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Management of Balance and Gait in Older Individuals with Parkinson Disease

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Summary

Difficulties with walking and balance are common among people with Parkinson disease (PD). Effective management of these walking and balance problems is critical, as these issues can contribute to decreased mobility, falls, social isolation, reduced quality of life, and increased mortality. This review provides an overview of the gait and balance disorders associated with PD and discusses the methods currently utilized to manage gait and balance problems among people with PD. These methods include pharmacological, surgical, and rehabilitative approaches. Remaining challenges and future directions, including the need for comprehensive, multidisciplinary, patient-centered care provided by qualified movement disorders experts, are also highlighted.

Keywords: gait, balance, Parkinson disease, deep brain stimulation, exercise, levodopa, physical rehabilitation

What is Parkinson Disease?

Parkinson disease (PD) is a progressive neurodegenerative disorder that affects between 1-2% of individuals over 65 years of age and 3-5% of those 85 or older [1]. Age appears to be the greatest risk factor for PD, but many other contributing factors have also been identified [2-4]. At present, PD affects 1-1.5 million people in the United States and an estimated 40 million people worldwide. The number of individuals with PD will increase in coming decades, as the percentage of the U.S. population over age 65 rises from its current level of 12% to over 20% by 2030 [5].

PD is characterized by four cardinal features: tremor, bradykinesia, rigidity, and postural instability. The symptoms of PD arise only after substantial loss of dopaminergic neurons in the substantia nigra pars compacta. In fact, PD was originally attributed only to neuronal loss within the substantia nigra pars compacta, and a concomitant loss of dopamine. Pharmacologic replacement of dopamine is the most common, and arguably most effective, treatment for PD. However, PD is now thought to involve not only the dopaminergic system, but also other neurotransmitter systems whose role may become more prominent as the disease progresses [6]. These non-dopaminergic systems may be particularly implicated in balance and gait disorders, the management of which is the focus of this paper. Balance and gait impairments are particularly problematic for individuals with PD, as they can lead to falls, injury, and fear of future falls. As a result of injury and/or fear of falling, individuals may limit their physical activity which may result in social isolation as well as subsequent muscle weakness and osteoporosis. These in turn may contribute to increased risk of future falls and fall-related injuries [7]. The purpose of this paper is to provide an overview of the gait and balance disorders associated with PD and discusses the methods currently utilized to manage gait and balance problems among people with PD. The ideal combination and prioritization of these approaches needs to be determined on an case by case basis.

Gait, Balance, and Falls in Parkinson Disease

Gait Impairments

Many individuals with PD have gait difficulties that greatly limit functional mobility. The majority of studies focusing on Parkinsonian gait examined walking in a straight line. These studies showed that straight ahead walking in PD is characterized by: 1) a flexed posture, 2) short, shuffling steps, 3) deficits in stride length regulation, 4) reduced foot clearance during swing, 5) increased cadence, 6) limited extension at the hip and knee and reduced ankle plantarflexion, 7) reduced transverse rotation of the trunk and pelvis, 8) inappropriate coactivation of muscle agonist-antagonist pairs, and 9) reduced muscle activation amplitudes [8-14]. The cause of these gait impairments is thought to be a disturbance in the motor set function of the basal ganglia, which is involved in regulation of movement amplitude [15]. It has also been hypothesized that the basal ganglia contribute to the regulation of postural alignment and motor control, which may play a role in gait dysfunction in PD [16,17].

People with PD often have even more difficulty walking in challenging situations than they do walking forward. For example, individuals with PD experience exacerbated gait impairments when required to perform a concurrent task. Specifically, during dual task walking, gait speed and step length are reduced and stride to stride variability is increased relative to single task walking [18-23]. In backward walking, gait speed and stride length are also reduced relative to forward walking in people with PD compared to people without PD [24,25]. Both dual task walking and backward walking have been recommended as important tasks to evaluate when assessing gait in people with PD.

In addition to difficulties with dual task walking and backward walking, many people with PD have more difficulty turning while walking than they do walking in a straight line. Individuals with PD, particularly those with a history of freezing or falls, use an increased number of steps to turn as compared to people without PD [26,27]. People with PD also tend to turn en bloc, i.e. rotating the head and trunk simultaneously rather than in sequence, and require greater time to

turn [28-30]. The work of Crenna et al. [28] is particularly interesting because it reveals that turning deficits are present even in individuals with mild PD who as yet have no alteration or impairment in their straight walking. This suggests that turning difficulty may affect individuals with PD even from a very early stage of the disease when other motor symptoms are not yet apparent.

