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Impaired Step Up/Over in Persons With Parkinson's Disease

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Abstract

This study explored the functional movement task of stepping up and over an obstacle in individuals with Parkinson's disease to their aged-matched controls. Ten participants with Parkinson's disease and 10 aged matched participants were assessed on the Step Up/Over task completed on a NeuroCom EquiTest long force-plate and analyzed using Group MANOVAs. The results indicate that individuals with Parkinson's disease produce less lifting force and exhibited an increased time to complete the task of stepping up and over an object when compared with their aged matched peers. Considering the substantial risk of falls demonstrated in this population these preliminary finding demonstrate the need for interventions aimed at improving this component of function.

The ability to negotiate obstacles in the environment is required for independent living. This task may become particularly dif cult as strength and postural stability are compromised during the aging process and/or in a progressive disease state such as in Parkinson's disease (PD). Annually, approximately 70% of individuals with PD fall, and 13% fall more than once a week (Robinson et al., 2005). Because PD is a multifactor progressive disease, individuals with PD may lack the necessary physical requirements to safely step up and over an obstacle and therefore may be at an increased risk of falling. Research suggests that healthy older adults who would typically be classified as independently mobile demonstrate limitations to walking as the task becomes more complex; however, limited research exists on the characteristics of obstacle clearance in patients with PD (Frank & Patla, 2003; Shumway-Cook et al., 2003).

Previous research has demonstrated that the motor control requirements to complete functional tasks are diminished in PD (Koller, Glatt, Vetere-Overfield, & Hassanein, 1989). For example, a lack of muscular strength required to perform functional tasks has been well documented in individuals with PD (Inkster & Eng, 2004; Inkster, Eng, MacIntyre, & Stoessl, 2003). Other examinations have revealed individuals with PD have difficulty sequencing motor programs for postural correction during perturbations (Horak, Nutt, & Nashner, 1992). Similarly, the underlying problem of akinesia is an inability to drive the necessary motor output to complete complex task (Marsden & Obeso, 1994). Further, individuals with PD have difficulty maintaining steady upright posture (Horak, Nutt, & Nashner, 1992; Mitchell, Collins, De-Luca, Burrows, & Lipsitz, 1995) and responding to external and internal perturbations (Frank, Horak, & Nutt, 2000; Horak, Frank, & Nutt, 1996). These instabilities in patients with PD are related to abnormal patterns of postural responses, such as excessive antagonist activity and inflexibility (Horak et al., 1992). Clinically, locomotion in PD patients is characterized by limited balance, shuffling steps, difficulties in gait initiation and bradykinesia, reduced stride length, and increased duration of double limb support. Taken together, these studies indicate that movement efficiency is compromised, which may limit the ability of patients with PD to step up and over an obstacle.

A limitation in movement efficiency not only increases the risk of a fall event but also limits the ability of individuals with PD to be self-sufficient and independent. The decreased independence and inactivity associated with these outcomes may accelerate and enhance disability seen in this population (Balash et al., 2005; Cummings, 1992; Karlsen, Tandberg, Arsland, & Larsen, 2000). Previous literature has demonstrated decreased capacity to perform functional tasks (i.e., sit to stand and gait) in the PD population (Bond, 2000; Hass, Waddell, Fleming, Juncos, & Gregor, 2005; Inkster & Eng, 2004; Inkster et al., 2003); however, less investigated is how individuals with PD compare with their healthy counterparts while stepping up and over an obstacle. Because a trip is one of the most common contributors to a fall (Berg, Alessio, Mills, & Tong, 1997), understanding the movement characteristics of stepping up and over an obstacle is critical for fall prevention and interventions in individuals with Parkinson's disease. Therefore, the purpose of this study was to evaluate and compare the NeuroCom Step Up/Over test in individuals with PD to their age matched healthy peers. Based on the previous research demonstrating diminished motor function in this population, it was hypothesized that individuals with PD would exhibit a decreased Lift-Up Index, Movement Time, and Impact Index during the NeuroCom Step Up/Over test when compared with their healthy counterparts.

Method

Participants

An age and gender matched sample of 10 individuals with PD (4 females, 6 males) and 10 aged matched controls (4 females, 6 males) were recruited for this study (Table 1). This number was a convenience sample of participants within the surrounding community. All participants with PD were evaluated by a neurologist and categorized as Stage II to III, according to the Hoehn and Yahr scale and had an average disease duration of 8.9 (± 3.54) years (Table 2). Briefly, the Hoehn and Yahr Scale ranges with increasing severity from stage 0: no signs of disease; stage 1: unilateral disease; stage 2: bilateral disease without impairment of balance; stage 3: mild to moderate bilateral disease with some postural instability and physical independence; stage 4: severe disability but can still walk and stand unassisted; to stage 5: wheel chair bound or bedridden unless aided. Additional evaluation by the neurologist excluded those with fluctuating responses to medication and functionally disabling dyskinesia or dystonia. Other exclusion criteria for all participants included (a) preexisting lung disease, (b) history of cardiac disease, (c) uncontrolled psychiatric illness, and (d) major musculoskeletal or metabolic disorders.

