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Immediate positive effects of physical therapy on gait disturbance in patients with parkinson's disease

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Abstract

Background: Gait disturbance is major disturbance of Parkinson's disease (PD). Although continuous physical therapy (PT) has been demonstrated to improve gait disturbance and prevent falls among PD patients, few studies have reported on the immediate effect of PT. The aim of this study is to investigate the immediate effects of PT on gait parameters and joint kinematics in patients with PD.

Methods: Forty patients with idiopathic PD (Hoehn and Yahr stage 3–4) participated to the study. Participants were allocated to two groups: the intervention group participated in asingle 30-min PT session consisting of stretching exercises, strengthening exercises, balance training and gait training; the control group rested for 30-min. Gait parameters and range of angular motion of the joints were assessed using a three-dimensional motion analysis system in all patients before and after the session. Differences in the mean scores before and after intervention were examined.

Results: Walking speed and step length were significantly improved after PT. The range of angular motion of the shoulder, elbow and knee joint were expanded after PT. There was a significant interaction effect for improved walking speed, step length, trunk forward inclination and range of angular motion of the joints between the two groups and before and after PT sessions.

Conclusions: PT confers immediate positive effects on gait parameters. Gait disturbance, the main disorder of PD, is expected to be improved by single session of PT.

Keywords: Parkinson's disease, physical therapy, gait disturbance, motion analysis

Introduction

Parkinson's disease (PD) is a progressive neurological disorder that causesloss of functional abilities in areas such as gait. Gait disturbancein PD is characterized by reduced walking speed, shortened step length, freezing, pulsion, anteversion of posture and reduced arm swing [1-3]. Reduced walking speed in PD appears to result from a deficit in producing an appropriate steplength, rather than in cadence (step frequency) [4], and it is this particular disturbance in gait that tends to lead to a fear of falls among PD patients. Indeed, previous studies have reported that 38–54% of PD patients had experienced one or more falls in the previous 3 months [5,6]. Some studies have suggested that the impairment in the ability to regulate step-to-step variability might be responsible for falls in patients with PD [7,8]. Although physical therapy (PT) alongside the administration of antiparkinsonian drugs has been demonstrated to improve gait disturbance and prevent falls among PD patients, few studies have reported on the efficacy of PT alone [9].

As suggested by Morris et al., [10], there are two major rehabilitation approaches for PD. Motor learning and motor control training is based on compensatory strategies to bypass the defective basal ganglia, teaching PD patients to move easily and safely. In contrast, musculoskeletal exercises aim to improve the strength, range of motion, endurance and aerobic capacity of PD patients. A meta-analysis of studies investigating the effects of PT in PD showed significantly improved scores in relation to activities of daily living (ADLs) and the Unified Parkinson's Disease Rating Scale (UPDRS), as well as significantly improved step length and walking speed [11].

Thus far, there has been little attempt to evaluate the gait of PD patients using quantitative biomechanical analysis. Some studies have measured the effect of surgical treatment or L-dopa

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medication on gait using three dimensional (3-D) motion analysis [2,12] and othershave demonstrated the effect of treadmill exercise by biomechanical analysis [13,14]. However, the effect of conventional PT on gait disturbance as examined by a quantitative biomechanical method remains to be clarified. Moreover, it is unclear whether a single session of PT training has a measurable effect on gait and other standardized measures of function in PD. To this end, the present study evaluated the immediate effects of a single session of PT in PD patients by quantitatively analyzing gait parameters and posture.

Materials and methods

Participants

We recruited the patients with idiopathic PD who were being treated on an out patient basis at our hospital. Between December 2004 and November 2006, 60 participants were recruited. The diagnosis of idiopathic PD was confirmed by a general examination and a neurological examination conducted by trained neurologists according to the UK Brain Bank criteria [15]. Exclusion criteria wereas follows; (1) Patient could notwalk independently without an assistive device such as a cane or walker. (2) Patient had anyother neuromuscular, cardiopulmonary, osteoarticular or psychiatric disorders. (3) Patient with cognitive impairment (Mini-Mental Status Examination score <25). (4) Patient hadmanifested the on-off phenomenon. (5) Patient had participated in PT or any rehabilitation program in the previous 2 weeks. Medication for PD was not modified at least one month prior to the study. The study protocol was approved by the Institutional Review Boardat our hospital (IRB No. 378) and written informed consent was obtained from all participants.

