Physiotherapy for people with movement disorders arising from basal ganglia dysfunction

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ABSTRACT
Two of the most common diseases of the basal ganglia are Huntington’s disease (HD) and Parkinson’s disease (PD). In this article we compare and contrast the aetiology, pathogenesis and movement disorders associated with HD and PD, as a basis for deriving a framework for physiotherapy practice for people with basal ganglia dysfunction. Although much has been written about therapy for PD, little is known about the effects of allied health interventions on outcomes in HD. It is possible that strategies used to optimise movement in PD could also be beneficial for select movement disorders in HD because PD and HD share some common pathological features and symptoms. Movement disorders common to HD and PD include hypokinesia, akinesia and dyskinesia. Secondary musculoskeletal and cardiovascular changes can also occur as a result of inactivity or disuse. A framework for physiotherapy practice for people with basal ganglia disorders is proposed, based upon scientific evidence from the movement disorders literature. For both conditions, the major aim is to teach people how to by-pass the defective basal ganglia structures and to use frontal neural pathways to control movement.


Key Words: Huntington’s disease, Parkinson’s disease, Physiotherapy, Movement disorders

INTRODUCTION
The onset of Huntington’s disease (HD) and Parkinson’s disease (PD) is associated with the development of movement disorders that may affect participation in activities of daily living, leisure, work, and community. Movement disorders in HD and PD are thought to be due to dysfunction of the basal ganglia, which normally play an integral role in the control of well learned motor skills such as walking, moving from sitting to standing, writing and swallowing (Brotchie et al 1991b). Physiotherapy may be useful in assisting people with basal ganglia disorders to maintain or regain functional activity. There is a growing body of information examining physiotherapy outcomes in PD, however little is known about the effects of physiotherapy for people with HD. Parkinson’s disease and HD share some common pathological features and symptoms, thus it is possible that some physiotherapy strategies used for PD may also be beneficial for select movement disorders in HD. In this article we compare and contrast the aetiology, pathogenesis and movement disorders associated with HD and PD as a basis for deriving physiotherapy practice for people with basal ganglia disease.

(i) Aetiology and pathogenesis of Huntington’s and Parkinson’s disease
Huntington’s disease is an inherited genetic condition that affects 50% of offspring. Symptoms of the disease, often first detected between 35 and 45 years of age, include progressive movement disorders, cognitive deficits and behavioural changes (Kirkwood et al 2001). Huntington’s disease is caused by an abnormally long CAG repeat sequence on the IT15 gene that encodes a protein necessary for normal brain function called Huntingtin (Huntington’s Disease Collaborative Research Group, 1993). The
abnormal CAG sequence results in the production of mutated Huntingtin which has been linked to abnormalities in genetic transcription, formation of cell aggregates and abnormalities in mitochondrial energy production (Feigin and Zgaljardic 2002, Young 2003). Mutated Huntingtin causes cell dysfunction and eventually cell death (Young 2003). In Huntington’s disease the medium spiny projection neurons, which constitute approximately 90% of the caudate and putamen are primarily affected (Albin 1995). Degeneration occurs in the spiny neurons enriched in gamma aminobutyric acid (GABA) and enkephalin that project to the external globus pallidus. Neurons containing GABA and substance P that project to the substantia nigra also show evidence of degeneration early in the disease process (Albin 1995, Albin et al 1992, Joel 2001). A reduction in GABA and enkephalin input to the external globus pallidus is thought to cause hyperactivity of the external globus pallidus and inhibition of the subthalamic nucleus. In turn this results in reduced excitatory drive to the major output nuclei of the basal ganglia, which are the internal segment of the globus pallidus and substantia nigra pars reticulata (Parent et al 2000). The lack of excitatory drive is thought to account for hyperkinetic movement disorders such as chorea and tics (Parent et al 2000).

In contrast to HD, the aetiology of PD is not well known although it is thought to be multifactorial, possibly involving environmental factors such as exposure to toxins and a genetic susceptibility (DeStefano et al 2002). Gene mutations associated with inherited early onset PD have been identified (Payami et al 2002). Two gene locations (4q21-23/ PARK1 and 4p14/PARK5) are associated with autosomal dominant forms of PD, the third (6q25-27/PARK2) with early onset recessive PD (DeStefano et al 2002). In addition four gene sites have been linked to families with PD although the gene mutation has not yet been identified (DeStefano et al 2002, Grimes and Bulman 2002). Although the incidence of idiopathic PD is greater than familial PD, the causes of idiopathic PD are not yet known. The age of symptom onset in idiopathic PD is around 60 years (Jankovic and Kapadia 2001). Disruption of the dopamine pathways to the striatum is associated with hypoactivity of the external globus pallidus and disinhibition of the subthalamic nucleus of the basal ganglia (Parent et al 2000). In turn, disinhibition of the subthalamic nucleus is thought to cause increased excitatory drive of the internal globus pallidus and substantia nigra pars reticulata (Parent et al 2000). This is thought to be associated with hypokinesia of movement seen in people with PD.

