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Leg muscle strength is reduced in PD and relates to the ability to rise from a chair

Lisa M Inkster, MSc[1,2], **Janice J Eng, PhD**[1,2], **Donna L MacIntyre, PhD**[1,2], and **A. Jon Stoessl, MD**[3]

[1]Department of Physical Therapy, University of British Columbia, Canada

[2]Rehabilitation Research Laboratory, GF Strong Rehab Centre

[3]Pacific Parkinson's Research Centre, University of BC

Abstract

Individuals with Parkinson's disease (PD) have difficulties rising from a chair; however, factors contributing to this inability have never been investigated. This study compared lower extremity strength between individuals with PD and healthy controls and quantified the relationships between strength and the ability to rise from a chair. Ten males with mild PD and ten male age-matched controls performed maximal concentric, isokinetic knee and hip extensor torque on an isokinetic dynamometer to quantify muscle strength. Subjects also rose from a chair at their comfortable pace without the use of their arms and the duration of this task provided a measure of sit-to-stand (STS) ability. Subjects with PD were tested in an on- and off-medication state on different days. Mean hip and knee extensor torques were less in subjects with PD, with greater deficits found at the hip. Greater hip strength was related to better STS ability in subjects with PD while greater knee strength was related to better STS ability in controls. These results show that individuals with mild PD generate smaller extremity forces compared to controls. Reduced strength, particularly at the hip, may be one factor that contributes to the difficulty of persons with PD to rise from a chair.

Keywords

Parkinson's disease; sit-to-stand; hip torque; knee torque; strength

INTRODUCTION

Rising from a chair, bed, or toilet is a physically demanding function required for independent living. In a survey of 101 individuals with Parkinson's disease (PD), 81% of respondents reported having difficulty with rising from a chair.[1] Despite the apparent difficulties that these individuals have with this functional task, the ability to rise from a chair in PD has never been investigated. The sit-to-stand task (STS) requires greater lower extremity strength and range of motion compared to walking or stair climbing.[2] In particular,

Corresponding Author: Janice Eng, PhD, PT/OT, Professor, Department of Physical Therapy, University of British Columbia, 212-2177 Wesbrook Mall, Vancouver, BC, Canada, V6T 1Z3 Tel: (604) 714-4105, fax: (604) 714-4168, Janice.Eng@ubc.ca.

large hip and knee extensor muscle forces are required at the point when the buttocks lift from the chair.[3,4] In fact, older adults have been reported to use up to 87% of their available knee strength to rise from a knee height chair[5,6] and up to 97% of available knee strength to rise from a low chair height.[6]

Although a reduced rate of muscle force production has been documented in PD,[7–9] evidence to support a reduced magnitude of force in persons with PD is less definitive. The mixed results may be a result of the specific muscles tested, the severity of the disease, the type of muscle action, or the specific strength variable measured. Jordan et al.[8] found no difference in the maximal isometric hand grip force between control subjects and individuals with PD. Stelmach and Worringham[9] reported a reduction in isometric elbow flexor force in PD patients that did not reach statistical significance. Koller and Kase[10] reported no significant difference between groups for isometric grip strength, however, compared to controls, subjects with PD demonstrated a significant decrease in dynamic (isotonic) strength for the wrist, arm and knee. Others have reported asymmetry of muscle strength in PD[11] and reduction of strength following withdrawal of medications[7,12] which suggests that reduced strength could be attributed to the disease process.[7,11]

Few studies have examined the relationship between muscle strength and functional performance in persons with PD. One study[13] found a relationship between isokinetic strength of the ankle dorsiflexors and gait variables (velocity, stride length) in males, but not females with PD. Another study[8] reported a low correlation (r=0.45) between the rate of isometric force generation measured with a hand grip dynamometer and motor disability in PD assessed with the Kings College Rating Scale (a rating scale of activities of daily living). A more recent study[14] reported moderate increases in knee flexor and extensor strength and improved static standing balance, in persons with PD following a strength and balance training program. These preliminary studies suggest that in PD, there may exist relationships between strength and function.

The purpose of this study was to compare the ability to generate force of the hip and knee extensor muscles, as assessed by the torque measured by an isokinetic strength dynamometer, among three groups: 1) persons with PD in an off-medication state (PD-off), 2) persons with PD in an on-medication state (PD-on), and 3) age-matched controls. Secondly, the relationships (correlations) between ability to rise from a chair (duration of one STS maneuver) and lower extremity strength were assessed. This is the first study to evaluate the role of lower extremity strength and the ability to rise from a chair in persons with PD.