Turning is particularly problematic because it is one of the primary triggers for freezing of gait (FOG). FOG, "an episodic inability (lasting seconds) to generate effective stepping", affects more than 50% of patients who have had PD for over 5 years [31,32]. FOG commonly occurs during turning, but may also occur at gait initiation or when walking through doorways or other narrow spaces. Those who experience FOG are more negatively affected than those without FOG by challenging conditions like dual task walking and backward walking [25]. FOG is a prominent cause of falls, particularly during turning [33-35]. Falls that occur during turning are eight times more likely to result in hip fracture than falls during straight line walking [36].

Balance Impairments

Postural instability is one of the cardinal symptoms of PD. Though it is often associated with mid-to-late disease progression, recent studies have shown subclinical manifestations of postural instability in the early stages of PD as well [37-40]. Many different factors are believed to contribute to postural instability including impaired peripheral sensation and somatosensory integration, decreased strength, axial rigidity, and impaired postural responses [41-46]. Disturbed motor programming within the basal ganglia as well as abnormally processed proprioceptive signals are thought to be underlying causes of postural instability in PD [47]. Recent studies have also consistently shown that postural instability is not relieved with dopaminergic medication, therefore, non-dopaminergic pathways have been hypothesized to contribute to postural instability [48, 41].

Many different modes have been used to quantify instability in PD. In a clinical setting, quick screening of postural instability may include the UPDRS Retropulsion/Pull test [49] or the Push and Release test [50]. Assessments of static postural control have found that individuals with PD have increased sway area and abnormal shifts in the center of pressure [38, 39, 51]. Dynamic posture, such as during gait and functional activities, has also been shown to be impaired with slower velocities of movement and decreased ability to move the center of mass appropriately [40, 42, 46, 52, 53].

Both anticipatory postural adjustments and reactive postural adjustments are impaired in individuals with PD, with decreased amplitude and coordination of these movements [40, 54, 55]. An association exists between fear of falling and postural instability, though whether it is a causative relationship or a correlation is unclear [56]. However, postural instability is also related to falls in individuals with PD [57-59].

Falls

Individuals with PD are five to nine times more likely to sustain recurrent falls than age-matched individuals without PD [60, 61]. Falls and fractures are the primary reason for hospital admissions in individuals with PD [62, 63]. Studies have shown that 25-32% of falls result in injury [58, 64] with at least 3% [65] resulting in serious injury requiring medical attention. These are substantial numbers considering in prospective studies, 45-68% of individuals with PD will fall during a 12 month period with 29-51% experiencing two or more falls [58, 61, 64, 66]. In a given six-month period 29% of individuals with PD without a history of falling will experience their first fall [43]. Furthermore, individuals with PD have a 3.2 fold greater risk of hip fracture than age-matched individuals without PD [67]. Falls and subsequent hip fractures carry substantial personal costs, such as fear of falling, withdrawal from social activities, and a decreased quality of life [7, 68]. Hip fractures also represent a substantial financial burden to society, with the cost of hip fracture care in individuals with PD totaling approximately $192

million per year in the United States alone [69, 67]. One study suggests that frequent falls in an individual with PD can be used as a marker to predict life expectancy [70].

The majority of falls in this population occur in the home and have intrinsic causes (i.e. disease processes such as postural instability, freezing, loss of concentration, etc.) as opposed to extrinsic causes (i.e. a wet floor, obstacle, etc.) [60, 64, 65]. Falls often occur during transfers, when bending or reaching, while walking especially in dual task situations, and during turning as well as due to freezing and tripping/accidental causes [7, 60, 64, 65]. It is interesting to note that 2/3 of individuals who fell said their signs and symptoms were under control when they fell [60].