A major projection site of the output nuclei of the basal ganglia is the supplementary motor area (SMA). In both HD and PD, dysfunction of the basal ganglia causes a disruption in neural transmission to the SMA. The SMA in combination with the basal ganglia is thought to play a role in the production of well-learnt movement sequences (Cunnington et al 1995). Phasic neuronal activity within the basal ganglia may act as a cue to switch off the preparatory activity within the supplementary motor area to allow the next movement in the sequence to be completed (Brotchie et al 1991a, 1991b, Georgiou et al 1993). Alternatively, activity within the basal ganglia may act as a cue to signal the supplementary motor area neurons to reset, in order that activity from the previous movement sequence does not interfere with preparation for the next movement (Georgiou et al 1993). Disruption of the neural pathways from the basal ganglia to the supplementary motor area may be associated with the disorders in voluntary movement seen in HD and PD.

(ii) Movement disorders associated with basal ganglia disease

Movement disorders common to HD and PD include akinesia, hypokinesia, dyskinesia and postural instability. Secondary musculoskeletal and cardiovascular changes may also occur as a result of inactivity or disuse. The following section draws upon the evidence from the movement science literature to describe the movement disorders associated with HD and PD.

**Hypokinesia** refers to movement that is slower than normal due to reduced speed and amplitude of complex multi-joint sequential and simultaneous movements (Benecke et al 1986, Bradshaw et al 1992, Georgiou et al 1997, Phillips et al 1996, Thompson et al 1988). In both HD and PD the overall time to complete movements is increased due to prolongation of movement initiation time and movement execution time (Bradshaw et al 1992, Georgiou et al 1993, Georgiou et al 1997). Electromyographic studies of upper limb movement tasks in people with HD have shown the first burst of agonist muscle activity to be prolonged and highly variable (Berardelli et al 1999, Thompson et al 1988). This is in contrast to PD, for which upper limb agonist activity is small but of normal duration (Thompson et al 1988). People with PD also have reduced force generation (Morris et al 2001, Stelmach 1991) which may affect movement size. In people with HD, force generation can either be unaffected or excessive and highly variable (Gordon et al 2000, Quinn et al 2001, Serrien et al 2001).

**Akinesia** describes an inability to move or difficulty in initiating movement. People with HD and PD demonstrate akinesia when asked to complete simple or complex movement sequences (Benecke et al 1986, Georgiou et al 1995). Difficulty initiating the first step in the gait sequence (start hesitancy) occurs in approximately 20% people with PD (Giladi et al 1992). An associated sign is freezing, which is a sudden cessation of a planned movement sequence, usually occurring during well learnt, automatic tasks such as walking or speaking (Giladi et al 1998, Giladi et al 1992, Morris 2000). An episode of freezing during walking may be triggered by a change in floor surface, the presence of an obstacle or the narrowing of the space to be negotiated such as a doorway (Fahn 1995). Freezing may occur when the amplitude of a movement...
becomes progressively smaller, eventually resulting in movement with zero amplitude (Morris et al 2001).

**Timing disorders** also occur in some people with HD and PD. People with HD may have difficulty producing upper limb movements at regular time intervals (Freeman et al 1996). The ability to regulate the timing of footsteps in order to match an auditory rhythmic cue may also be impaired in people with HD (Churchyard et al 2001, Thaut et al 1999). Although people with PD can entrain their footsteps to an auditory cue with greater accuracy than people with HD (McIntosh et al 1997, Morris et al 1994b), constraint imposed by the cue may lead to increased step-to-step variability in stride duration and step length regulation (Ebersbach et al 1999). Increased movement variability in association with basal ganglia dysfunction provides some evidence for a role of the basal ganglia in temporal regulation of movement sequences (Ebersbach et al 1999).