Methods

Subjects

Ten male subjects with PD (mean ± 1 standard deviation; age=64.1 ± 10.1 years; mass=84.0 ± 4.5 kg; height=173.9 ± 5.7 cm) and ten male age-matched control subjects (age=65.5 ± 12.4 years; mass=80. 1 ± 9.7 kg; height=176.5 ± 8.7 cm) were recruited from local PD support organizations and medical clinics. Inclusion criteria for subjects with PD included 1) clinical diagnosis of PD for a minimum of one year, 2) ability to rise from a chair, without

the use of armrests in the off-state, and 3) no other neurological, orthopaedic, or cardiovascular condition(s) which could affect their ability to perform the STS task. The PD subjects fulfilled published criteria for clinically definite Parkinson's disease[15] and other forms of Parkinsonism had been excluded. In addition, subjects with PD were all responsive to levodopa. All subjects were informed of the research procedures before they gave written consent. The experimental protocol was approved by the local university and hospital ethics committee.

Quantitative sit-to-stand assessment

Subjects with PD were tested on two different days, two or three days apart, to minimize fatigue and were randomly assigned to commence the first testing in either an on-medication (on-state) or off-medication state (off-state). On both days, the motor section of the Unified Parkinson's disease rating scale (UPDRS)[16] and Hoehn and Yahr scale[17] were assessed. Testing commenced between 8:00 a.m. and 10:00 a.m. and required an overnight withdrawal of medications for the off-state testing (CAPIT guidelines).[18] Control subjects were tested during a single morning test session.

Subjects sat on an armless, backless, height adjustable chair instrumented with a six component force plate (Bertec Corp, Columbus, OH) under the buttocks. An Optotrak (Northern Digital, Waterloo, Canada) imaging system was used to track infrared emitting markers attached to the subjects' ears with double-sided tape to track motion of the head.

The chair height was adjusted for each subject to allow for a 90α angle at the knee, in sitting. The start position for each subject was with the feet 20 cm apart and with thigh support so that the distance between the anterior edge of the chair and the most anterior point of the patella was 20 cm. Subjects performed approximately 10 to 15 sit-to-stand trials at their own pace (self-paced trials) without the use of their arms (subjects kept their arms relaxed by their sides). Six seconds of simultaneous force plate and kinematic data were collected for each trial.

Data were analyzed for five self-paced trials for PD-on, PD-off, and for controls. The first five trials that did not have any obstructed markers were used for the analysis. Movement onset was identified from the force plate under the buttocks as the initial horizontal force beyond a baseline level. Movement termination was identified as the point in time when the vertical movement of the right ear marker reached a plateau. The duration of the task was defined as the number of seconds to complete one STS maneuver.

Computerized isokinetic strength testing

A Kin-Com Isokinetic Dynamometer (Chattanooga Group Inc., TN) was used to test the bilateral concentric, isokinetic hip extensor strength in a supine posture and knee extensor strength in an upright seated posture with 90° of hip flexion. These measurements were chosen based on the findings of previous studies that have reported that the largest joint forces generated during the STS task are from the knee and hip extensors.[4,19] The Kin-Com has been shown to be accurate and reliable for position, velocity and force.[20,21] The calibration of the instrument was tested prior to the study with known weights and was accurate to within +/− 1 N. Three submaximal cycles and one maximal cycle were

completed as practice prior to the collection of three maximal repetitions at 45°/sec as per the protocol described by Kramer.[22] Average torque over the range was calculated and was normalized by the subject's body mass as recommended by Brown.[23] Test-retest reliability over separate days for five subjects with PD produced high intraclass correlations (as categorized by Munro et al.[24] where 0.26–0.49=low correlation; 0.50–0.69=moderate; 0.70–0.89=high; 0.90–1.00=very high) for both isokinetic measures and sit-to-stand duration.

Statistical Analysis

Paired t-tests were used to determine whether the age-matched groups were similar for age, mass, height and activity level. One-way AVOVAs blocked for subject were used to compare differences between the three groups (PD-on, PD-off and age-matched controls) for 1) hip torque, 2) knee torque and 3) STS duration. Post-hoc analyses using Tukey's test were undertaken when applicable. Pearson product correlations were used to assess relationships between the ability to rise from a chair (STS duration) and lower extremity strength (torque of the hip and knee). An alpha level of .05 was used to identify statistical significance.

Results

Subject characteristics are summarized in Table 1 (PD). Due to the inclusion criteria (e.g., able to rise from a chair in an off-state), subjects with PD were mildly affected by the disease, as indicated by a mean of 2.1 on the modified Hoehn & Yahr scale[17] and low motor UPDRS score (on-state=11, off-state= 17.4 out of a maximum of 108). Mild PD also minimized the possible effects of deconditioning and inactivity which are often associated with advanced stages of PD. There was no difference in the Hoehn & Yahr scale between on and off-states. All 10 subjects with PD were right side dominant with seven subjects affected to a greater extent on the right side. The number of hours of physical activity (generally moderate activities were reported, e.g., walking, golf, gardening) was similar between groups with the means of 2.7β2.1 and 2.6β1.7 hours per week for the PD and control groups, respectively. There was no statistical difference between the two groups for age, sex, height, mass and activity level.