Figure 1 shows the flow of patients through the study. Of the 60 patients invited to participate, 57 agreed to participate (95%), and 17 excluded due to not meeting inclusion criteria. Forty patients were randomized, 20 allocated to receive PT and 20 to receive no training (control).

Study design

A single-blind randomized controlled clinical trial design was used to assess the immediate effect of PT. Subjects were randomly allocated to either the PT intervention group or the control group by using computer generated random number sequences. The investigators were unaware of the group allocation.

Intervention

Participants randomized to the PT intervention group received a single 30-min session of PT. The PT was dministered by licensed, experienced physical therapists. The session included: (1) Stretching exercises (5 min): Exercises mainly targeting the trunk and lower extremities, especially the ankle joint. (2) Strengthening exercises (5 min): Exercises mainly targeting hip flexor and knee extensor muscles. Low intensity (20–30

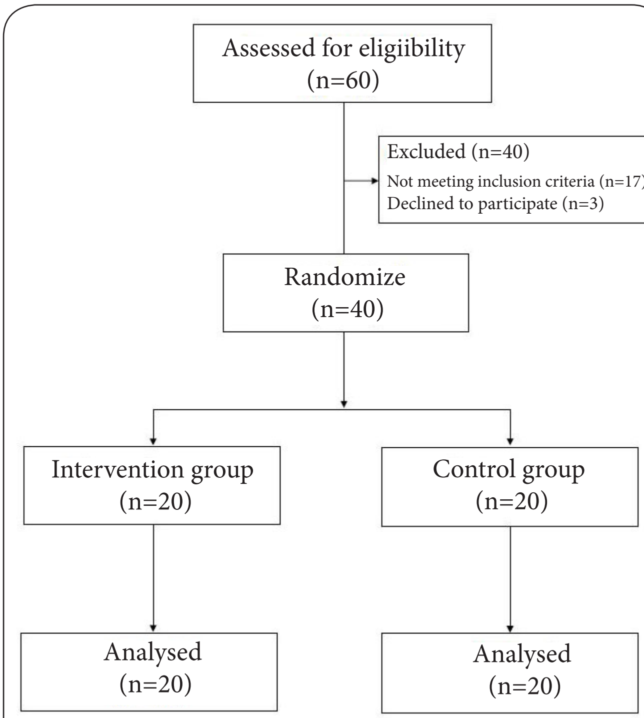

Figure 1. Study flowchart.

repetitions maximum) isokinetic exercises were chosen. (3) Balance training (5 min): Maintaining balance on a soft mattress in a standing position. While inthe quadruped position, extending one upper limb together with contralateral lower limb. (4) Recreational game played with a ball (5 min): Playing catch with the therapist using balls of different sizes and weights while sitting and standing. (5) Gait trainingwith external auditory cueing (10 min): Walking in time to music or a metronome (120 beats per minute).

Participants randomized to the control group rested for 30 min in a comfortable sitting position and received no therapeutic intervention.

Assessments

Participants were assessed for disease severity using standard clinical tests, including the Unified Parkinson's disease Rating Scale (UPDRS) and the Hoehn & Yahr score before the intervention by one physician certified on the UPDRS. Gait assessments were conducted immediately before and immediately after the PT or resting session. Gait data were recorded by a 3-D motion analysis system (Vicon Oxford Metrics, Ltd., Oxford, UK) equipped with 10 cameras which reconstructed the movement trajectories of retro-reflective markers placed on the body at a 60Hz sampling rate. Eighteen markers were attached to the following locations on the subject's body: on the top of head, forehead, seventh cervical vertebra, lumbosacral joint and bilateral acromion, elbow, wrist, great trochanter, knee, ankle and fifth metatarsal joint. Subjects were asked to walk

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at a comfortable pace across a 10-m walk way, with data acquired in the 5-m central zone.