Participants with PD were tested in an *on* medication state, 1–1.5 hr post ingestion to minimize the effects of medication status on functional performance (Gordon & Reilmann, 1999). Before beginning any aspect of the study, participants received verbal explanation of the protocol and signed a consent form in accordance with the Institutional Review Board procedures and ethical standards.

Procedures

The NeuroCom Equitest Long Force Plate (NeuroCom International, Clackamas, Oregon) was used to assess the participants' performance on the Step Up/Over task. The long force plate has been used to evaluate balance and stability under dynamic conditions that reflect the activities of daily life (Davies, Fernando, McLeod, Verma, & Found, 2002). The EquiTest Long Force Plate consists of two 150 × 23-cm forceplates placed side by side, with computer-linked force transducers under each corner. The EquiTest software program then uses these data to calculate, for example, how much force is exerted by the lead leg quantified as the Lift-Up Index. Participants were given a verbal description of the test followed by a visual demonstration, as well as a practice trial, before performing the test. A standard testing foot placement was achieved by aligning the lateral malleolus with markings on the force platform.

The test commenced with participants standing on the force plate with a (20.3cm high × 40cm wide × 40cm long) box in front of them. Each participant was given the commands: "Look straight ahead. When I say go, step up with your lead leg, swing your other leg up and over the step, then step down with your lead leg. Hold that position as steady as possible until I say stop." Participants held their position for 5 s after the test leg descended the step. Three trials were performed with a 30 s rest between trials. Outcome measurements include the following:

1. Lift-Up Index-quantifies the maximal lifting force exerted by the lead leg; expressed as a percent of body weight.
2. Movement Time-quantifies the number of seconds required to complete the maneuver, beginning with the initial weight shift to the nonlead leg and impact of the lead leg onto the force plate.
3. Impact Index-quantifies the maximum vertical impact force as the lead leg lands on the force plate, expressed as a percent of body weight.

Statistical Analysis

Demographic variables assessed for this study included (a) age, (b) height, (c) weight and (d) body mass index (BMI). These data, as well as the Step Up/Over (Lift-Up Index, Movement Time and Impact Index) results were analyzed using a nonequivalent two-group MANOVA. A Wilks' Lambda procedure was used to determine multivariate effects by assessing the effect of the dependent variables between the groups (Weinfurt, 2000).

Levene and Box's M tests were conducted to assess group difference on demographic data as well as compare between and within-group variability to determine if all data sets adhere to the requirements of normality (Cohen, 1988).

Results

Means and standard deviations for the demographic measures are found in Table 1. Results indicated no significant differences ($p > .05$) between PD and non-PD participants on any of the four demographic measures.

Means and standard deviations for the Step Up/Over measures are found in Table 3. Variables assessed in the MANOVA analysis included (a) Lift-Up Index, (b) Movement Time, and (c) Impact Index. Significant differences were found between groups among the dependent variables, Wilks' Lambda = 0.440, $F(3, 16) = 5.072$, $p = 0.017$. Univariate significant differences were found with the Lift-Up Index, $F(1, 18) = 5.486$, $p = 0.034$ and Movement Time, $F(1,18) = 5.528$, $p = 0.034$, with individuals with PD demonstrating decreased lifting force and increased time to complete the movement. No significant difference ($p > 0.05$) was demonstrated on the Impact Index. To control for multivariate Family-wise error rate the level of significance (0.05) was divided by the number of dependent variables analyzed (Huberty & Olejnik, 2006). The multivariate effect size was 0.559, indicating a large effect size between groups on the Step Up/Over test (Cohen, 1988; Huck & Cormier, 1996).

A follow-up descriptive discriminate analysis was computed to determine which of the three variables made up the variable construct and how the variable(s) differed between groups. The structure *r*'s indicated that the Lift-Up Index (0.55) and Movement Time (0.55) had the strongest relationship, while Impact Index (0.11) had very little relationship.

Discussion

The results of this study demonstrate that individuals with PD exhibit decreases in the Lift-Up Index (force exerted by the lead leg) and increases in the Movement Time outcome measures during the Step Up/Over task when compared with their aged matched peers. This research is the first, to our knowledge, to quantify the difficulties individuals with PD experience when stepping up and over an object. As such, given the paucity of research concerning this functional task, this study provides preliminary information on the movement characteristics of individuals with PD when stepping up and over an obstacle.

