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Physical Therapy – Exercise and Parkinson's Disease

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Introduction

Since the first studies on the benefits of physical activity appeared in the literature, a new insight came out into how the human body can be manipulated and modified for different purposes. This change of paradigm produced more practical and scientific knowledge and it allowed the development of new intervention strategies that could benefit individuals with motor dysfunctions. As more studies were developed it was demonstrated the potentiality of exercise in reversing or minimizing physical loss in aging. It was observed that individuals with neurological disorders could also benefit from physical practice by improving mobility and functional independence. This aspect has found new perspectives on the treatment of various diseases, particularly on the Parkinson's disease (PD).

There has been an occurrence of important changes in current studies when compared to earlier studies of exercise efficacy in PD, particularly in regards to methodological rigor, consistency and scientific basis in the researches conducted. Thus, in the last decade there has been a greater understanding of motor needs and types of exercises suitable for physical and functional improvement of individuals with PD, and recently in the role of exercise in promoting brain reorganization and self-recovering (Smith & Zigmond 2003, Hirsch & Farley 2009). Although the results related to brain function have been observed in animals with PD, it is possible that the exercises used in physiotherapy programs have even more relevant effect on this illness and its limitations than previously believed.

Therefore, the PD characteristics and the main exercises used in the physiotherapy treatment for this disease are presented in this chapter. It will also be highlighted the potentiality of physical activity as an effective strategy to delay or reverse motor and functional loss in individuals with PD.

Parkinson's disease - clinical characteristics

Parkinson's disease is a chronic neurodegenerative disease with major impact on patients' lives and in the society as a whole (Weintraub et al 2008). It is the second most common neurological disease in the world, second only to the Alzheimer's disease (Lau & Breteler 2006). Neurochemically, PD is characterized by an imbalance in the dopaminergic pathway which connects the substantia nigra to the striatum (Agid 1991). The deficit in Dopamine is due to a progressive loss of neurons in the midbrain's substantia nigra resulting in changes within the nigrostriatum neural conduction. Besides the loss of dopaminergic neurons, PD is characterized by the presence of intracytoplasmic inclusions called Lewy bodies (Michell et al 2004, Lang & Obeso 2004).

PD clinical presentation may vary between individuals. The typical motor symptoms are tremor at rest, rigidity, bradykinesia, and postural instability (Obeso et al 2002). Motor symptoms usually begin on one side of the body and gradually progress to the opposite side. Although these symptoms may be present in other forms of Parkinsonism, symptoms with asymmetric onset, gradual progression and response to treatment based on levodopa are indicative of idiopathic PD diagnosis (Pallone 2007).

Tremor occurs in the absence of voluntary movement. It is the most common initial symptom found in the PD and often involves the thumb and wrist. Tremor may be the most visible symptom in the PD, but is rarely the most disabling (Pallone 2007). Rigidity is measured by the amount of resistance imposed by a limb when passively mobilized. The limb of a person with PD has a higher resistance to passive movement than individuals without the disease. Changes in muscle and joints' mechanical properties can also contribute to the presence of parkinsonian rigidity (Rogers 1991). Bradykinesia or slowness of movement is the most disabling symptom of the disease (Berardelli et al 2001, Robichaud & Corcos 2005) and contributes to common complaints such as difficulty in rising from a chair and getting in and out of a car (Pallone 2007). Akinesia and hypokinesia are directly related to bradykinesia and also limit mobility (Robichaud & Corcos 2005). Akinesia is slowness in initiating movement, while hypokinesia refers to decreasing range and size of movement (Berardelli et al 2001). Besides the amended operation with the basal ganglia circuit, other factors such as muscle weakness, tremor and irregular pattern of muscle activation contribute to the typical PD bradykinesia (Berardelli et al 2001, Robichaud & Corcos 2005). Postural instability refers to the gradual loss of balance, leading to an increased likelihood of falls with devastating impact on mobility (Sammi et al 2004). Initially, postural instability is presented as an inability to regain balance when a person suffers an outside disturbance and gradually changes to the inability to stand without support or even to sit independently (Horak et al 1992). The reason for the instability is still uncertain, however, factors such as bradykinetic postural response, difficulty in using relevant sensorial and environmental information to anticipate or react to balance threats, or showing little or no adaptive ability to the different action or environment demands, can contribute to imbalance in the PD (Chong et al 2000, King & Horak 2009).