The evaluated parameters of gait include: walking speed, step length, cadence, double support duration, single support duration, trunk forward inclination, and range of angular motion of the shoulder, elbow, hip, knee and ankle joints. Step length is defined as the distance between the point of initial contact of one foot and the point of initial contact of the other foot. Cadence is defined asthe number of the steps taken per minute. Double support duration signifies the duration of the double-limb standing balance as a percentage of gait cycle, while single support duration signifies the duration of single-limb standing balance as a percentage of gait cycle. Trunk forward inclination is defined as the trunk angle (C7-lumbosacral markers versus sagittal plane). Shoulder angle is defined as the links between the acromion and elbow trochanter markers; elbow angle as the links between the elbow and shoulder-wrist markers; hip angle as the links between the trochanter and acromion-knee markers; knee angle as the links between the knee and trochanter-ankle markers; ankle angle as the links between the ankle and knee-fifth metatarsal joint. Finally, range of angular motion was calculated as the difference between the maximum flexion and extension angles in the gait cycle.

After two rehearsals, the gait parameters were evaluated three times with 1-minute intervals separating the trials, and mean values were used for outcome measures. Data are presented as means and standard deviations (SD).

Table 1. Baseline characteristics of patients.

	PT group (n=20)	Control group (n=20)	*P*
Gender (M/F)	10/10	11/9	0.752
Age (years)	67.2±7.9	66.9±6.3	0.877
Height (cm)	159.3±10.2	158.7±7.9	0.769
Weight (kg)	55.0±13.4	56.1±10.3	0.668
Duration of disease (Y)	8.7±6.1	11.4± 5.8	0.166
Hoehn & Yahr stage	3.3±0.5	3.4±0.5	0.635
UPDRS score			
Total	39.4±17.1	38.4±13.0	0.882
Mental	1.4±1.7	1.8±1.4	0.221
ADL	11.1±6.0	12.5±7.4	0.529
Motor	25.1±10.7	21.1±7.8	0.414
Complications	1.9±2.0	3.0±3.7	0.512
Medication			
Levodopa use	16 (80%)	17 (85%)	0.677
Dopa agonist use	12 (60%)	16 (80%)	0.168
Other PD medication	15 (75%)	16 (80%)	0.705
Mean dose of levodopa (mg/day)	318 (139)	350 (153)	0.486

Note: Values are given as mean(SD) unless otherwise indicated
ADL: Activities of daily living; PD: Parkinson's disease;
UPDRS: Unified Parkinson Disease Rating Scale

Statistical analysis

Differences in the baseline characteristics between the two groups were evaluated by the independent *t* test for continuous data, the chi-square test for categorical data and the Mann-Whitney U test for the ordinal variable. A two-way analysis of variance (ANOVA) with repeated measures was used to examine the differences between the groups before and after the session and analyze the interaction between Group and Session in order to quantify the effects of PT. Where a significant interaction existed between Group and Session, a post hoc analysis was performed by drawing an interaction plot. The comparison of step length and range of joint was evaluated for the left and right sides separately. Statistical analysis was performed using the SPSS software package Version 17.0 (SPSS Inc, Chicago, IL).

Results

All patients completed the intervention (PT or control) session without incident (e.g., no falls, cardiac symptoms or joint problems). Patient baseline characteristics are summarized in **Table 1**. There were no significant differences between the 2 groups with respect to the measured characteristics.

Gait parameterand range of angular motion of joint results are shown in **Table 2**. In general, although walking speed and step length were improved after PT intervention, the changes in ROM of joints were <5 degrees.

