Muscle strength and spatiotemporal gait parameters in people with Parkinson´s disease. A pilot study

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Introduction. Muscle weakness in persons with Parkinson disease (PD) has been frequently recognized as a nonspecific symptom. In other neurological conditions, lower limb weakness, specifically quadriceps weakness, is the factor that causes greater gait disability. Little research has evaluated the relationship between lower limb muscle strength, using objective tools, in PD persons and gait performance. The aim of this study was to analyze the correlation between lower limb muscle strength, using an isokinetic dynamometer, and the spatiotemporal gait parameters in PD, compared with age- and sex- matched healthy controls.

Subjects and methods. The study was conducted with 7 persons with PD –Hoehn and Yahr (HY) between II-III– and 7 healthy controls. Isokinetic knee and ankle tests at 60 and 120°/s and the 10-meter walking test at comfortable and fast walking speed, were performed on all recruited subjects.

Results. Significant differences in lower limb strength-related measures and gait parameters were observed between persons with PD and controls. Gait parameters showed excellent correlations (rho ≥ 0.7) for both lower limb: ankle plantar flexion work/body wearing at 180°/s with number of steps (indirect) and stride (direct) at both speeds, and between the ankle plantar flexion peak torque/ body wearing at 180°/s with number of steps (indirect) and stride (direct) at maximum speed; and between knee extension work/body wearing at 60°/s) with stride (direct) at self-selected speed.

Conclusions. Persons with PD (HY II-III stages) lower limb muscle strength correlates excellently with gait pattern, showing lower isokinetic strength than healthy subjects of the same age and sex. This protocol showed safety to be performed in a larger sample.

Key words. Gait analysis. Gait parameters. Movement disorders. Muscle strength. Neurological disorders. Parkinson’s disease.

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Ethical approval:
The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Universidad Rey Juan Carlos.

Informed consent statement:
Informed consent was obtained from all subjects involved in the study.

Accepted:
15.06.23.

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Introduction

Muscle weakness in persons with Parkinson disease (PD) has been frequently recognized as a nonspecific symptom [1]. However, several investigations have provided objective evidence that muscle strength has been reduced in persons with PD compared with age-matched controls [2,3]. Diminished performance caused by weakness may be a primary sign of PD and may be explained by disturbed motor programming in the basal ganglia [4]. It is known that in other neurological conditions, lower limb weakness, specifically quadriceps weakness, is the factor that causes greater gait disability [5,6]. Muscle strength seems to be reduced in PD compared to healthy subjects, even in the early stages of the disease [1]. Torque usually decreases with increasing isokinetic speed, but muscle weakness is more evident in PD as speed increases, especially in advanced stages, being a hallmark of PD (combination of bradykinesia and weakness) [1]. Objective techniques such as isokinetic dynamometry could be a key element in a rehabilitation assessment context, as it could have clinical and functional consequences.

Gait in persons with PD has been extensively studied; numerous studies have compared the gait parameters of persons with PD with healthy controls; however, the relationship between isokinetic strength parameters and spatiotemporal parameters of gait in PD has not been extensively studied. Inkster et al [2] observed that the mean hip and knee extensor torques were lower in persons with PD. Greater hip strength was related to better sit-

Conflict of interests:
The authors declare no conflicts of interest.

How to cite this article:
Fernández-Vázquez D, Molina-Rueda F, Navarro-López V, Straudi S, Cano-de-la-Cuerda R. Muscle strength and spatiotemporal gait parameters in patients with Parkinson´s disease. A pilot study. Rev Neurol 2023; 77: 115-24. doi: 10.33588/rn.7705.2023098..