Besides its typical symptoms, individuals with PD often have speech disorders, important gait deficits, posture alterations, muscular weakness and deconditioning (Protas et al 1996, Morris 2000, Cano-de-la-Cuerda et al 2009). This disease is also characterized by non-motor symptoms such as mental disorders, anxiety, sleep disturbances, fatigue and depression (Morris 1996, Jankovic 2008, Shulman et al 2002). In general, individuals with PD have progressive deterioration on physical fitness. They become less confident in their coordination and begin to restrict their activities leading to social isolation (Scandalis et al, 2001, Poewe 2006).

Clinical treatment of the Parkinson's disease

Overall, the treatment of the PD aims to preserve a patient's independence and quality of life (Pallone 2007). Medication is used to treat motor and non-motor symptom relief and also seeks to minimize adverse effects. Medical treatment with levodopa is considered the most effective for the management of motor symptoms. The use of levadopa has been associated with an increased risk of motor fluctuations and the occurrence of involuntary movements or dyskinesias (Weintraub et al 2008). These effects may cause functional and social deficits, and limit the quality of life of individuals with PD (Rezak 2007).

Currently, there is an arsenal of drugs that can maximize the treatment and delay the need for levodopa, partially preventing the occurrence of complications due to its use (Rezak 2007). These types of drugs are generally similar in substance to dopamine. They work by "tricking" the brain and are used in the mild or moderate stage of the disease. These substances allow a delay in using the levodopa based therapy and are also effective in the treatment of motor fluctuations (Rao et al 2006). Another group of substances are catechol-o-methyltransferase (COMT) inhibitors. The COMT is an enzyme that destroys levodopa and dopamine. Therefore, its inhibition produces a prolonged effect of these two substances. These medications, are only useful when combined with levodopa, are effective for the management of levopoda complications, particularly motor fluctuations (Rao et al 2006, Rezak 2007).

Surgical procedures have been used in combination with PD drug treatment. Nowadays, there are basically two techniques used: the destruction method through heat of certain nerve nuclei, and the method of deep brain stimulation through the implantation of a pacemaker that inactivates the brains' chosen area (Kleiner-Fisman et al 2006, Weintraub et al 2008). The surgeries are indicated for those patients with tremor which can't be controlled by drugs and those with severe involuntary movements, even under levodopa treatment.

Parkinson's disease and physical activity

People with disabilities are less physically active than those without disabilities. In PD, individuals at an early and moderate stage of the disease have greater reduction in physical activity level than asymptomatic individuals of the same age (Goulart et al 2004). Furthermore, inactivity is considered an important factor in accelerating the degenerative process of PD (Tillerson et al 2002). Otherwise, there is consensus in the literature that regular exercise practice improves physical and functional performance in different populations (Nelson et al 2007, Dalgas et al 2009).

The practice of regular physical activity seems to be preventive for individuals both pre- and post diagnosis of Parkinson's disease. Some epidemiological studies have suggested there is an inverse relation between physical activity and risk of PD, i.e., moderate and high levels of physical activity are associated with lower risk in developing the disease (Chen et al 2005, Sasco et al 1992). In addition, the study by Tsai et al suggested that regular physical activity can delay the onset of symptoms in patients with PD (Tsai et al 2002).

A growing number of studies suggest that the exercises treatment approach brings greater benefits in functional performance in individuals with PD than isolated medication use and surgical procedures (Ellis et al 2005, Ridgel et al 2009). The participation of individuals with PD in physical exercise programs has shown to be effective in reducing co-morbidities, disuse and limitations caused by this disease.