The 2-way ANOVA with repeated measures showed significant improvement in walking speedand amplitude of range of angular motion of the shoulder, elbow and knee joints after PT intervention. There was also asignificant interaction effect for improved walking speed, step length, trunk forward inclination and range of angular motion of all joints between Group and Intervention (**Table 3**).

Post hoc analysis revealed that walking speed, step length, trunk forward inclination and the range of angular motion of joint differed between the two groups (**Figure 2**).

Discussion

This study examined the immediate effects of PT in PD patients by quantitative gait analysis. Although some patients have attempted to exercise by themselves before activities from their experiences, there have been no data to support their theory. To our knowledge, there is only one study to evaluate the immediate effects of PT in PD patients using a 3-D motion analysis system [16]. They reported that the frontal lobe dysfunction prevent the immediate effect of PT in PD by using Frontal Assessment Battery. The dysfunction of programming or working memory might affect the immediate effect of PT.

There are few guidelines for PT in PD that have practical recommendations based on scientific evidence, and the lack of uniform treatment recommendations has hindered research into the efficacy of PT in PD. Keus et al., [17] were able to extract some specific treatment recommendations on the basis

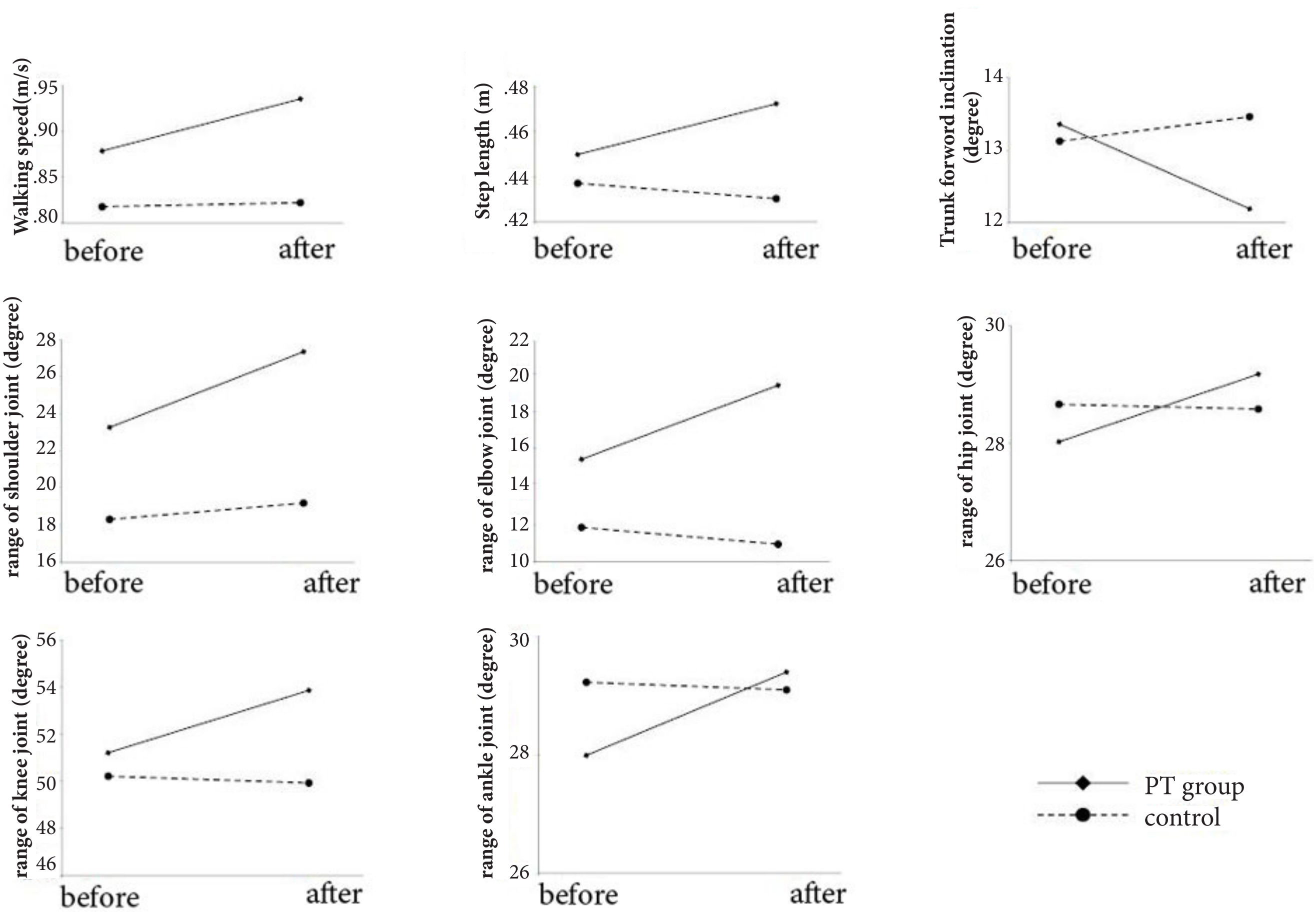

Figure 2. Interacton plot of the change in the gait parameters and range of joints between PT group and the control group.

Table 2. Change of gait parameters and range of joints after PT intervention.

	PT Group		Control	
Parameters	**Before**	**After**	**Before**	**After**
Walking speed (m/s)	0.88±0.30	0.94±0.28	0.82±0.31	0.82±0.33
