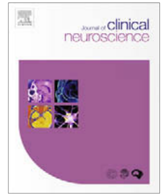
Journal of Clinical Neuroscience 17 (2010) 893–896

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn



Clinical Study

Lower extremity isokinetic muscle strength in patients with Parkinson's disease

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ARTICLE INFO

Article history:
Received 29 May 2009
Accepted 22 November 2009

Keywords:
Parkinson's disease
Isokinetic muscle strength
Muscle strength
Lower extremity

ABSTRACT

We evaluated lower extremity isokinetic muscle strength to determine affected muscle groups and their dependence on movement velocity, and to establish the relationship between muscle strength and clinical severity, as well as muscle strength and falls, in Parkinson's disease (PD). Twenty-five patients diagnosed with PD and 24 healthy volunteers were enrolled in this study. Lower extremity muscle strength was measured using an isokinetic dynamometer. Each participant's clinical status was examined in accordance with the Unified Parkinson's Disease Rating Scale; fall history was also recorded. We observed a significant decrease in isokinetic muscle strength in the patient group, especially in both hip and knee flexors and extensors. Decreased muscle strength was independent of velocity, and correlated with clinical severity and falls. Movement velocity-independent lower extremity isokinetic muscle weakness has been observed in patients with PD, especially in the knee and hip joints. The evaluation of isokinetic muscle strength may be a useful tool for the assessment of clinical severity and falls in PD.

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1. Introduction

Parkinson's disease (PD) is a common neurodegenerative condition characterized by slowness of movement (bradykinesia), stiffness of the muscles (rigidity), tremor, balance disturbances, and a progressive decrease in motor function.[1–3] When combined with additional factors, decreased muscle strength can lead to falls among elderly patients, causing fractures, joint dislocations, severe soft tissue lesions, and head trauma.[4,5] Available statistics indicate the fall rate is higher among people with PD compared to healthy elderly individuals.[4,6]

Muscle weakness is one of the main symptoms of PD.[7] In recent clinical trials, decreased muscle strength has been observed in patients with PD.[8–12] Kakinuma et al. measured the isokinetic muscle strength of knee extension and flexion and observed isokinetic strength reduction on the side more affected by PD.[12] Nallegowda et al. tested the strength of the trunk, hip, and ankle flexor and extensor muscles using isokinetic measurements, and reported a decrease in strength in all the flexor and extensor muscle groups.[9] Pedersen et al. obtained lower isokinetic concentric torque results on quantitative assessment of dorsiflexors for patients with PD compared to control subjects.[10] Inkster et al. observed that reduced strength of the hip muscles contributes to the difficulty experienced by patients with PD in rising from a chair.[11] Finally, Nogaki et al. hypothesised that muscle weakness in PD is likely to depend on movement velocity.[8,13]

In contrast to the isokinetic evaluations described, some studies have evaluated quantitative isotonic and isometric muscle strength.[7,14,15]

To date, no reported study has evaluated the isokinetic strength of the hip, knee, and ankle joints together. Some limited studies, however, have evaluated muscle groups at different isokinetic velocities in the lower extremities,[13] as well as the correlation between muscle strength and clinical status, and muscle strength and falls,[9] among patients with PD.

We evaluated the lower extremity flexor and extensor isokinetic muscle strength at the hip, knee, and ankle joints in patients with PD. We aimed to determine which muscle groups and movement velocities of the lower extremity are more greatly affected by the disease, and to discover the relationship between muscle weakness, clinical status, and falls.

2. Materials and methods

2.1. Patients

This investigation was designed as a cross-sectional, controlled study. Patients were recruited from the outpatient clinics of the Physical Medicine and Rehabilitation and Neurology Departments, and were diagnosed with PD according to the United Kingdom Parkinson's Disease Society Brain Bank criteria.[9] The study was approved by the ethical committee at the Inonu University School of Medicine. Written consent was obtained from all participants.

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doi:10.1016/j.jocn.2009.11.014

Twenty-five patients (17 male, 8 female) were included in the study. The mean age of patients was 62.1 ± 10.3 years (with a range from 42 to 81). All patients were at Hoehn and Yahr stage II or III, and were receiving treatment for PD. None of the patients had any serious orthopedic, neurological, vestibular, or visual disorders that could affect their muscle strength, and all could walk unsupported.

Twenty-four healthy volunteers (13 male, 11 female) with no orthopedic, neurological, or other diseases comprised the control group, which was age-matched with the patient group.