Many studies have compared individuals with PD who fall and those who do not fall. Those who fall tend to have longer disease duration, increased disease severity, a history of previous falls, increased levodopa replacement medication use, and increased freezing and dyskinesia [64, 71, 43, 58, 59]. They perform more poorly in balance and functional mobility measures, have increased fear of falling, have increased sway in standing, and have decreased lower extremity strength [60, 71, 43, 72, 59]. Cognitive factors such as decreased memory, power of attention, and reaction time have also been shown to be associated with falling [64, 58]. Though cardiovascular issues such as orthostatic hypotension and postprandial hypotension have been shown to be present in individuals with PD, their contribution to falls has been debated [64, 43, 58, 73].

Therapeutic Approaches to Management of Gait and Balance in Parkinson Disease

Pharmacological Treatment

Levodopa (L-DOPA) is often the drug of choice in the pharmacologic management of motor symptoms in PD as it replaces endogenous dopamine which is reduced in individuals with PD [74]. Bradykinesia and rigidity often respond well to treatment with L-DOPA, while there is increased variability in response with respect to tremor [75]. The introduction of L-DOPA also has proven to be beneficial in improving gait disturbances. Several gait parameters are

negatively influenced by withdrawal of L-DOPA therapy [26]. The parameters most consistently impacted when patients are *off* L-DOPA are stride length and speed [76-84]. Additional features noted in individuals *off* L-DOPA include decreased arm swing and reduced trunk rotation, decreased ground reaction forces and reduced range of motion at the knee [85], and reduced plantarflexor power [84]. Many studies have demonstrated that stride length and gait speed are responsive to L-DOPA, with one study showing an increase of 0.25 meters/sec from o*ff* to *on* medication [86, 80], while other parameters such as stance duration and arm swing are dopa-resistant [8, 76-78, 87]. These dopa-resistant aspects of gait support the idea that the pathology of PD extends further than just the nigrostriatal dopaminergic system [75].

Freezing of gait (FOG) is one of the most debilitating and least understood gait disturbances in PD [88]. Treatment of freezing is often extremely difficult, and specifically regarding L-DOPA, results are mixed. Those patients who experience FOG during the *off* state often experience improvements in freezing after taking L-DOPA [89]. Schaafsma and colleagues found that among those participants who experience primarily *off* state freezing, FOG episodes occurred more frequently, had a longer duration, and also involved significant akinesia. In the same study, the observation of FOG in the *on* state was quite different as the episodes occurred less frequently, had a shorter duration, and did not involve complete blocks in movement [90]. Individuals with PD experiencing *on* state freezing present a much more challenging problem as their FOG is not responsive to L-DOPA. This problem is considered to be quite rare [88], and it has been suggested that dopaminergic agents be reduced in individuals with *on* period freezing [91]. For patients experiencing FOG that is resistant to L-DOPA, other therapeutic options may be considered [92].

Some alternative pharmacologic approaches aimed at treating FOG have been somewhat effective, while others have not. Selegiline, an MAO-B inhibitor, was shown to be effective in reducing the development of FOG in patients with early PD [93]. Shoulson and colleagues found similar results in individuals in the advanced stages of PD [94, 95], and it is

suggested that this may be of greater clinical significance as FOG and falls are highly related in the later stages of PD [92]. Rasagiline, another MAO-B inhibitor, has also been shown to have a positive effect on FOG, however, the clinical significance of this improvement is not yet understood [92]. Amantadine has been shown to have conflicting results with respect to FOG. Giladi and colleagues reported that those treated with amantadine were less likely to develop FOG [96], while Macht and colleagues reported an association between treatment with L-DOPA and amantadine and increased FOG frequency [97]. Botulinum toxin was originally found to have a positive effect on FOG [98, 99]; however, Gurevich and colleagues found dissimilar results and also found that botulinum toxin increased fall risk [100]. Methylphenidate has also been examined as a treatment for FOG [101, 102]. In a study examining apomorphine, an alternative option for those with advanced PD with motor complications, researchers found that FOG was not improved following a single dose of this medication [103]. In summary, FOG remains a substantial problem that is not well addressed by current pharmacologic approaches.