The ability to negotiate obstacles in the environment is a critical component of overall mobility. To review, the Step Up/Over test quantifies the motor control characteristics as an individual steps up with the lead leg, lifts the body through an erect standing position, swings the opposite foot over the "step," and then lowers the body to land. Although numerous studies have examined steady state gait parameters as well as the Sit-To-Stand task in the PD population, none have quantified this aspect of mobility. In order for individuals to complete this task, they must exhibit the necessary lifting force to propel the body up and over the obstacle.

We hypothesized that individuals with PD would show a reduced Lift-Up Index and therefore exhibited a decrease in lifting force exerted by the step-up leg. This hypothesis was based on clinical speculation as well as previous research that have demonstrated decreased peak vertical force and peak torque in those with PD during other functional tasks (Ramsey, Miszko, & Horvat, 2004). The results of our study did indicate that individuals with PD do exhibit significant decreases in their force output compared with their healthy aged matched counterparts. The statistical difference on this measure found that the PD participants provided 25% less force while pushing up with their lead leg when compared with than that of the healthy controls.

Furthermore, we had hypothesized that the Movement Time outcome measure would be increased, with the PD participants exhibiting a longer time to complete the Step Up/Over task. Previous studies have demonstrated longer time to complete functional tasks (e.g., Sit-To-Stand) in individuals with PD (Bishop, Brunt, Pathare, Ko, & Marjama-Lyons, 2005). Our results did confirm this hypothesis with the PD participants taking 22% longer than the aged matched controls to complete the movement.

Several mechanisms may explain the deficiencies seen in the PD participants on the Step Up/Over task. First, deficits in the ability to generate lower extremity force may contribute to the decreased force output and an overall slower movement. For example, in PD decreased mean hip and knee extensors torques have been demonstrated (Inkster et al., 2003; Ramsey et al., 2004). Other studies examining PD have documented impaired knee and ankle muscular strength (Koller & Kaseb, 1986). Similarly, those with PD demonstrate decreased isometric production and rate of force generation (Jordan, Sagar, & Cooper, 1992). Collectively these muscular impairments suggest an inability to generate the necessary force required to efficiently perform the Step Up/Over task.

Further, the reduced ability to generate force in the PD participants may be a result of not only limitations in the periphery but also central mechanism. Although our study did not measure muscle activation, previous studies examining functional tasks in those with PD have demonstrated altered neural activation and firing patterns (Bishop et al., 2005; Ramsey et al., 2004; Sabatini et al., 2000). For example, studies of cortical motor areas demonstrate decreased neural activation in individuals with PD when compared with the healthy peers (Sabatini et al., 2000). Further, decreased neural drive has been shown in patients with PD (Brown, Corcos, & Rothwell, 1997). In addition, reports of firing irregularities to single motor units in PD may also contribute to this discrepancy seen in muscle activation (Dengler et al., 1990). In sum, alterations in neural activation demonstrated in this population may limit the ability to adequately perform this functional task.

Lastly, it has been suggested that a psychological fear of falling is association with altered postural control (Adkin, Frank, & Jog, 2003) and suggests that the limited output in the Step Up/Over task may be associated with a compensatory strategy to decrease the risk of falling. This suggestion would be further demonstrated had our hypothesis of a decreased Impact Index been proven. The Impact Index calculates the maximum vertical impact force as the lag leg lands on the force plate. A lesser impact force would have been indicative of a more conservative “stepping down” pattern. Further, it was expected that the decrease in force exerted by the lead leg as well as an increase in the overall time to complete the task would result in a lesser degree of landing impact; however, our results did not confirm this hypothesis, which may be a function of the large variation seen in the measure.

Clinical Implications

Based on our research it is evident that the functional task of stepping up and over an obstacle is compromised in PD. In addition, based on previously mentioned research, other functional tasks are deficient in individuals with PD. Taken together, these investigations provide the rational for intervention programs aimed at enhancing functional movement and thus improving quality of life for individuals with PD. Concurrently, we believe it is vital that these interventions are evaluated based on not only traditional measures, but measures that evaluate daily functional tasks performance in this population.

Several efforts have been used, including therapeutic interventions, to benefit those with PD. Traditionally these techniques are aimed at improving gait, increasing muscular strength and balance, and therefore collectively attempting to improve overall function. Many of these therapies, however, do not examine functional daily task beyond traditional balance, strength, and gait measures to evaluate the effectiveness of the intervention. Based on our findings, it is evident that this aspect of daily function is limited in the PD population. It seems reasonable to suggest that additional functional task measurements be used as an evaluation tool for examining the quality of the intervention. This would allow for evaluation of the effectiveness of the intervention and thus enhance the ability to improve quality of life in individuals with PD.