**Dyskinesia** is an umbrella term used to describe involuntary movement disorders (Hoff et al 1999). In basal ganglia diseases, dyskinesias may include chorea, tremors, tics, athetosis, myoclonus and dystonia. Chorea, which is described as purposeless, irregular and rapid movements of the body, is a classical feature of HD and may be the first motor sign of disease (Kirkwood et al 2001). Chorea typically affects the face, head, neck, trunk and limbs. Choreiform movements are extremely variable in duration, ranging from short myoclonic bursts to tonic discharges of longer duration (40-400ms) (Hefter et al 1987). The onset of chorea during voluntary movement may decrease the quality of the planned movement. For example, analysis of handwriting affected by chorea showed that writing was of poor quality and required additional sub-movements to complete the writing sequence (Phillips et al 1994). Letter construction was poor due to the insertion of additional writing strokes (Phillips et al 1994). The influence of chorea on gait and postural stability is not yet well understood. Reynolds et al. (1999) examined joint angles and joint velocities of six ambulant subjects with HD. Although chorea appeared to contribute to frequent changes in joint velocities during gait, this produced minimal impairment of walking (Reynolds et al 1999).

In PD, the onset of abnormal involuntary choreiform-like movements (termed “dyskinasias”) appears to be related to disease duration and the extent of striatal damage (Fahn et al 2002, Nutt 2001). The effect of pharmacotherapy in the pathogenesis of dyskinesia is not yet well understood (Boraud et al 2001). Dyskinesias may vary according to the phase of the levodopa medication cycle and may be distinguished from chorea because the postures are induced by activity and sustained for variable amounts of time (Hallett 1993). Dystonia may be distinguished from chorea because the postures are induced by activity and sustained for longer periods than choreic movements (Fahn 1988). The most prevalent dystonic postures in people with HD and PD are internal rotation of the shoulder, sustained fist clenching, excessive knee flexion and inversion of the foot during walking (Louis et al 1999). In PD dystonia causing excessive plantar flexion and inversion during the stance phase of gait may be associated with an increased risk of falling (Morris et al 2001).

**Resting tremor** is a classical sign of PD described by James Parkinson in 1817 (Parkinson 1817). Resting tremors are more frequently noted distally, affecting the fingers and thumbs. An **action tremor** that occurs during movement may also be a feature of PD (Findley et al 1981). **Postural tremors** may occur when a limb, the head or trunk is maintained in a position for an extended time (Findley et al 1981). Although tremors are characteristic of PD, little is known about the affect of tremors on activity. Tremors are not characteristic of HD.

**Rigidity** describes an increase in resistance to movement when a limb is passively moved through range of motion. Rigidity is thought to occur due to overactivity of the long latency stretch reflex (Tatton and Lee 1975). In PD, rigidity is often classified as “lead pipe” where there is increased resistance as the limb moves through range, or “cog-wheeling” which is thought to occur due to tremor superimposed upon rigidity (Findley et al 1981). Rigidity is a characteristic feature of a juvenile onset variant of HD known as Westphal. Rigidity, in combination with severe hypokinesia, may be associated with the rapid decline in functional ability shown in people with the Westphal variant of HD (Topper et al 1998). In adult onset HD and idiopathic PD, rigidity may become more severe as the disease progresses (Young et al 1986). The relationship between the severity of rigidity and decline in functional ability is not yet well understood.

**Postural instability** is common in advanced basal ganglia disease. Reported falls incidence rates for people with PD range from 40 - 64 % (Ashburn et al 2001, Smithson et al 1998). There is some evidence that the incidence of falls is also high in people with HD. For example, Koller and Trimble (1985) reported that 11 of 13 subjects with HD who participated in a gait study had a history of two or more falls. The cause of falls in people with HD has not yet been empirically determined, however it is most probably multifactorial.

Platform posturography studies have shown that people with PD, as well as those with HD, have abnormal responses to external and self-generated perturbations to their centre of mass (Horak et al 1988, Huttunen and Hömberg 1990, Tian et al 1992). For both groups, the sequence of muscle activation in response to perturbation is intact (Horak et al 1988, Huttunen and Hömberg 1990). However, in PD the medium latency anticipatory postural responses are delayed in combination with a reduction in the movement amplitude required to counter the perturbation (Frank et al 2000, Horak et al 1996). In contrast, people with HD have a
delayed and prolonged long latency response, yet normal response amplitude (Huttunen and Hömberg 1990, Tian et al 1992). The difference in response to postural perturbation suggests that abnormalities in the neurophysiological mechanisms contributing to postural instability may be different in people with HD compared to people with PD.

Finally, the primary movement, cognitive and behavioural disorders associated with PD and HD may result in secondary changes to the musculoskeletal and cardiovascular system. These changes may be due to disuse or inactivity. There is evidence that people with PD have a loss of joint range of movement (Schenkman et al 1998), reduced cardiopulmonary fitness (Canning et al 1997) and reduced muscle strength (Inkster et al 2002, Scandalis et al 2001). People with PD may also experience pain in the limbs and trunk due to dystonia or dyskinesias (Goetz et al 1986). Secondary impairments such as reduced muscle strength and reduced muscle length in people with HD have not yet been empirically measured and reported in the literature. However, clinical evidence suggests that secondary impairments associated with HD may be similar to those found in PD.