Deep Brain Stimulation

Surgical intervention, in the form of deep brain stimulation (DBS), is an increasingly common treatment method often employed in advanced stages of PD where pharmacological therapy does not adequately control parkinsonian symptoms and/or complications such as wearing off of medication and levodopa-induced dyskinesias have developed. With the intent of improving the predominant symptoms in PD, including gait disturbances and postural instability, the favored target for stimulation is most often the subthalamic nucleus (STN) [104]; however, there is conflicting evidence regarding gait improvement following STN stimulation in those with PD [105-110]. It is important to note that stimulation of the internal globus pallidus (GPi) has been a target for DBS in the past, but STN stimulation is now preferred by many because the antiparkinson medications can typically be reduced more following STN as compared to GPi surgery, and less stimulation energy is needed [111]. Recently, support for stimulation of the

pedunculopontine nucleus (PPN) [112-114] has gained traction among surgeons, but again, evidence supporting this technique without pairing it with STN stimulation is controversial [115]. It is imperative that healthcare professionals understand these surgical techniques and how they may affect gait and balance in individuals with PD so that intervention plans may be designed properly.

Using quantitative measures, STN stimulation has been shown to improve gait parameters such as stride length and gait velocity [109]. In a meta-analysis conducted by Bakker et al., bilateral STN stimulation was found to improve gait disturbances and postural instability, as assessed by the UPDRS, in the *off* medication state [108]. When examining anti-Parkinson medication and STN DBS and their effects on gait and gait stability, Hausdorff et al. [110] noted that combined effects of medication and DBS on gait speed, stride length, and gait stability were larger than effects of DBS alone. Krack et al. [107] reported that STN stimulation provided an initial improvement in gait and postural instability, but performance declined with time, and by five years, patients' gait disturbances and postural instability were more impaired than prior to surgery. For those patients experiencing freezing of gait (FOG) that is responsive to levodopa (L-DOPA), STN stimulation has been shown to fully replicate the L-DOPA induced improvement seen prior to surgery [107, 116-119]. However, regarding L-DOPA resistant FOG, STN stimulation has proven to be ineffective [120, 121, 116, 118]. As such, new surgical targets are necessary to determine if DBS surgery is effective at improving FOG in individuals with PD.

It has been proposed by previous reports that the PPN plays a role in the origination of PD motor symptoms, particularly gait disturbances and postural instability [122, 123]. Moro and colleagues examined UPDRS II, III, and IV scores as well as sub-scores in six subjects at three and 12 months post unilateral PPN stimulation [114]. At three months post-surgery, UPDRS II scores significantly improved, predominantly due to marked decreases in sub-scores for falling and freezing [114]. The UPDRS III scores (including gait, postural stability) demonstrated a trend toward improvement; however the scores did not reach significance [114]. UPDRS II sub-

scores for falling at 12 months were similar to those at three months, and UPDRS III scores trended toward significant improvement from three to 12 months post-implantation [114]. In contrast, Stefani et al. found that in the *off* medication state, PPN DBS alone did not improve UPDRS III scores [115]. It was also found that PPN DBS + STN DBS when *on* medication improved UPDRS II scores [115]. In both *on* and *off* medication states, dramatic improvements in gait and balance were found in two patients post-PPN stimulation. It is important to note that these differences were found 42 (patient 1) and 16 (patient 2) days post-surgery and as such micro-lesion effects from the surgery might still have been present. Repeated clinical observations at time points more than 3 months post-surgery are necessary to avoid micro-lesion and placebo-like effects following this type of procedure [124]. In summary, while the PPN, especially when paired with STN DBS, has recently been proposed as a surgical target for improving gait and balance in those with PD, it is not yet recommended as a substitute for STN DBS [115]. Current evidence is limited by questions regarding electrode targeting and in some studies it is not clear that electrodes were successfully placed within the PPN. More data are needed to confirm or refute PPN DBS efficacy on gait and balance deficits in those with PD.

Physical Rehabilitation

Treadmill Training

Recently, the effects of treadmill training (TT) on gait parameters, balance, quality of life (QOL), and functional tasks have been examined to determine efficacy of this intervention for people with PD. Mehrholz et al. conducted a systematic review of studies investigating the effects of TT on specific gait parameters in those with PD [125]. Eight small studies were included and improvements were noted in gait speed, stride length, and walking distance when comparing individuals who underwent TT and controls [125]. With regards to training intensity, Fisher et al. reported that high-intensity TT yielded significant improvements in self-selected gait speed, stride length, step length, and gait kinematics [126]. When compared with conventional

gait training, structured TT led to significant improvements in over-ground walking speed (1.37 m/s pre to 1.56 m/s post-training) and stride length (0.72 m pre to 0.78 m post-training), as well as double stance duration [127]. Miyai et al. studied body weight-supported treadmill training (BWSTT) versus conventional physical therapy in individuals with PD and found the BWSTT group maintained improvements in gait speed and stride length at one and four months post intervention [128]. Multi-directional TT (forward, backward, sideways) and step-perturbation training have also been shown to improve cadence and gait speed in men with PD [129].