2.2. Assessments

2.2.1. UPDRS and Hoehn and Yahr staging

Patients were assessed using the Unified Parkinson's Disease Rating Scale (UPDRS) part II "activities of daily living" (UPDRS-ADL) and part III "motor examination" (UPDRS-ME),[16] and Hoehn and Yahr staging.[17]

2.2.2. Fall history

We used a standard definition for fall, which is "unintentionally coming to rest on the ground, floor, or other lower level".[18] Coming to rest against furniture or a wall was not accepted as a fall. The number of falls was determined using self-reported fall events during the past 6 months.

2.2.3. Isokinetic muscle strength

Isokinetic muscle strength tests were administered in the morning before the patients took any medicine. Patients first warmed up for 10 minutes on a bicycle ergometer with a load of 1 W/kg. We used the Biodex System 3 Pro (Biodex Inc., Shirley, NY, USA) isokinetic dynamometer for isokinetic measurements. During the tests, patients were restrained with seatbelts in order to provide joint stabilisation and to prevent them from falling off the test chair. All tests were performed on both extremities. The isokinetic protocol consisted of tests at three angular movement velocities of 90, 120, and 150 degrees/second at 10 rpm, with a 5 minute rest period between tests. We followed the same procedure for hip flexion-extension, knee flexion–extension, and ankle plantar–dorsiflexion. Tests on the knee and ankle were performed in a sitting position, while a supine position was used to determine hip flexion and extension strength. All tests were also performed for concentric muscle strength, and the maximum peak torque (Nm) was recorded at each angular velocity.[9]

2.3. Statistical analysis

We used Statistical Package for the Social Sciences version 16.0 software for statistical evaluation of the test results (SPSS; Chicago, IL, USA). The normality for continuous variables in groups was determined by the Shapiro–Wilk test. We used the Student's *t*-test or the Mann–Whitney U test for comparisons, and Spearman's rank correlation test was used for analysis of data. For correlation analysis, the average muscle strength was calculated by dividing the 90, 120, and 150 degrees/second angular movement velocities by the total values for the hip, knee, and ankle muscles. A *p*-value of less than 0.05 was considered significant.

3. Results

The characteristics of the patient and control groups are outlined in Table 1. There was no statistically significant difference between the two groups in age, weight, or height. The mean disease duration was 5.6 ± 3.9 years (with a range of 1 to 15 years). Fifteen patients (60%) were at Hoehn and Yahr stage II, and 10 (40%) were at stage III. In the patient group, the UPDRS-ME and -ADL scores were 26.3 ± 12 and 8.9 ± 5, respectively.

During the past 6 months, 12 patients with PD had fallen (48%), compared to only four people (16.7%) in the control group ($p < 0.05$). The average number of falls was 0.9 ± 1.1 in the patient group and 0.2 ± 0.5 in the control group ($p < 0.001$).

The isokinetic muscle strength of the patient and control groups is shown in Table 2. At all velocities, the muscle strength of hip flexors ($p < 0.01$), and extensors ($p < 0.05$), was significantly less in the patient group. Similarly, compared with the control group ($p < 0.05$), we observed a significant decrease in the muscle

Table 1
Demographic characteristics of trial subjects

	Patients ($n = 25$)	Controls ($n = 24$)	*p*-value*
Age (years)	62.2 ± 10.3	61.5 ± 7.5	0.799
Weight (kg)	73.7 ± 10.3	72.3 ± 10.9	0.326
Height (m)	1.64 ± 0.1	1.65 ± 0.1	0.582

* *p*-values determined by Student's *t*-test. Results expressed as mean ± standard deviation.

Table 2
Isokinetic muscle strength results in patients with Parkinson's disease and healthy controls (peak torque = Nm)

