number of men and number of women, time since diagnosis and medications used.

**Voluntary nature of the research project/ freedom to withdraw:** Your participation is completely voluntary. You may withdraw at any time for any reason, and you do not have to explain your reasons. Your decision about whether to participate or to withdraw will have no effect on your status as a patient at Kingston General Hospital.
Statement of Participant

I have read and understand the information provided about the research project. I have had the purposes, procedures and risks/benefits of this research project explained to me. I have been given sufficient time to consider this information and seek advice. I know that I may withdraw at any time. I will be given a photocopy of this page and the previous two pages for me to keep. I know that I have the right to discuss my concerns at any time with the investigator:

Rubia Meshack at 613-533-6000, Ext. 78005 or
Dr. Kathleen Norman at 613-533-6000, Ext. 78005; (613) 533-6104.

or with the Director of the School of Rehabilitation Therapy

Dr. Sandra J. Olney at 613 533 6102

I am voluntarily signing this form and thus agreeing to participate in this research project.

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Participant’s name in block letters

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---- Signature of Participant Date

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---- Signature of Witness Date

Statement of investigator

To my knowledge, the research project has been carefully explained to the participant. In my judgement the participant understands clearly the nature of the research project and the demands, risks and benefits involved. Therefore, in my judgement the participant is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research project.

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---- Signature of Investigator Date