While gait parameters are commonly measured when investigating the effects of TT, other studies have examined its effects on a variety of other outcome measures. Studies by Cakit et al. and Protas et al. have shown that different protocols for TT can improve balance [130], decrease fear of falling [130], and decrease number of falls [129]. A six week TT program in which participants with PD walked at 70%-80% of maximal heart rate led to improvements in lower extremity functional tasks (20-m walking time, timed U-turn, turning around a chair, ascending/descending stairs, standing from a chair, and standing on one foot) [131]. In addition to improvements in lower extremity capabilities and balance, Hermann et al. found that TT significantly improved QOL [132].

The mechanisms by which TT improves gait in individuals with PD are not yet fully understood. In a recent study by Bello and colleagues examining these mechanisms, the authors theorized that gait improvements following TT are related simply to the belt movement on the treadmill, which forces stepping through stretch facilitation of hip flexors and plantarflexors and the termination of the stance phase [133]. Other studies support the idea that TT forces step lengthening and may be an influential factor in gait improvements [9, 134, 135]. Protas et al. [129] hypothesized that visual and auditory cues, which have been shown to positively impact gait and balance in those with PD [136], provided by the treadmill could have lead to improvements in gait and balance, respectively. Herman et al. theorized that perhaps the treadmill provides an external rhythm that compensates for the ineffective internal rhythm of the

basal ganglia in those with PD. Another idea proposed by Herman et al. acknowledges that the intense, repetitive TT may add to motor learning which may explain the lasting improvements in gait five to six weeks post TT [132].

Although limited, there is good evidence supporting the short-term benefits of TT for people with PD. While the mechanisms behind the gait and balance improvements are not yet fully understood, the literature documenting such improvements should not go unnoticed. As such, rehabilitation professionals should consider TT as an adjunct to over-ground gait training for people with PD.

Use of External Cues and Assistive Devices

External cues are thought to benefit individuals with PD by bypassing the degenerated basal ganglia and utilizing other neural pathways. It is hypothesized that external cues act via the parieto-premotor pathways or the cerebellar circuits [22, 137]. Auditory, somatosensory, and visual cues have all been studied.

Auditory cueing has been shown to improve speed, cadence, stride length, and gait variability, though some studies have shown it has less effect on stride length and gait initiation than visual cueing [22, 138-141]. Auditory and somatosensory cues are comparable for improving turning velocity and in dual task situations in individuals with PD [142, 143]. Visual cueing can increase push off and improve gait initiation, and it has been shown to be most effective at increasing stride length [22, 138]. Some studies have demonstrated, though, that visual cues may decrease cadence and can interfere with dual task items [22, 140].

Some studies have attempted to combine different cueing types to see if they have an additive effect. When visual and auditory are combined for gait, it is less effective than either separately [140].However, when an audiovisual system was used to cue sit-to-stand transfers, speed and torque of the transfer were better than without cueing [144]. An attentional strategy and auditory cueing combined are effective in improving gait [143, 145, 146].

In a recent review of cueing for individuals with FOG, Nieuwbower [147] concluded that visual cueing may benefit movement initiation while auditory may be more effective to maintain gait symmetry and timing, though neither was able to consistently prevent FOG. Cueing should be individually altered, as some cueing can induce freezing in some individuals, and on-FOG and off-FOG may respond differently [147]. Freezers tend to benefit more from cueing during turns and at -10% of their preferred pace for normal walking [141, 142].

Bryant et al. [148] sent individuals home with an auditory stimulator that had been programmed during an initial evaluation. After one week of individuals practicing at home for 30 minutes a day, gait speed and stride length showed improvement, and 90% of participants thought the device was helpful and easy to use [148]. Self-cueing techniques can be utilized as well. Counting out loud, saying standard phrases, and singing are sometimes used [149]. Teaching individuals to sing in their heads while performing activities has been shown to improve gait and turning in individuals with mild to moderate PD [150].