Limitations

Most notability, the study limitations include small sample size. Based on the research environments surrounding community and corresponding small population, recruitment was especially dif cult. Although the results of this study are limited by the sample size, the results provide exciting preliminary results concerning the movement function of individuals with PD. Future studies may benefit from a larger sample size as well as a more homogenous (years since diagnosis as well as age) cohort. In addition, future studies may benefit greatly from examining neuro-muscular activation as well as qualitatively measuring fear of falling.

Conclusions

Our results indicate that individuals with PD exert less force and take longer to complete the task of stepping up and over an obstacle when compared with the aged matched peers. Due to the inherent increased risk of falls demonstrated in this population and the results of this study, those with PD may be at increased risk of falling during such a maneuver. Understanding this functional component of mobility in the PD population is vital to develop appropriate interventions aimed at increasing overall function in this population and quality of life.

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References

Adkin AL, Frank JS, Jog MS. Fear of falling and postural control in Parkinson's disease. Movement Disorders. 2003; 18(5):496–502. [PubMed: 12722162]

Balash Y, Peretz C, Leibovich G, Herman T, Hausdorff J, Giladi N. Falls in outpatients with Parkinson's disease. Journal of Neurology. 2005; 252(11):1310–1315. [PubMed: 15895303]

Berg WP, Alessio HM, Mills EM, Tong C. Circumstances and consequences of falls in independent community-dwelling older adults. Age and Ageing. 1997; 26(4):261–268. [PubMed: 9271288]

Bishop M, Brunt D, Pathare N, Ko M, Marjama-Lyons J. Changes in distal muscle timing may contribute to slowness during sit to stand in Parkinson's disease. Clinical Biomechanics (Bristol, Avon). 2005; 20(1):112–117.

Bond JM. Goal-directed secondary motor tasks: Their effects on gait in subjects with Parkinson disease. Archives of Physical Medicine and Rehabilitation. 2000; 81(1):110–116. [PubMed: 10638885]

Brown P, Corcos DM, Rothwell JC. Does parkinsonian action tremor contribute to muscle weakness in Parkinson's disease? Brain. 1997; 120(3):401–408. [PubMed: 9126052]

Cohen, J. Statisical power analysis. 2. Hillsdale, NJ: Erlbaum; 1988.

Cummings JL. Depression and Parkinson's disease: A review. The American Journal of Psychiatry. 1992; 149(4):443–454. [PubMed: 1372794]

Davies J, Fernando R, McLeod A, Verma S, Found P. Postural stability following ambulatory regional analgesia for labor. Anesthesiology. 2002; 97(6):5, 1576–1581.

Dengler R, Konstanzer A, Gillespie J, Argenta M, Wolf W, Struppler A. Behavior of motor units in parkinsonism. Advances in Neurology. 1990; 53:6, 167–173.

Frank JS, Horak FB, Nutt J. Centrally initiated postural adjustments in Par-kinsonian patients on and off levodopa. Journal of Neurophysiology. 2000; 84(5):2440–2448. [PubMed: 11067986]

Frank JS, Patla AE. Balance and mobility challenges in older adults: Implications for preserving community mobility. American Journal of Preventive Medicine. 2003; 25(3, Supplement 2):157–163. [PubMed: 14552940]

Gordon AM, Reilmann R. Getting a grasp on research: Does treatment taint testing of parkinsonian patients? Brain. 1999; 122(8):1597–1598. [PubMed: 10430842]

Hass CJ, Waddell DE, Fleming RP, Juncos JL, Gregor RJ. Gait initiation and dynamic balance control in Parkinson's disease. Archives of Physical Medicine and Rehabilitation. 2005; 86(11):2172–2176. [PubMed: 16271566]

Horak FB, Frank J, Nutt J. Effects of dopamine on postural control in parkinsonian subjects: Scaling, set, and tone. Journal of Neurophysiology. 1996; 75(6):2380–2396. [PubMed: 8793751]

Horak FB, Nutt JG, Nashner LM. Postural inflexibility in parkinsonian subjects. Journal of the Neurological Sciences. 1992; 111(1):46–58. [PubMed: 1402997]

Huberty, CJ.; Olejnik, S. Applied MANOVA and discriminate analysis. 2. Hoboken, NJ: Wiley-Interscience; 2006.