Angular velocity	Patients ($n = 25$)	Controls ($n = 24$)	*p*-value*
Hip flexors			
90 R	33.0 (24.3–41.1)	50.1 (37.3–69.1)	0.002
90 L	28.3 (18.7–44.8)	50.6 (31.9–67.2)	0.004
120 R	26.7 (20.4–39.3)	41.7 (27.2–58.6)	0.009
120 L	27.5 (6.4–41.5)	43.3 (25.5–61.4)	0.007
150 R	22.1 (15.5–29.6)	32.4 (24.6–49.1)	0.003
150 L	19.8 (5.6–32.2)	34.5 (16.6–51.9)	0.004
Hip extensors			
90 R	24.0 (16.7–40.0)	40.2 (25.8–68.1)	0.013
90 L	22.4 (17.8–50.7)	48.6 (28.6–70.8)	0.012
120 R	22.6 (11.3–35.2)	42.3 (22.7–71.1)	0.029
120 L	23.7 (16.1–33.7)	45.1 (25.1–62.8)	0.020
150 R	19.2 (4.2–33.3)	38.4 (16.8–66.3)	0.019
150 L	17.8 (4.7–41.9)	35.5 (19.4–51.3)	0.019
Knee flexors			
90 R	13.2 (3.3–24.7)	21.9 (18.1–31.4)	0.018
90 L	13.0 (5.8–23.0)	27.5 (14.6–35.7)	0.016
120 R	11.4 (3.4–24.2)	22.2 (18.8–28.6)	0.010
120 L	11.7 (6.0–21.3)	22.6 (11.0–35)	0.011
150 R	7.8 (4.0–19.9)	19.1 (10.5–24.3)	0.042
150 L	8.2 (3.5–17.9)	16.0 (8.0–28.1)	0.044
Knee extensors			
90 R	40.2 (26.5–63.5)	59.2 (44.4–83.1)	0.007
90 L	45.6 (32.0–63.5)	64.6 (40.2–80.8)	0.023
120 R	37.0 (28.9–58.4)	52.6 (43.6–72.5)	0.013
120 L	45.1 (27.6–59.1)	56.0 (42.8–77.5)	0.034
150 R	35.0 (26.5–53.8)	48.1 (37.2–60.4)	0.038
150 L	46.0 (24.6–52.2)	51.1 (35.1–68.7)	0.103
Ankle plantarflexors			
90 R	18.6 (11.0–29.6)	25.2 (14.8–36.6)	0.187
90 L	17.4 (8.7–26.9)	22.3 (18.4–30.6)	0.136
120 R	18.2 (9.6–28.4)	23.3 (14.7–34.9)	0.139
120 L	15.7 (10.4–24)	23.9 (15.9–32.5)	0.024
150 R	15.7 (7.3–22.2)	21.7 (12.7–28.1)	0.023
150 L	15.9 (9.1–21.2)	22.4 (16.8–29.1)	0.017
Ankle dorsiflexors			
90 R	6.8 (4.3–9.6)	10.1 (8.6–12.8)	0.014
90 L	7.2 (5.4–10.1)	9.1 (7.5–14.9)	0.080
120 R	5.6 (3.2–9.3)	7.2 (6.1–9.4)	0.042
120 L	5.8 (3.8–7.3)	7.8 (5.3–9.7)	0.017
150 R	3.4 (3.1–6.1)	5.0 (3.8–6.6)	0.028
150 L	3.9 (2.5–4.9)	4.9 (3.7–6.9)	0.070

* *p*-values determined by Mann–Whitney U test. Data are represented as median and interquartile range (Q1–Q3). L = left side, R = right side.

strength of knee flexors and extensors in the patient group, regardless of the velocity. Moreover, the isokinetic peak torques of ankle plantar and dorsiflexor muscles exhibited significantly smaller values at certain movement velocities in the patient group ($p < 0.05$).

We observed a considerable relationship between a patient's muscle strength and number of falls ($p < 0.01$). The correlation between muscle strength and the Hoehn and Yahr stage was statistically significant. There was also a strong correlation between muscle strength and all UPDRS scores ($p < 0.01$). However, there was no correlation between muscle strength and disease duration.

4. Discussion

Lower extremity muscle strength has a major effect on mobility. No previous studies have evaluated the overall flexor and extensor muscle strength in the hip, knee, and ankle joints in patients with PD, although several studies have evaluated the muscle strength in one or two joints separately.[10,12,13] We assessed muscle strength with an isokinetic dynamometer to determine which muscle groups were most affected, and at which of the predetermined movement velocities, to evaluate their correlation with clinical status and falls. While many studies have evaluated isokinetic muscle strength before (off state) and after (on state) medication, we tested all patients in the morning after withdrawal of medication (off state). This was done to exclude the effects of medication while evaluating the muscle weakness that commonly exists in patients with PD. The positive effects of anti-parkinsonian agents on muscle strength have already been shown in many studies and are outside the scope of this investigation.[9,19]

Nallegowda et al. evaluated isokinetic muscle strength at the trunk, hip, and ankle flexor and extensor muscles at 90, 120, and 150 degrees/second angular velocities; the same velocities were used in our study.[9] They found a significant difference in all muscle groups between patients who did not take medication and the healthy control group. In contrast, we evaluated the knee flexor and extensor muscle strength instead of the trunk flexor and extensor muscle strength. We observed a significant weakness in all hip and knee muscles at all velocities, as well as in ankle muscles at some velocities. There was also marked muscle weakness in the hip flexors compared to the other muscle groups. Hip flexors are the major accelerators in the swing phase of gait.[20] The difficulty in gait initiation in patients with PD may be related to the weakness of the hip flexors. However, Bartels et al. suggested that freezing of gait was not correlated with bradykinesia.[21] Additionally, ankle muscle strength is more important in preventing falls and for proper gait. Less severe ankle muscle weakness compared to other muscle groups demonstrates the importance of other factors, including proprioception. Zia et al. reported the impairment of joint position sense in patients with PD.[22] These results suggest the possibility of multiple underlying pathologic mechanisms.