Dual task walking seems to benefit more from cueing than single task walking in individuals with mild to moderate PD. In theory, the cueing allows an individual to decrease the amount of attention necessary for gait, freeing up more attention for the secondary task [139, 143].

Recent studies have shown short-term carry over after training, though it is believed that the cue must continue to be present to be effective long-term. Training with auditory cues for eight weeks, three times a week while increasing the tempo allowed a plateau in progress to be met, with a benefit in gait parameters (stride length, velocity, and cadence) being sustained six weeks later [151]. Other studies of shorter cue-training duration have shown shorter carryover in turning, dual task benefits, and fear of falling [142, 143].

Long-term delivery of cues may be accomplished via specialized assistive devices [152]. Assistive devices such as canes and walkers are frequently prescribed for people with PD and can be modified to include a laser that projects lines on the floor that serve as visual cues to

facilitate gait. Other devices may offer additional postural support beyond that offered by traditional devices [153]. Limited studies have been conducted to date to determine which assistive devices are optimal, but some guidance is available in the literature [154, 155]. Emerging devices may also hold promise for the treatment of FOG [156].

Resistance Training

Evidence suggests that muscle force production is reduced in individuals with PD, even in early stages of the disease, when compared to age-matched controls [157]. In fact, muscle weakness has been described as a primary symptom of PD [158]. Resistance training has been shown to be an effective intervention for improving strength, muscle mass, and function in healthy older adults [159]; however, evidence supporting the efficacy of this type of intervention for individuals with PD is currently limited. Falvo and colleagues suggest that resistive exercise may reduce the presence of PD sequelae such as impaired motor function, muscle and bone weakness, as well as reduced quality of life (QoL) and fear of falling, and as such stress the need for well-controlled clinical trials examining high-intensity resistance training in those with PD [160].

Recently, Dibble et al. studied the effects of a 12 week high-intensity, eccentric resistance training program on a variety of outcome measures for individuals with PD [161]. The investigation compared an active control group and an experimental group, both of which partook in the same resistance traditional resistance training program; in addition, the experimental group completed high-intensity eccentric training, while the control group did not. The experimental group had significant improvements in lower extremity muscle force, bradykinesia (measured by functional walking tasks), and QoL [161]. Similar results were found in a study examining eccentric resistance training and its effects on muscle structure, stair descent, and six minute walk test (6MWT) in individuals with PD [162]. Regarding specific gait parameters, Scandalis et al. found that an eight week strengthening program improved stride

length (0.83 m pre to 0.95 m post-training) and walking velocity (1.0 m/sec change pre to post-training) in individuals with PD [163]. Examining the effects of resistance training on balance, investigators have found that those with PD undergoing both balance and resistance training demonstrated significant improvements in balance and muscle strength [164, 165].

Balance Training

Balance training is a priority for individuals with PD to address postural instability. A recent systematic review by Dibble et al.[166] found moderate evidence supporting exercise-induced improvements in balance performance in mild to moderate PD. Keus et al.[167] recommend balance training as one of the top four recommendations for physical therapy, and the majority of exercise programs include some form of balance training [149, 166, 168-171]. Many mixed exercise programs (not balance training exclusively) have shown improvement in balance assessments (i.e. TUG, BBS, 5-step test speed) and during functional activities (i.e. gait parameters, turning, possible decrease in falls) after treatment [166, 169, 172]. Each of these treatment protocols has been studied for different durations and frequencies, most without specifying the length of balance training specifically. Many different modes of balance training can be utilized including, but not limited to, perturbations on a treadmill, calisthenic/balance exercises, practicing functional tasks that require increased balance, and balance specific training on a force plate [166, 171-173]. Further details on activities included in the balance exercise portion of treatments are not specifically described in most studies and, therefore, cannot be compared between studies.

An individual's confidence in his balance should also be addressed during balance training, as decreased balance confidence and fear of falling can negatively impact quality of life and are associated with falls [167]. Whole body vibration was thought to increase balance in individuals with PD, however, more recent studies show no added benefit using this form of therapy [174, 175]. Some individuals with PD might also have vestibular deficits that contribute

to their balance impairment; some studies show vestibular rehabilitation techniques may be beneficial [176, 177].