Step length (m)	0.45±0.14	0.47±0.13	0.44±0.14	0.43±0.15
Cadence (step/min)	114.1±12.8	116.6±10.2	111.4±8.9	112.7±11.3
Double support duration (%)	25.1±5.4	24.2±5.6	28.2±8.6	26.8±8.3
Single support duration (%)	37.4±3.0	37.6±3.5	36.6±5.2	36.3±4.8
Trunk forward inclination (degrees)	13.4±9.9	12.2±11.2	13.0±9.5	13.4±9.6
Shoulder Flx/Ext range (degrees)	23.3±13.9	27.3±13.2	18.4±16.1	19.3±17.4
Elbow Flx/Ext range (degrees)	15.6±10.4	19.6±11.0	11.9±8.5	11.0±8.0
Hip Flx/Ext range (degrees)	28.1±7.8	29.2±7.7	28.7±8.6	28.6±8.8
Knee Flx/Ext range (degrees)	51.2±9.3	53.9±8.3	50.2±12.8	49.9±12.6
Ankle Dor/Pln range (degrees)	28.0±7.7	29.5±8.3	29.4±10.7	29.2±9.9

Flx: flexion; Ext: extension; Dor: dorsal fexion; Pln: plantar flexion

of evidence from controlled trials: cueing strategies to improve gait and training of joint mobility and muscle power to improve physical capacity. In our study, we decided to use treatment recommendations in our PT session that were supported

Table 3. Results of two-way ANOVA for gait parameters and range of joints.

	Group (PT vs control)		Intervention (before vs after)		Interaction (Group×Intervention)	
Parameter	**F**	***P***	**F**	***P***	**F**	***P***
Walking speed (m/s)	0.821	0.371	6.089	0.018*	4.545	0.040*
Step length (m)	0.755	0.388	3.768	0.056	12.823	0.001*
Cadence (step/min)	0.996	0.325	3.258	0.079	0.333	0.567
Double support duration (%)	1.701	0.200	3.513	0.069	0.200	0.657
Single support duration (%)	0.661	0.421	0.009	0.923	0.353	0.556
Trunk forward inclination (degrees)	0.053	0.818	1.458	0.231	4.883	0.030*
Shoulder Flx/Ext range (degrees)	3.709	0.058	23.428	<0.001*	9.721	0.003*
Elbow Flx/Ext range (degrees)	8.863	0.004*	10.223	0.002*	25.920	<0.001*
Hip Flx/Ext range (degrees)	0.000	0.989	3.083	0.083	4.114	0.046*
Knee Flx/Ext range (degrees)	1.033	0.313	15.647	<0.001*	24.574	<0.001*
Ankle Dor/Pln range (degrees)	0.070	0.792	3.142	0.080	4.439	0.038*