Pedersen et al. evaluated the ankle dorsiflexor isokinetic muscle strength both concentrically and eccentrically, and found significantly lower values for the concentric muscle strength at all movement velocities compared to the control group, while the eccentric muscle strength differed from the control group only in male patients.[10] Kakinuma et al. separated the subjects into two groups, according to how severely their extremities were affected, and found that isokinetic muscle strength decreased at both slow and fast movement velocities during early disease.[12] They also observed that the difference in muscle strength between the more- and less-affected extremities decreased in advanced disease. Our study, and the studies discussed above, demonstrated no relationship between decreased muscle strength and movement velocity.[9,10,12] Nogaki et al. found a significant decrease in the peak torque of the isokinetic muscle strength compared to the less-affected extremity at high movement velocities but no difference between the two extremities at lower movement velocities.[13] Therefore, the observation of increased muscle weakness at higher movement velocities, proposed by Nogaki et al., is comparable with our findings.[13]

Although Corcos et al. indicated an asymmetrical distribution of muscle weakness, our study shows the common muscle weaknesses in patients with PD are similar to those found by Nallegowda et al.[9,23] In some studies, the importance of the central effect on muscle weakness has been emphasised, but the effect of immobilisation was not considered in patients with PD.[9,13] The effects of immobilisation on muscle weakness should be noted, especially in elderly patients with PD.

Various studies report that the risk of falling in patients with PD ranges from 38% to 70%.[2,4,9] Our results regarding the percentage of patients who have suffered falls were similar. There is a significant relationship between falling and muscle strength, but we have not found any studies associating muscle strength with falls in patients with PD. Muscle weakness of the lower extremity may be a risk factor for falling.[24,25] Therefore, the risk of falling may be examined in connection with lower extremity isokinetic muscle strength in patients with PD.

We found a marked correlation between muscle strength and UPDRS-ME and -ADL scores. As the UPDRS-ME and -ADL scores are related to clinical status, we expected to find a correlation between these parameters and muscle strength. The UPDRS is frequently used to evaluate the clinical status of patients with PD.[26] Given the significant correlation between muscle strength and the UPDRS, isokinetic muscle strength may be used to evaluate the clinical status of patients.

Disease progression in PD was evaluated using Hoehn and Yahr staging. Increased disease severity ($\geqslant$stage III) leads to more marked locomotor system abnormality.[27] Most of our patients were at Hoehn and Yahr stage II. There appeared to be a significant

Table 3
Analysis of correlation coefficients between muscle strength and clinical status, falls (the average muscle strength was calculated by dividing the 90, 120, and 150 degrees/second angular movement velocities by the total values for the hip, knee, and ankle muscles)

	90°		120°		150°	
	Flexors	Extensors	Flexors	Extensors	Flexors	Extensors
No. falls	−0.65*	−0.70*	−0.68*	−0.64*	−0.66*	−0.60*
Disease duration	−0.46	−0.47	−0.47	−0.39	−0.49	−0.33
Hoehn and Yahr†	−0.62*	−0.61*	−0.64*	−0.61*	−0.60*	−0.62*
UPDRS-ME	−0.64*	−0.52*	−0.68*	−0.56*	−0.64*	−0.48
UPDRS-ADL	−0.60*	−0.70*	−0.56*	−0.57*	−0.54*	−0.53*
Sample size	25	25	25	25	25	25

ADL = activities of daily living, ME = motor examination, UPDRS = Unified Parkinson's Disease Rating Scale.
* $p < 0.01$.
† Kendall's rank-correlation.

correlation between isokinetic muscle strength and Hoehn and Yahr stage, as shown in Table 3. Muscle weakness in some patients was not prominent, as they were at an early stage of PD. It seems muscle weakness is related to clinical severity rather than disease duration.

The main limitations of our study were the inadequate number of patients and the absence of lower velocities, such as 60 degrees/second, at which isokinetic muscle strength could be evaluated.

In summary, we found a significant decrease in bilateral hip, knee, and ankle flexor and extensor isokinetic muscle strength, which was especially prominent in the hip muscles at 90, 120, and 150 degrees/second angular movement velocities. In addition, we noted a relationship between disease severity and muscle weakness. There was also a significant correlation between muscle strength and UPDRS-ME and -ADL scores. Finally, there was a marked association between muscle strength and the number of falls.

5. Conclusion

Although muscle strength decreased in the lower extremity, especially in the hip and knee, muscle weakness was not associated with the velocities at which it was evaluated in this study. The evaluation of muscle weakness may be a useful tool for the assessment of clinical severity and fall risk in patients with PD. It should be noted, however, that conflicting previous results and the lack of specific standards necessitate further studies.

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