Flexibility Exercises

Since rigidity is known to be one of the cardinal symptoms of PD, stretching is often recommended to be included in a rehabilitation program for this population [167, 170, 149]. Many exercise protocols that have shown improvement in individuals with PD include stretching or flexibility as one component of the program [57, 169, 172, 171]. Increased rigidity in the hip and trunk musculature in individuals with PD has been focused on as it is thought that this increased axial rigidity may contribute to poor posture and abnormal coordination during walking and turning [42, 178, 179]. Individuals with PD may have decreased axial flexibility, which can contribute to decreased functional reach [180, 181].

Very few studies have truly examined the outcomes of a stretching or flexibility program in individuals with PD. Since studies have shown that axial rigidity is not affected by levodopa replacement therapy, a stretching program may be an effective alternative [182, 179]. Flexibility training has been shown to improve functional reach with subjective improvements in daily tasks such as driving, scratching their back, and rolling in bed but not in other functional tasks such as stand to supine time or six-minute walk distance [180]. The flexibility training focused on decreasing overall activation, relaxation into stretches with emphasis on axial structures, and performing functional task [180]. A promising study by Bartolo et al.[183] evaluated a rehabilitation protocol for individuals with PD who also had lateral trunk deviations. During this exercise program, which included stretching and relaxation exercises, functional strengthening, and gait and balance training, emphasis was placed on correcting postural trunk deviations and improving trunk control. They found improved posture, flexibility, and trunk mobility with gains lasting up to six months [183].

In a recent article presenting a new exercise program framework, King and Horak [170] summarize that rigidity impacts posture by increasing flexor tone, decreasing trunk range of motion during functional tasks and walking, and increasing muscular co-contraction which is unfavorable during automatic postural responses. They suggest that activities be performed that have increased emphasis on trunk and head rotation, postural awareness/erect alignment, flexor muscle lengthening, and increasing limits of stability [170]. As of now, this exercise program has not been evaluated for its effectiveness.

Neck rigidity, which is also greatly increased in individuals with PD, has recently been shown to correlate with posture and gait as well as have significant impact on functional mobility and balance [182]. At this time, no studies have addressed the efficacy or effectiveness of stretching or neck flexibility exercises on neck rigidity or functional tasks. In summary, there is very little research that supports stretching in individuals with PD; however, expert opinion continues to prioritize the inclusion of stretching and flexibility exercises in rehabilitation and prevention exercise regimens for individuals with PD [169, 172, 167, 170, 149, 171].

Alternative Exercise Programs

Alternative modes of exercise such as dance and Tai Chi have also been shown to be effective for improving balance and gait function in individuals with PD. Dance may be ideally suited to those with PD, as it is a social activity that is inherently motivating [184]. Dance is also performed to music which can provide an external cue to facilitate movement. In addition, dance involves the teaching and practice of specific movement strategies and incorporates dynamic balance challenges. Dance can also result in improved cardiovascular function, a testament to the fact that, if done with sufficient intensity, dance is an excellent form of aerobic exercise [185, 186]. Several studies have reported significant improvements in balance, six minute walk distance, and gait velocity in groups with PD who participated in Argentine tango or waltz/foxtrot classes [187-191]. For a comprehensive review of the literature regarding dance

and PD please see Earhart [192]. For recommendations on implementing dance classes for individuals with PD see Hackney & Earhart [193].

Tai Chi is another alternative exercise approach that has been examined in several studies with mixed results (for review see 194). Two studies have specifically reported balance outcomes, and both noted reduced falls or improved balance [195, 196]. Many of the Tai Chi studies are limited by a small sample size and some also lack a control group. It is also unclear whether Tai Chi is superior to traditional exercise, as one study found no differences between a conventional exercise group and a Tai Chi group [197].

Multidisciplinary Care Approaches

Most care for individuals with PD is currently performed on an outpatient basis using monodisciplinary care [198]. Few studies have assessed the effectiveness of the use of collaborative, intense inpatient rehabilitation for individuals with PD. One observational study found that individuals who participated in an inpatient rehabilitation program post-DBS placement had expedited optimization of their DBS settings and medications due to the 24-hour monitoring, reducing the process from a period of months to a period of weeks. The intense therapy post-surgery also allowed functional changes and gains to be immediately utilized, balance and gait training optimized, psychological changes to be monitored, and a home exercise program to be created to hopefully maintain gains [199].