Versión española disponible en www.neurologia.com

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to-stand ability in persons with PD, whereas greater knee strength was related to better sit-to-stand ability in controls. Only one previous study [7] has studied the relationship between isokinetic muscle strength in persons with PD and gait parameters, but only for the ankle dorsiflexors. Pedersen et al [8] studied gait and isometric and eccentric strength in persons with PD compared with age-matched control subjects. In persons with PD, the mean concentric torque was significantly decreased, and they walked with significantly slower speed. However, isokinetic movements and velocities at other joints have not been evaluated in persons with PD, nor have persons with moderate PD been evaluated, which justifies the relevance of this pilot study. The purpose of this pilot study was to analyze the correlation between isokinetic knee and ankle muscle strength and spatiotemporal parameters of gait in persons with PD. In addition, force production was compared with age- and sex-matched healthy controls. We hypothesized that persons with PD show lower limb muscle strength compared to healthy subjects and that this muscle strength is related to major spatiotemporal parameters of gait in persons with PD.

Subjects and methods

Design

A pilot study was conducted at the Rey Juan Carlos University (Madrid, Spain) with outpatient PD patients with Hoehn and Yahr (H&Y) stage between II and III and age- and sex- matched healthy controls. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement guidelines were followed.

The study was conducted in accordance with the national and international ethics standards. Ethical approval was granted by the Local Ethics Committee. Informed consent was given in writing by all participants before inclusion in the study, and all procedures were conducted according to the Declaration of Helsinki.

Participants

Individuals with diagnosis of PD according to the United Kingdom PD Society Brain Bank Research Center criteria [9] were recruited from the Parkinson Association APARKAN (Madrid, Spain). Non-probabilistic sampling of non-consecutive cases was performed for the PD group. In addition, age- and sex- matched healthy controls were also recruited by local announcements. The severity of PD was assessed in the ON period with the Hoehn and Yahr (H&Y) stage [10]. Persons with H&Y stages II–III were included, all persons with PD were able to walk independently without technical aids and all were stable on anti-Parkinsonian medication.

Exclusion criteria included any known neurological disease, diabetes mellitus, renal disease, cancer, any chronic or acute pain condition, and any severe psychiatric disease. Persons scoring < 24 points on the Mini-mental test [11] or >13 points on the Beck Depression Inventory (BDI) [12], and intervened by deep brain stimulation, continuous duodenal infusion of levodopa/carbidopa or continuous subcutaneous infusion of apo-morphine were excluded. None of the subjects had undergone orthopedic surgery or arthritic diseases on the trunk and lower extremities, and all were free of knee and ankle pain at the time of testing and during the previous 12 months. No subjects were included in the present study that were taking any psychotropic or antidepressant medication.

Procedure

The sample was divided into two groups: persons with PD determined by a neurologist expert on movement disorders and age- and sex- matched healthy control group.

Measures

Isokinetic testing

Concentric muscle strength of the knee and ankle was measured with a Biodex Multi-Joint System II isokinetic dynamometer and Biodex advantage software, version 4.0. All subjects were allowed to familiarize themselves with the equipment prior to testing. To account for the influence of torque (newton-meters) due to the effect of gravity on the data, each subject's lower extremity was weighed. The warm-up period consisted of three to five submaximal concentric contractions with the same speed settings used in the tests. Isokinetic knee extension and flexion torques were measured seated and with the hip flexed at 90°, with resistance placed proximal to the upper edge of the medial malleolus. The subject's thigh, trunk, and pelvis were stabilized with straps, and subjects held onto handles located on both sides of the seat throughout the test. The test was initiated in available full knee flexion. To assess the isokinetic pairs of plantar and dorsiflexion, the test was performed in supine with the knees fully extended. Proximal stabilization of the thigh and trunk was provided. Subjects were instructed to maintain full knee extension throughout the movement. The test was initiated with subjects in maximum available dorsiflexion.

Knee muscle strength was measured at a rate of 60°/s and 180°/s with ROM tested from 0° to 100° of flexion. Ankle muscle strength was measured at a rate of 60º/s and 180º/s with a ROM tested from 15º (extension) to 60º (flexion). Each subject performed ten maximal concentric contractions of the knee and 10 of the ankle, with a 30-second rest interval between the two evaluation speeds. The isokinetic measures used were: peak torque (PT)/body wear, total work (TW)/body wear. All tests were performed with both hemi-body and in the 'on' phase of medication.