There was low variability within the trials of each subject for each condition; coefficients of variation were less than 11% (standard deviation/mean of trials × 100) for both STS duration measures and strength measures.

Knee and Hip Torque

No significant differences were found for the hip or knee torques between the dominant (as identified by self-report) and non-dominant limb for the controls or between the most affected (as identified by self-report) and least affected limb of the subjects with PD. Thus, the subsequent ANOVA analyses compared the three groups: 1. dominant limb for the controls, 2. most affected limb of the subjects with PD in the on-state, and 3. most affected limb in the off-state. Significant differences among the three groups were found for hip torque ($F(2,18)=4.5$, $p< 0.05$) and knee torque ($F(2,18)=9.0$, $p < 0.05$). The post-hoc analyses found the hip and knee torques of the control group were greater than the PD groups (Table 2), however, the PD-on and PD-off groups were not different. The torque for

the hip extensors in PD-on were only 70% of the value for controls while torque for the knee extensors in PD-on was 90% of the value for controls.

Ability to rise from a chair

Significant differences were found among the three groups for duration of the STS ($F(2,18)=6.8$, $p < 0.05$). The post-hoc analyses found that the self-paced duration of the STS for the PD-off was significantly slower than PD-on and controls. The duration of the STS for PD-on and the controls was the same (1.86 and 1.89 seconds, respectively).

Relation between strength and function

Using the correlational descriptors of Munro et al.[24] (0.26–0.49=low correlation; 0.50–0.69=moderate; 0.70–0.89=high; 0.90–1.00=very high), correlations were high between hip torque and STS duration in PD for the on-state and off-state ($r= -0.71$ and $r= -0.80$, respectively, $p < 0.05$), but were not significantly related to knee torque ($p > 0.05$). In contrast, controls demonstrated a moderate correlation between knee torque and STS duration ($r= -0.67$, $p < 0.05$), but STS duration was not related to hip torque ($p > 0.05$). Therefore, for subjects with PD, the greater the hip strength, the faster they performed the STS, while for controls, the greater the knee strength, the faster they performed the STS.

Discussion

Lower extremity torque is reduced in PD

At both the hip and the knee, the controls produced greater torque values compared to subjects with PD. The greater deficit at the hip compared to the knee joint may relate to suggestions that there is greater proximal versus distal motor impairment in PD.[25] It is possible that the reduced extensor strength that we noted may be a contributing factor to the flexed posture observed in later stages of PD, however, none of these subjects with PD yet exhibited any noticeable postural changes and the mean score for posture on the UPDRS score was 0.5 where 0 is “normal erect” and 1 is “not quite erect, normal for older person”.

Central mechanisms could contribute to a reduced ability to generate torque in PD where reports of firing irregularities of single motor units in PD have been attributed to an alteration of central input to the motor neuron pool.[26,27] In addition, peripheral changes have been reported in PD, e.g., muscle biopsies taken from the biceps brachii[28] and tibialis anterior[29] from persons with PD have shown increased type I fibres and decreased type II fibres. However, it is not known if these muscle changes are attributed to the disease process or if these changes are secondary to reduced mobility. In the current study, subjects had mild PD and were as active as the control group, hence, reduced mobility was not likely an important factor.

Some authors have suggested that strength differences between the more and less affected sides[11,30] or between an on and off-state in PD,[7] indicate that decreased strength is due to the effects of the disease process. However, since the subjects with PD who participated in this study were affected by the disease to a mild degree, the lack of differences between on

and off-state strength testing and between sides does not exclude that the reduced strength found in subjects with PD was due to central mechanisms.

It is possible that the clinical symptoms of tremor and rigidity may have affected torque generation, however, the degree of rigidity and tremor were very low for all the subjects in this study. Furthermore, others have reported that reduced strength in PD does not correlate with the degree of rigidity and tremor.[10,31]

Hip strength is related to the ability to rise from a chair in PD

Differences in the relationship between strength and ability to rise from a chair were not due to how quickly the task was performed because the PD-on and control group completed the STS at the same speed. STS ability in subjects with PD appeared to be more dependent on the hip than on the knee. This finding may have resulted from the greater reduction in force generating ability of the hip and suggests that hip strength is a limiting factor in the performance of STS in the subjects with PD.