(iii) Physiotherapy for disorders of motor control associated with basal ganglia pathology

The current model of physiotherapy intervention for people with basal ganglia disorders is based upon an assumption that people can be taught to achieve more normal movements by utilising strategies that by-pass defective basal ganglia structures (Morris 2000). For example, the performance of well learned movement sequences in people with PD can be enhanced when additional external information is provided or when the person is directed to focus their attention upon specific aspects of movement (Morris et al 1994b, 1996). The use of external cues or attentional strategies is thought to enable the regulation of automatic movement to by-pass the defective basal ganglia and instead utilise frontal neural networks to control the movement sequence. Alternatively, treatment strategies may improve motor performance by increasing the readiness of the neurons within the basal ganglia to signal the supplementary motor area to begin preparation for movement.

Auditory and visual cuing techniques have been effective in improving hypokinesia of gait, reaching and writing in people with PD. There is some evidence that techniques such as these may also be useful for some people with HD. Auditory cues embedded in music or produced by a metronome have been used to alter cadence of people with both PD and HD (Churchyard et al 2001, Thaut et al 1996, Thaut et al 1999). Both groups have the ability to increase their cadence in the direction of the auditory cue, although unlike people with PD (McIntosh et al 1997, Morris et al 1994a), those with HD do not achieve accurate footstep and cue synchronisation (Churchyard et al 2001, Thaut et al 1999). Despite an inability to synchronise with the metronome cue, Thaut et al. (Thaut et al 1999) showed that people with HD were able to maintain an increase in cadence after a short period of training. The use of external cuing techniques may therefore be a useful strategy for increasing the cadence of people with HD. However, additional research is required to determine if increases in stepping rate can be retained after training and maintained in a variety of contexts. The relationship between increased cadence, step length and speed should also be investigated in order to ensure that stride length is not compromised in order to achieve higher step frequencies.

Visual cues may also enhance movement, provided that they specify the desired movement amplitude. For example, people with PD can increase their stride length in response to horizontal lines spaced appropriately along the length of a walkway (Lewis et al 2000, Martin 1967, Morris et al 1994b). The mechanisms underlying the increase in stride length remains unknown. It has been suggested that visual cues increase attention to stride length, enabling this gait variable to come under conscious control (Morris et al 1996). Alternatively, visual cues may provide a template for appropriate step length enabling people with PD to utilise visual feedback to regulate their movement amplitude (Lewis et al 2000). People with HD are also able to normalise step length and reduce step length variability with visual cues (Bilney et al 2002). However, in this small study the use of visual cues did not result in an increase in gait speed because the subjects reduced their cadence (Bilney et al 2002). This is in contrast to subjects with PD who can normalise gait speed with visual cues (Morris et al 1996). The reason why people with HD and PD respond differently to visual cues is unknown. It is possible that people with HD use visual cues as a source of feedback in order to guide motor performance. To allow additional time to process and utilise visual feedback arising from this task, people with HD may reduce their footstep cadence. Additional research is required to determine if visual cues may be a useful physiotherapy technique to increase step length of people with HD. The impact of visual cues upon gait speed, cadence and base of support should be examined.

Attentional strategies can also be used to enhance performance in people with PD (Morris 2000). Morris et al. (1996) demonstrated that people with PD are able to increase their stride length when their attention is focused upon walking with longer steps. Similarly, people with PD can improve movement amplitude during writing when they attend to the size of the letters (Phillips 1997). Increasing attention to the task may also reduce the delay in the onset of movement in people with PD (Cunnington et al 1999).

Attentional strategies may be a useful treatment technique for people with HD. Recently, Johnson et al. (2002) demonstrated that the use of an attentional strategy in people with HD increased the cortical activity related to movement preparation for an upper
limb tapping task. However, increased cortical preparatory activity did not correspond with an improvement in motor performance (Johnson et al 2002). The efficacy of attentional strategies for improving gait in people with HD has not yet been empirically tested. However, the strategy may be useful in reducing akinesia and hypokinesia of gait. Future investigations are required to determine the effectiveness of an attentional strategy in people with HD taking into consideration the cognitive and attentional deficits, altered mood and motivational state that may be present in HD (Johnson et al 2002).