by evidence obtained from more than two controlled trials. Our PT session consisted of stretching exercises, strengthening exercises, balance training, a recreational game and gait training with external auditory cueing. The exercises aimed at improving range of angular motion, with the stret-ching exercises designed to improve ADL function [18]. We especially focused on training movements of the trunk and ankle joint, which are frequently disordered in PD. Previously, a strength training and high-intensity resistance training program was found to increase muscle power in PD patients [19,20]. Moreover, dose-dependent benefits of exercise were suggested to normalize corticomotor excitability in early PD [21]. We therefore trained trunk muscles and hip flexor muscles mainly aiming to stabilize posture and improve step length. Balance training has been found to be effective in improving balance in PD patients [22,23], and in this study we used balance training with proprioceptive feedback. In terms of the recreational training component of our session, patients engaged in a ball-catching exercise since it has been demonstrated that PD patients move as fast as healthy subjects when reaching for a moving or stationary ball under temporal constraints [24].

Gait in PD patients is reported to be improved by the use of visual or auditory cues [25], although it is not clear exactly how such cues improve gait. Perhaps they provide an external rhythm that can compensate for the improperly supplied internal rhythm of the basal ganglia or correct the motor set deficiency in PD. Hackney et al., reported the positive effects of dance for patients with PD [26], where the effects were derived from the musical cue and rhythmical steps. We therefore used auditory cues with rhythmic music at a tempo of 120 beats per minute in our PT session.

The improvement in walking speed among our subjects did not result from an improvement in cadence but rather an increase in step length. This finding may not be unexpected, however, since cadence control is reported to be intact in PD [8]. Instead, our results revealed significant improvements in step length as well as in range of the joints and posture.

Several studies have investigated the effect of PT using assessment batteries such as the UPDRS or Functional Independence Measure (FIM) [27,28]. We assessed the effect of PT using a quantitative biomechanical method. PT training was clearly shown to improve joint excursion in not only the lower extremities but also the upper extremities. The improvement in range of motion of the shoulder suggested that restricted arm swing, which is common in PD, was improved by the PT session. Increased range of motion of the lower extremities can contribute to prolonged step length, and some studies mentioning range of motion of the lower extremities in PD [4,5,12] report that improvement in arm swing influences improvement in balance and appearance of the gait.

Walking performance in patients with PD is variable. Although Urquhart et al., [29] demonstrated that measures of gait speed, cadence, step length and double support duration were highly consistent over a 7-day period, in the present study we collected gait data immediately before and immediately after intervention in order to minimize the variation from the on-off phenomenon.

Some limitations of this study should be noted. First, the number of subjects was small, which limits the generalization of the results. Second, the reliability (repeatability) of the computerized 3D system has not been investigated for PD patients, but the test-retest reliability of the system has been described for stroke patients [30]. In addition, the duration of the positive effects of PT under taken in this study were not evaluated. Herman et al., [31] reported the effects of tread mill training were retained 4 weeks later and Miyai et al., [14] demonstrated that the effects of body weight-supported treadmill training on short-step gait in PD lasted for 1 month. Further studies should include a sufficient number of participants who should be followed over the longerterm.

Conclusion

The results demonstrate thata single PT session can confer immediate positive effects on gait parameters. PT might improve not only gait parameters, but also posture and range of joints. Single session of PT programs can therefore be expected to prevent falls if carried out before going out.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Authors' contributions	NW	MS	MT	YI	KO	KS
Research concept and design	✓	--	--	--	--	--
Collection and/or assembly of data	--	✓	✓	✓	--	--
Data analysis and interpretation	✓	--	--	--	--	--
Writing the article	✓	--	--	--	--	--
Critical revision of the article	--	--	--	--	✓	✓
Final approval of article	✓	--	--	--	--	--
Statistical analysis	✓	--	--	--	--	--

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