Different types of exercises were proposed by randomized controlled trials in order to minimize the negative effects of the PD on motor and functional performance. These studies have focused on different physical therapy approaches, such as specific exercises to improve mobility (Schenkman et al 1998), muscular strength (Dibble et al 2006, Dibble et al 2009), balance (Hirsch et al 2003), aerobic conditioning (Herman et al 2007) and gait (Nieuwboer et al, 2007). The results of these studies opened a way for the development of an evidence-based practice in the treatment of PD. In addition they can guide the clinical management of professionals working with individuals who present with this disease.

Exercises to improve mobility

Decreased flexibility decrease in the body axis of individuals with PD may interfere with their balance and impair performance of activities that require trunk mobility. A study by Vaugoyeau et al demonstrated that an increased tonus of the body axis in individuals with PD results in "en bloc" axial movement, and also disturbs the execution of important activities such as movement in bed and turning while walking.

Schenkman et al developed a program which emphasized exercises for axial mobility associated with muscle relaxation and diaphragmatic breathing to increase range of motion of the neck and trunk. The results showed that 10 weeks of exercise improved in axial mobility and postural control of individuals with PD (Schenkman et al 1998). Recently, Schenkman suggested that postural control and functional capacity specific training should incorporate axial mobility exercises to maximize gains in physical and functional performance as a whole (Schenkman 2010). (see Rodriguez JW et al., 2006).

Exercises to improve muscle strength

Recent studies have shown that muscular strength is reduced in Parkinson's patients when compared to individuals without the disease (Inkster et al 2003, Nallegowda et al 2004, Allen et al 2009). The cause of decreased muscular strength remains unclear. However, it is believed that central mechanisms may be responsible through the reduction of facilitative stimulus for motoneurons (Glendinning 1997). Despites the causes, individuals with PD often complain of weakness in their lower limbs. Researchers have observed the presence of some selectivity in the distribution of muscle weakness (Corcos et al 1996, Bridgewater & Sharpe 1998). Clinically, there is an inability of proximal and axial muscles to generate adequate power, especially the extensors of the trunk and hip. It is possible that the selective alteration in muscular strength contributes to a flexion posture, gradually observed in patients. The ability to perform various functional activities such as sitting to standing and walking can be compromised due to muscle weakness in the lower limbs of individuals with PD (Inkster et al 2003, Nallegowda et al 2004, Schilling et al 2009).

Strength training programs were effective in increasing muscular strength, and in some cases, the mobility of individuals with PD (Scandalis et al 2003, Hass et al 2007). These programs were implemented in a relatively short period of time with a training frequency of 2-3 times per week, one set of exercise per muscle group, and involved only concentric contraction. More recent studies suggested muscular strength and functional gains are greater when high-intensity protocols are used involving primarily eccentric contraction (Dibble et al 2006, Dibble et al 2009). The principle of this type of exercise is that high levels of force are generated during muscle stretching with minimal oxygen consumption in relation to the amount of work produced (Lastayo et al 1999). Some studies have found that high intensity strength training was better for motor and functional performance in individuals with PD than training based on flexibility exercises, balance and concentric strength training of limbs (Dibble et al 2006, Dibble et al 2009). It is possible that these results are associated with a greater muscle hypertrophy observed in the high intensity protocol group. According to Dibble et al, the observed increase in muscle volume may be important for improving muscular strength and mobility of PD patients. Moreover, high-intensity training can minimize loss in bone integrity, preserve eccentric muscular strength and promote metabolic and structural plasticity in the musculoskeletal system (Pang & Mak 2009, Falvo et al 2007).

Thus, it is possible that high-intensity exercises are most desirable to minimize the progressive dysfunction of PD. However, since individuals with PD have a lower physical fitness and are often unmotivated to practice physical activity, it is necessary to raise awareness about the use of high-intensity exercise in their treatment, since such exercise will require more physical effort which could lead to individuals’ fatigue.