The dependence on the hip in the subjects with PD, compared to the dependence of the knee in the age-matched controls, may also reflect different motor control strategies used by these two groups to rise from a chair. In healthy subjects, Doorenbosch et al. (1994)[32] reported that a STS which involved greater trunk flexion resulted a greater extensor torque about the hip, reduced extensor torque about the knee, increased activation of the hamstrings and reduced activation of the rectus femoris muscles. Such a strategy could potentially explain the greater dependence on the hip muscles in our subjects with PD. Riley et al. (1997)[33] suggested that the altered movement strategies which they documented in older adults who had difficulty rising from a chair, may stem from muscle weakness, poor postural control, in addition to impaired coordination of body momentum and joint torque.

The finding that hip muscle strength accounted for 50% (PD-on) and 64% (PD-off) of the variability in STS performance is notable, given the large number of factors which could potentially affect STS performance. It would be useful in the future to develop a multivariate regression model which includes factors such as balance function, rate of muscle force production, joint range of motion, in addition to muscle strength to delineate the contributions of different variables to STS performance.

Implications for strength training

Strength training has not been traditionally included as treatment of PD.[34] The results from this study showed that subjects with PD have a reduced ability to generate force into hip and knee extension and that hip strength is related to their ability to rise from a chair. However, since correlation studies do not infer causation, further research is required to evaluate whether improving lower extremity muscle strength would lead to improved STS performance.

While we were able to detect a reduced ability to generate force in subjects with PD, the relative contribution of the central and peripheral system could not be assessed. However, in support of a strengthening program, studies with healthy elderly subjects have shown that such a strengthening program can prevent weakness secondary to disuse atrophy.[34,35] It has

also been documented that strengthening in healthy elderly has been associated with increased motor unit recruitment[36] and neural adaptations such as increased consistency of EMG activity.[37] Therefore, motor unit abnormalities seen in persons with PD[26,27] may be amenable to change with a strengthening program.[34]

Limitations of the study

The small sample size precluded analyses using multivariate regression where greater numbers of subjects would be required. In addition, the small sample size may have also increased the chance of a Type II error.

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Table 1

Clinical data summary of PD subjects

N	Years PD[1]	H&Y[2]	Motor[3] UPDRS	Bradykinesia[4]	Tremor[5]	Rigidity[6]	Medication[7]
1	3	2	9/15	3/7	1/1	2/3	LC 50/12.5
2	5	3	20/26	9/10	0/0	2/5	LC 500/125
3	4	2	12/13	5/5	6/5	1/3	LC 500/150
4	5	3	12/23	2/11	4/3	3/4	LC 400/100
5	2	2.5	14/19	5/5	1/2	4/8	LC 250/75 Rop 3.25
6	3	2.5	17/22	10/10	0/0	2/6	LC 300/75 Bro 3.75
7	7	1.5	7/15	3/4	0/6	4/1	LC 900/225 Rop 10 Tol 200
8	6	1	6/12	5/7	1/4	0/1	LC 400/100 Rop 3
9	5	2	6/15	1/5	1/2	4/6	LC 800/200 and 50/12.5
10	4	1.5	7/14	4/8	1/3	0/0	LC 300/75 Tol 300 Rop 3
Mean	4.4	2.1	11/17.4	4.7/7.2	1.5/2.6	2.2/3.7	
Std	1.5	0.7	4.9/4.8	2.9/2.5	2.0/2.0	1.6/2.6	

[1] Number of years with diagnosis of PD

[2] Hoehn and Yahr - same score for on and off states, for all subjects

[3] Unified Parkinson's disease Rating Scale (UPDRS), on-state score/off-state score Motor score maximum=108

[4] UPDRS items reflecting bradykinesia, maximum=36 (items #23,24,25,26, and 31).

[5] UPDRS items reflecting resting and action tremor, maximum=28 (items #20 and 21)

[6] UPDRS items reflecting rigidity, maximum=20 (item #20).

[7] LC= Values are the total daily dose (mg). CR levodopa/carbidopa, Rop= Ropinirole, Brom = Bromocriptine, Tol = Tolcapone.

Table 2

Mean (SD) Torque and Sit-to-Stand duration

Group	PD-off	PD-on	Control
Sit-to-stand duration (sec)	1.97 (0.27)[a]	1.86 (0.37)	1.89 (0.16)
Hip Extensor Torque (Nm/kg)	0.76 (0.30)[d]	0.68 (0.19)	0.96 (0.32)[b]
Knee Extensor Torque (Nm/kg)	1.00 (0.22)	1.07 (0.16)	1.18 (0.24)[c]

PD-off=Parkinson's disease group, off-medication state; PD-on=on-medication state; Control=age-matched control

[a]Tukey's Test, PD-off significantly different from PD-on and Control, $p < 0.05$

[b]Tukey's Test, Control significantly different from PD-on, $p < 0.05$

[c]Tukey's Test, Control significantly different from PD-on and PD-off, $p < 0.05$

[d]Tukey's Test, PD-off different from control, $p < 0.10$ (trend towards statistical significance as defned by Rosner[38])