Postural instability is very common in advanced basal ganglia disease. Balance retraining strategies for people with PD involve focusing their attention upon the task (Morris et al 1999, Morris et al 2000). It is thought that directing attention to the balance task may recruit fronto-cortical circuits to increase set related activity within the basal ganglia. This may enhance the readiness of postural muscles that respond to perturbations, effectively reducing the delay in response to perturbation (Smithson et al 1998). People with HD may also benefit from balance retraining strategies that aim to improve their readiness to respond to perturbations or increase their attention towards identifying potential threats to their postural stability. Although further research examining the effect of dual tasks upon postural stability and gait is required, people with HD should be educated to avoid carrying out additional complex motor or secondary tasks whilst walking.

Involuntary movement disorders such as dyskinesia, dystonia and chorea can be difficult to treat. Currently there is no evidence that physiotherapy interventions can modify these movement disorders. There are anecdotal reports that dyskinesia and dystonia can be temporarily reduced by directing attention to this aspect of movement (Louis et al 1999). In some instances people with severe dyskinesia clasp their hands together such as during walking which may reduce the amplitude of the involuntary movements. To date there have been no trials to examine the usefulness of this intervention or relaxation techniques to reduce the severity of involuntary movements. There is no evidence that physiotherapy intervention can alter the severity or frequency of dystonia. However, prolonged passive stretching may theoretically counter muscle shortening that occurs as a secondary consequence of dystonia. Physiotherapists also have a role in measuring the severity of involuntary movements and in determining if the involuntary movements impact upon the person's activity and participation. This may be particularly important when medications are introduced, when the medication regimen is changed or when neurosurgery to reduce the severity of dyskinesias or hypokinesia is considered.

Physiotherapy management of the secondary consequences of basal ganglia pathology is targeted at impairments such as loss of joint range of movement, muscle length, muscle strength, muscle endurance and cardiopulmonary fitness. There is some evidence that stretching and range of movement exercises result in increased muscle length and joint range of movement in people with HD (Peacock 1987). Regular aerobic exercise may maintain the exercise capacity and resistance exercises may improve the strength of people with PD (Canning et al 1997, Scandalis et al 2001). Changes at an impairment level may also result in improvement of functional activities such as gait and balance and the ability to perform activities of daily living (Quinn and Rao 2002, Scandalis et al 2001).

Environmental enrichment is also a potential treatment strategy for people with basal ganglia pathology. Recent investigations using a mouse model of HD have reported delays in disease progression in mice “treated” in an enriched environment (Hockly et al 2002, van Dellen et al 2000). Environmental enrichment included greater levels of social interaction, warmth, additional space, opportunities to exercise and the presence of novelty items to increase stimulation. Findings from the enriched mouse model may have implications for the development of physiotherapy treatment programs for people with HD.

It has also been suggested that people performing at high cognitive and physical levels before the onset of HD may have a reduction in the rate of functional decline (Hockly et al 2002). Although yet to be tested, exercise in combination with cognitive stimulation may delay the progression of HD in humans (Hockly et al 2002). For this reason, physiotherapists may have a role in helping people who are at risk of developing HD to establish a routine of effective exercise.

When determining the best interventions for movement disorders, it should be recognised that cognitive impairments associated with HD and PD may impact upon the effectiveness of physiotherapy. Evidence that new skill learning is impaired in the presence of basal ganglia degeneration (Gabrieli 1995, Gabrieli et al 1997, Heindel et al 1988) suggests that it may be more effective to establish movement retraining and fitness programs early in the disease process (Imbriglio 1992). The onset of planning, organising and short-term memory deficits may require modification to the delivery of treatment information or education. Written instructions, videotapes or photographs may be of assistance. In cases of more severe disease a second person may be required to provide supervision, encouragement or assistance to complete a program of physiotherapy (Imbriglio 1992, Quinn and Rao 2002).

In conclusion, HD and PD are acquired degenerative disorders of the basal ganglia that lead to progressive deterioration in movement control, postural stability and the ability to fully participate in activities of everyday living. Hypokinesia is apparent in the early stages of both HD and PD. In the latter stages of HD and PD, postural instability and falls are common. Involuntary movements such as chorea in HD and dyskinesia in PD are also common in the advanced stages of disease. Given the similarities in the neuro-anatomical deficits and the resultant movement disorders, it is possible that...
some of the physiotherapy strategies shown to be effective for people with PD may also be helpful for some people with HD. There is a small amount of evidence that attentional strategies and external cuing techniques may be beneficial for people with PD and HD. In addition, there is limited evidence that muscle strengthening, muscle stretching and cardiovascular exercise may enable people with HD and PD to maintain musculoskeletal and cardiovascular fitness. The extent to which physiotherapy enhances participation in societal roles needs to be confirmed with controlled clinical trials.

References