Exercises to improve balance

Despite medical treatment, individuals with PD fall frequently with devastating consequences (Canning et al 2009). Approximately 66% of individuals with PD will suffer falls and 46% will experience recurrent falls (Wood et al 2002).

Factors such as gait freezing, muscular weakness and balance disorders were found as causes of falls in individuals with PD (Boonstra et al 2008, Toole et al 2000, Olanow & Koller 1998). Accordingly, different authors have used external cues for gait training, balance exercises, and strength training programs (Hirsch et al 2003, Dibble et al 2006, Nieuwboer et al 2007) finding improvement in each of these factors.

Hirsch et al showed greater gains in muscular strength and balance when individuals with PD underwent a combined protocol of strength and balance training compared to the balance exercises group. After the intervention, the combined group had an increase of 52% in muscular strength, better performance in balance and permanence of gains after four weeks. It is possible that the intensity of strengthening exercises with 80% of the maximum resistance elicited permanent non-hypertrophic muscle adaptations favoring maintenance of the effect after one month of intervention.

Recently, an exercise program was developed with the aim of delaying the progressive loss of mobility associated with balance and gait disorders in individuals with PD (King & Horak 2009). In this program, movements used in techniques such as "Tai Chi" and Pilates can be combined in order to facilitate sensory integration in postural control. Thus, somatosensory information can be encouraged by large and coordinated movements in order to move the center of mass with speed, safety and balance (King & Horak 2009). Some recent studies have investigated the effects of “Tai Chi” in motor and functional performance of individuals with PD (2008 Hackney & Earhart, MS et al 2008). Hackney & Earhart showed that individuals with PD practicing “Tai Chi” for 13 weeks achieved gains in balance and functional performance when compared to the control group without intervention. The authors suggest that “Tai Chi” can be a safe and beneficial exercise in the treatment of moderately to severely affected PD patients (Hackney & Earhart 2008). Nevertheless, a recent literature review concluded that the evidence is not sufficient to support “Tai Chi” as an effective treatment for PD patients yet (MS et al 2008). Therefore, further studies are needed to assess the possible effects of “Tai Chi” in improving balance and reducing the occurrence of falls in individuals with PD.

The physiological mechanisms involving gain of muscular strength and balance is not well known. The results of the studies mentioned strongly suggest that the postural control in PD must be worked through exercises that involve both somatosensory and musculoskeletal systems so individuals will be able to respond to sudden center of mass perturbations inherent in daily activities.

A recent study investigated the circumstances of the occurrence of falls in 124 patients with PD (Ashburn et al 2008) and observed that most falls occurred at home. The main causes were tripping on obstacles and falling while standing, i.e., one in three falls occurred in the standing posture (Ashburn et al 2008). Therefore, physiotherapists should address specific training in standing position, such as activities involving clothing and hygiene. Therapists should also carry out an environmental assessment in order to remove possible obstacles and suggest holders such as handrails and / or walking aids.

Importantly, the use of mechanical supports for walking should be investigated and its prescription should be made with caution. Based on the slowness in adapting to changes in support surfaces and difficulties in performing simultaneous activities (Morris 2000), such as walking and moving the stick at the same time, patients with PD may fall during walking using a mechanical support as it becomes a potential destabilizing agent.

Exercises to improve physical conditioning

Individuals with PD show loss in muscle and cardiorespiratory function. These individuals have similar levels of maximal aerobic capacity when compared to asymptomatic individuals, but the maximum peak occurs at lower intensities of exercise suggesting low metabolic efficiency (Protas et al 1996). This result is consistent with recent studies that have shown a lower cardiovascular response in individuals with PD (Barbick et al 2007, Oka et al 2006). According to Protas et al., these individuals spend about 20% more energy than healthy individuals during exercise stress testing, which may indicate reduced movement efficiency due to the higher energy cost required for the test.

Aerobic exercise programs on a treadmill and walking training showed improvement in gait and quality of life of individuals with PD (Herman et al 2007, Rodrigues-de-Paula et al 2006). The study by Rodrigues-de-Paula et al demonstrated a significant improvement in quality of life after a strength training program and aerobic exercises using walking and stepping activities with heart rate monitor. The advantage of this training is that it can be applied clinically, since it does not require complex or expensive equipment.