Ellis et al.[200] further suggests that the comprehensive, multidisciplinary environment might be effective for individuals with PD who are experiencing a decline in function, falling more frequently, or are having more complex symptoms. After an average of 21 days of rehab, 71% of the patients in this cohort, including patients who did and did not require medication alterations, showed a clinically important improvement according to the Functional Independence Measure [200]. The inpatient rehabilitation team has been suggested to include some combination of neurosurgeons, neurologists, physical therapists, occupational therapists,

speech-language pathologists, nurses, case managers, nutritionists, sexologists, psychiatrists, and physiatrists, as is necessary for the individual patient [198-200]. As of now, however, no comparison of outcomes to standard care or cost analysis has been made. Effects on quality of life, carryover of training into the home environment, long term outcomes after inpatient rehabilitation, and characteristics of individuals who are most appropriate for inpatient rehabilitation are still unknown at this time.

Multidisciplinary care has also been advocated for outpatient settings, though research is again limited [198]. Utilization of both medication and physical therapy approaches combined was superior to medication alone [201]. Multidisciplinary care can result in both short-term [202] and long-term benefits, and can help most individuals to maintain or improve function for up to three years [203].

Remaining Challenges & Future Directions

While there are multiple approaches to the treatment of gait and balance disorders in PD, and multidisciplinary approaches offer promise for the best overall management of these conditions, several areas of challenge remain. One major issue is the fact that many aspects of gait and balance are unresponsive to levodopa and likely represent non-dopaminergic features of disease. Freezing of gait is an example of a very disabling symptom that is currently not well addressed by any approach. Another area of challenge is that of motor complications, i.e. dyskinesias and wearing off phenomena, that arise after long-term treatment with levodopa. In addition to the lack of effective treatments and the presence of treatment side effects, there is also challenge related to a lack of medical professionals with the specialized training and knowledge necessary to deliver the most up to date and evidence-based care for people with PD.

Future directions for the field of gait and balance management in PD are many and will likely include a shift from monodisciplinary care, where the focus has been on treating the

symptoms, to a multidisciplinary approach that is patient-centered and focuses not only on symptoms and impairments but also emphasizes quality of life. Future work is needed to develop new medications, advance the targeting and application of DBS, and implement more uniform and informed approaches to physical rehabilitation using evidence-based guidelines. Several studies are currently underway that will provide new evidence regarding the effectiveness of exercise-based approaches in the management of PD and should serve to inform future care models for individuals with PD.

EXECUTIVE SUMMARY

- **Gait, Balance and Falls in Parkinson Disease**
  - Gait and balance difficulties are a major problem for people with Parkinson disease.
  - Gait is characterized by shuffling steps, decreased trunk rotation, flexed posture, decreased speed, and in some cases freezing.
  - Postural instability is one of the four cardinal features of PD and is associated with increased fall rates.
  -
- **Therapeutic Approaches to Management of Gait and Balance Problems**
  - Medical management of PD has, until relatively recently, focused primarily on pharmacological approaches but many aspects of gait and balance impairments are not adequately addressed by medication.
  - More recently, deep brain stimulation has been added to the arsenal of treatment tools but again does not fully address gait and balance issues.
  - As such, physical rehabilitation approaches are a key aspect of managing gait and balance in PD and can include specific gait and balance training, resistance training to improve muscle strength, as well as prescription of assistive devices and use of external cueing.

- No current treatments effectively deal with all aspects of gait and balance impairments, with freezing of gait being particularly resistant to treatment.

- **Remaining Challenges and Future Directions**
  - Multidisciplinary, patient-centered care models are emerging and hold promise for improving quality of care for individuals with PD.
  - Such approaches will become critical in the management of gait and balance in PD using a combination of medications, surgery, and rehabilitation.
  - Management of gait and balance in PD is essential as impairments in gait and balance have a major impact on quality of life, and quality of life may become the main outcome measure for evaluating the effectiveness of PD management approaches.

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