Spatiotemporal parameters of gait

A 10-m walking test (10MW) at a comfortable and fast walking speed was performed on all subjects to obtain the main spatiotemporal parameters of gait [13]. The start of the 10-m walk was marked with a tape line on the ground. Participants were instructed to walk at a speed they were comfortable with and to continue down the corridor until instructed to stop. The command to stop was given approximately 5m after the finish line to avoid deceleration. A vertical line attached to the adjacent wall demarcated the finish line, as a line on the ground might have encouraged them to alter their speed. The evaluator counted the number of steps and calculated stride length (10m/number of strides), walking speed (10m/time taken) and cadence –(number of steps during the test x 60 seconds)/test time– for both speeds. This test has demonstrated excellent reliability for comfortable and fast speed in persons with PD [13-16] and has been recommended by the European Physical Therapy Guideline for PD.

Statistical analyses

Statistical analysis was performed with the SPSS statistical program (version 27.0). The Shapiro-Wilk test was used to examine the normality of the distribution of the sample data. Data on demographic variables were expressed as median and interquartile range, and as proportions, when appropriate. A nonparametric test (U-Mann Whitney) was performed to compare gait characteristics and isokinetic strength parameters of subjects with PD and healthy controls. As persons with PD with bilateral involvement were included, gait parameters and isokinetic strength were compared between the more affected leg of persons with PD, with the dominant leg of healthy controls, and the more affected leg of persons with PD, with the less dominant leg of healthy controls. A Spearman correlation analysis with 95% confidence intervals was performed to assess the correlation between variables related to gait parameters at preferred and maximum possible speed (speed, cadence, stride length, stride velocity) and isokinetic strength variables. Correlation coefficients of 0.00-0.30 were interpreted as poor, those of 0.30 to 0.70 as moderate, and those of 0.70 or more as excellent [17]. The significance level was set at 0.05.

Results

A total of 10 persons with PD and 10 healthy controls were initially recruited. Finally, 7 persons with PD (3 with H&Y II and four with H&Y III) and 7 healthy controls were included. The causes of dropouts were changes in the health status of the participants, not meeting any of the inclusion criteria at the time of assessment, and death. Sociodemographic information and gait spatiotemporal parameters data for persons with PD and healthy controls are showed in table I and table II. All persons completed the protocol safely, with the isokinetic dynamometer system being easily understood by all participants.

Relatioship between isokinetic strength and gait parameters in persons with PD

The correlations found for both lower limbs were between the ankle plantar flexion work/body wearing at 180º/s with number of steps (indirect) and stride (direct) at both self-selected and maximum speed, and between the ankle plantar flexion peak torque/ body wearing at 180º/s with number of steps (indirect) and stride (direct) at maximum speed; and between knee extension work/body wearing at 60º/s with stride (direct) at self-selected speed (Table III and Table IV).

The more affected lower limb showed correlations between ankle plantar flexion peak torque/ body wearing at 180º/s with number of steps (indirect) and stride (direct) at self-selected speed; between knee flexion work/body wearing at 180º/s) with time (in-direct) and velocity (directly) at maximum speed; and between knee extension work/ body wearing at 60º/s with number of steps (indirect) at maximum speed (Table III).

Table I. Demographic data for persons with PD and healthy controls.

	PD (*n* = 7)	Healthy Controls (*n* = 7)
Age Mean SD	61.4 ± 7.64	60.5 ± 6.11
Sex (male/female)	4/3	3/4
Height (cm) Mean SD	158 ± 5	165 ± 14
Mass (kg) Mean SD	72.38 ± 10.5	74.66 ± 13.75
Level of Education (no studies/primary education/ secondary education)	0/5/2	4/2/1
Years Since Diagnosis Mean SD	3.5 ± 2.06	
Affected side (unilateral/bilateral)	0/7	
More affected side (right/left)	5/2	
Medication PD (no/yes)	0/7	
Tremor (no/yes)	1/6	
Bradykinesia (no/yes)	0/7	
Rigidity (no/yes)	2/5	
Postural Instability (no/yes)	1/6	
Pain (no/yes)	3/4	
MMSE (dementia/cognitive impairment/no dementia)	2/1/4	
H&Y median (range)	2.5 (2-3)	
H&Y n (I/II/III/IV/V)	0/3/4/0/0	
S&E median (range)	10 (9-10)	

H&Y: Hoehn and Yahr scale; MMSE: Mini-Mental State Examination; PD: Parkinson's disease; S&E: Schwab and England Activities of Daily Living Scale.