Huck, SW.; Cormier, WH. Reading statistics and research. 2. New York: Harper Collins College Div; 1996.

Inkster LM, Eng JJ. Postural control during a sit-to-stand task in individuals with mild Parkinson's disease. Experimental Brain Research. 2004; 154(1):33–38.

Inkster LM, Eng JJ, MacIntyre DL, Stoessl AJ. Leg muscle strength is reduced in Parkinson's disease and relates to the ability to rise from a chair. Movement Disorders. 2003; 18(2):157–162. [PubMed: 12539208]

Jordan N, Sagar HJ, Cooper JA. A component analysis of the generation and release of isometric force in Parkinson's disease. Journal of Neurology, Neurosurgery, and Psychiatry. 1992; 55(7):572–576.

Karlsen KH, Tandberg E, Arsland D, Larsen JP. Health related quality of life in Parkinson's disease: A prospective longitudinal study. Journal of Neurology, Neurosurgery, and Psychiatry. 2000; 69(5): 584–589.

Koller W, Glatt S, Vetere-Overfield B, Hassanein R. Falls and Parkinson's disease. Journal of Clinical Neuropharmacology. 1989; 12:98–105.

Koller W, Kaseb S. Muscle strength testing in Parkinson's Disease. European Neurology. 1986; 25(2): 130–133. [PubMed: 3948887]

Marsden CD, Obeso JA. The functions of the basal ganglia and the paradox of stereotaxic surgery in Parkinson's disease. Brain. 1994; 117(4):877–897. [PubMed: 7922472]

Mitchell SL, Collins JJ, De-Luca CJ, Burrows A, Lipsitz LA. Open-loop and closed-loop postural control mechanisms in Parkinson's disease: Increased medio-lateral activity during quiet standing. Neuroscience Letters. 1995; 197(2):133–136. [PubMed: 8552278]

Ramsey VK, Miszko TA, Horvat M. Muscle activation and force production in Parkinson's patients during sit to stand transfers. Clinical Biomechanics (Bristol, Avon). 2004; 19(4):377.

Robinson K, Dennison A, Roalf D, Noorigian J, Cianci H, Bunting-Perry L, et al. Falling risk factors in Parkinson's disease. NeuroRehabilitation. 2005; 20(3):169–182. [PubMed: 16340098]

Sabatini U, Boulanouar K, Fabre N, Martin F, Carel C, Colonnese C, et al. Cortical motor reorganization in akinetic patients with Parkinson's disease: A functional MRI study. Brain. 2000; 123(2):394–403. [PubMed: 10648446]

Shumway-Cook A, Patla A, Stewart A, Ferrucci L, Ciol MA, Guralnik JM. Environmental components of mobility disability in community-living older persons. Journal of the American Geriatrics Society. 2003; 51(3):393–398. [PubMed: 12588584]

Weinfurt, KP. Multivariate analysis of variance. Washington, DC: American Psychological Association; 2000.

Table 1

Participant Demographics

	Age (years)	Height (cm)	Weight (kg)	BMI
Group	**(Mean ± *SD*)**	**(Mean ± *SD*)**	**(Mean ± *SD*)**	**(Mean ± *SD*)**
PD	73.40 ± 8.50	173.30 ± 7.00	77.57 ± 8.72	25.80 ± 2.31
AMC	73.50 ± 7.53	172.10 ± 12.60	78.35 ± 16.20	25.54 ± 2.97

Note. PD = Parkinson's disease; AMC = Aged Matched Controls

Table 2

Characteristics of Participants With Parkinson's Disease

	Age (years)	Gender	Years since diagnosis	Hoehn and Yahr score	PD medications
PD1	80	M	14	3	Sinemet, Mirapex
PD2	64	F	11	3	Sinemet, Mirapex
PD3	82	F	8	3	Sinemet, Mirapex
PD4	66	F	4	2	Sinemet
PD5	72	M	6	2	Sinemet, Tolcapona
PD6	70	M	14	3	Sinemet, Mirapex
PD7	75	M	11	2.5	Sinemet
PD8	88	M	9	3	Sinemet, Mirapex
PD9	61	F	5	2	Sinemet
PD10	76	M	7	2.5	Sinemet

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Table 3

Results for the Step Up/Over

	PD (M ± SD)	AMC (M ± SD)
Lift Up Index (% body weight)	*17.22 ± 3.99	*23.14 ± 5.94
Movement Time (sec)	*1.78 ± 0.35	*1.45 ± 0.21
Impact Index (% body weight)	26.19 ± 8.16	24.62 ± 4.38

Note.

*Indicates significance at 0.05;

PD = Parkinson’s disease; AMC = Aged Matched Controls