Recently, Muhlack et al suggested aerobic exercise can improve the effectiveness of levodopa, and therefore patients’ motor response. As suggested in some studies using animal models, it is also possible that regular and intense aerobic exercises produce a neuroprotective effect and contribute to the restoration of neuronal pathways impaired by the PD (Fisher et al 2004, Pothakos et al 2009).

Despite some promising results, few studies have investigated the effect of aerobic fitness in physical function of individuals with PD. Thus, this subject needs more through exploration.

Exercises to improve gait

Gait impairment is an important clinical manifestation of PD and is considered as one of the most disabling aspect of this disease (Herman et al 2009). Gait related mobility problems have a negative impact on quality of life and well being of individuals with PD (de Boer et al 1996, Martinez-Martin 1998). Despite advances in medical therapy and surgical techniques, gait dysfunctions are observed throughout the disease with limited improvement of symptoms (Bloem et al 2004).

From a physical therapy standpoint, several studies have emphasized the contribution of specific exercises and intervention strategies to improve gait in individuals with PD. Treadmill training, use of external cues and specific task training have been investigated and different parameters of gait and quality of life of these individuals (Nieuwboer et al 2007, Miyai et al 2000, Miyai et al 2002).

According to Herman et al, treadmill training can promote a more stable and dynamic gait pattern in individuals with PD. Furthermore, some studies suggested that treadmill training is more effective in improving gait than other traditional approaches (Miyai et al 2000, Miyai et al 2002). It is possible that this intervention is beneficial because the subject is induced to maintain a steady rate with regular and uniform speed through the generation of rhythmic gait cycles due to periodic somatosensory and vestibular receptor stimulation (Frenkel-Toledo et al 2005a, b, Toole et al 2005). Thus, stimuli are transferred to neural circuits modulating gait in different central nervous system levels with rhythmic steps. Therefore, training on a treadmill can be seen as a kind of external cue to trigger the motor activity to be performed (Frenkel-Toledo et al 2005 b). A recent review suggested that training on a treadmill can be performed in combination with physiotherapy at a frequency of three times per week, for about 20-30 minutes (Herman et al 2009). For these authors, long-term treadmill training without weight-bearing is a safe and economical method to increase gait speed, restore gait rhythm and improve the quality of life of individuals with PD. Moreover, these effects may last for several weeks after the end of training (Miyai et al 2002, Herman et al 2007).

External visual and auditory rhythmic cues are important features in the treatment of PD, although not widely used in clinical practice. Studies have shown improvement in electromyographic and spatio-temporal parameters of gait in Parkinson's patients undergoing gait training with auditory, visual and tactile cues, (Thaut et al 1996, Muller et al 1997, Marchese et al 2000, Lewis et al 2000, Nieuwboer et al 2001). Cues are defined as environmental stimuli or the one generated by the patient, consciously or not to facilitate automatic and repetitive movements (Kwakkel et al 2007). Although the way which cues improve movement is not clear yet, recent neurophysiologic studies have suggested theoretical mechanisms for how external cues affect movement performance (Rowe et al 2002). Thus, it is believed that individuals with PD have a lower activity in certain brain areas which are responsible for the internal markup needed to implement automatic and sequential movements, common for most of our motor activities (Rowe et al 2002). It is also possible that individuals with PD can use alternative circuits such as the pre-motor parietal-thalamic pathways, which are usually activated by external stimuli in individuals without neurological disorders (Kwakkel et al 2007).

Recently, Nieuwboer et al demonstrated that three weeks of external cue training at home improved walking speed, step length and freezing severity of individuals presenting these frequent and disabling symptoms. Each individual chose their preferable cue modality (auditory, visual or somatosensory) and was trained in a variety of situations and daily activities. The authors suggested that further studies should be performed to develop duration and intensity criteria as well as the most appropriate training period so the benefits obtained through the use of cues in individuals with PD would be extended for as long as possible.

Task specific training proved to be more effective than traditional exercises to improve functional performance in individuals with neurological disorders such as stroke survivors (Sullivan et al 2007, Wolf et al 2008). For example: Task –specific training during treadmill walking with body-weight support is more effective in improving walking speed and maintaining these gains at six months than resisted leg cycling alone (Sullivan et al 2007). This type of training has proven to be beneficial in gait and balance restoration in individuals with PD (Morris et al 1996, Jobges et al 2004, Lehman et al 2005). Lehman et al showed improvement in gait velocity and step length in individuals with PD after 10 days of walking and specific orientations for a longer step length. The literature indicates that learning is more effective when the task is carried out repetitively, and generalized to different contexts (Carr & Shepherd 1998). Even though, studies are needed to explain the mechanisms behind this type of motor training at improving different mobility aspects in individuals with neurological disorders such as Parkinson's.

Exercises on brain’s health of individuals with PD

Recent studies in neuroscience have shown the effect of exercise on the brain’s function through animal models with neurological disorders (Petzinger et al 2007, Pothakos et al 2009). These studies have emphasized the role of exercise on neuroplasticity (the brain's ability to form new synaptic connections) and on brain self-repairing. These findings suggest that intensive exercise programs can improve brain performance in individuals with PD. Changes in brain function changes through physical activity can lead to behavioral alterations as a result of the plasticity mechanisms and protection of brain function (Tillerson et al 2002, Fisher et al 2004).

Some studies have shown that exercise can restore motor function through a variety of molecular repair mechanisms in the basal ganglia circuit affected by PD (Fisher et al 2004, Petzinger et al 2007). Fisher et al initiated an intensive and progressive protocol of training on a treadmill in rats with PD for 30 days at a frequency of 2 times a day. The results showed significant improvement in motor performance of animals (running duration and speed). Moreover, changes were observed in neurotransmitter interaction (i.e. glutamate-dopamine) and were considered as a possible mechanism responsible for the neuroprotective effect of exercise. Petzinger et al using the same protocol showed similar motor gains in treadmill performance and an increase in dopamine release within the motor basal ganglia area.

Tillerson et al 2002 suggested that the molecular mechanism responsible for cerebral protection may require continued use of the exercise. In addition, the results of other studies highlighted the importance of exercise intensity and suggested that PD patients without specific contraindications should be encouraged to practice physical activities in a higher intensity than that self-selected by the patient (Hirsch & Farley 2009).

The emerging knowledge about the effects of physical exercise on brain function is accompanied by more information about the effects of physical inactivity in PD. Nowadays, it is possible to have a better understanding on the consequences of lack of exercise not only in the musculoskeletal system, but also in the brain's ability to respond negatively to a lack of stimulus. Studies showed that periods of inactivity or stress in PD can revert protection and behavior benefits gained by doing regular physical activities leading to deterioration of brain’s function and disease progression (Tillerson et al 2002, Howells et al 2005).

The results highlighted above demonstrate the ability of the PD brain to restructure under some circumstances. However, it is important to take caution in generalizing these findings to the whole population of individuals with PD. The results should be the basis for further research conducted in humans allowing a better understanding of the effect of exercise on brain’s function in individuals with PD.

Conclusion

Multiple studies point to the benefits of exercise in improving muscular strength, flexibility and balance with subsequent functional improvement in individuals with PD. However, the information in the literature suggests that physical activities require some specific characteristics for this population. Exercises focusing on strength training, balance, aerobic conditioning as well as the use of external cues during gait can result in overall improvement in motor performance and quality of life related to PD patients’ health. Moreover, according to studies using animals with PD, it is possible that intensive exercise contributes to brain repair and hence reversing the progressive functional damage of this disease in humans.

Therefore, efforts should be implemented in the clinical and investigative research to gather more information related to more effective types of exercises, its frequency and program duration.

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