Regarding less affected lower limb we obtained correlations between ankle plantar flexion work/body wearing at 60°/s with number of steps (indirect) and with stride directly at maximum speed; between knee flexion peak torque/body wearing at 60°/s with time (indirect) and velocity (direct) at both self-selected speed and maximum speed; between knee extension peak torque/body wearing at 60°/s with stride (direct) at maximum speed; between knee flexion work/body wearing at 60°/s with time (indirect) and with velocity (direct) at both self-selected speed and maximum speed; and between knee flexion peak torque/body wearing at 180°/s) with time (indirect) and with velocity (direct) at maximum speed (Table IV).

Comparison of isokinetic strength between persons with PD and healthy controls

Differences were observed in all spatiotemporal gait parameters both at self-selected speed and at maximum speed, except for cadence (Table II) between persons with PD and healthy controls. All the isokinetic values had significant differences between healthy subjects and persons with PD except for the knee flexion and extension peak torque (180°/s) and the ankle plantar flexion peak torque (60°/s). The knee flexion and extension peak torque (60°/s) are different only between the more affected lower limb and the non-dominant lower limb (Table V).

Discussion

A pilot study was conducted to analyze the correlation between the isokinetic knee and ankle muscle strength and the gait parameters in persons with PD (II-III H&Y). Our protocol was carried out safely, being able to evaluate muscle strength and spatio-temporal gait parameters. Significant differences in lower limb strength-related measures and gait parameters at self-selected speed and at maximum speed were observed between persons with PD and age-matched healthy controls. The lower isokinetic muscle strength observed in persons with PD compared to healthy controls showed strong correlations with the gait parameters evaluated in the present pilot study, being consistent with different findings that relate in PD, decreased strength with worse gait performance [15,16].

Correlations were found for both lower limbs between the ankle plantar flexion work/body wearing at 180°/s with number of steps and stride at both self-selected and maximum speed, between the ankle plantar flexion peak torque/ body wearing at 180°/s with number of steps and stride at maximum speed; and between knee extension work/body wearing at 60°/s with stride at self-selected speed in persons with PD. Also, an indirect correlation was observed between peak torque/ body wearing of plantar flexors on the more affected side in PD and spatiotemporal gait parameters. Ankle plantar-flexor muscles generate forward acceleration during the pre-swing phase of gait [18], so low plantar-flexor strength can be related to a shorter stride length in persons with PD. In relation to this finding, Keloth et al [19] reported that per-

Table II. Gait parameters for persons with PD and healthy controls.

	PD (n = 7)	Healthy controls (n = 7)	p
Time Self-Selected Speed median (IR)	7.71 (2.07)	5.9 (2.09)	0.002[a]
Steps Self-Selected Speed median (IR)	7.5 (2)	6 (1)	0.002[a]
Velocity Self-Selected Speed median (IR)	1.29 (0.3)	1.69 (0.64)	0.003[a]
Cadence Self-Selected Speed median (IR)	57.93 (8.16)	60.58 (7.35)	0.085
Stride Self-Selected Speed median (IR)	2.66 (0.7)	3.32 (0.78)	0.004[a]
Time Max Speed median (IR)	6.25 (1.37)	3.75 (1.63)	0.013[a]
Steps Max Speed median (IR)	6.5 (1.7)	4.5 (1)	0.005[a]
Velocity Max Speed median (IR)	1.6 (0.41)	2.66 (0.87)	0.015[a]
Cadence Max Speed median (IR)	67.71 (17.43)	73.77 (14.98)	0.142

PD: Parkinson's disease; IR: Interquartile Range. [a] Statistical significance <0.05.

sons with PD have lower gastrocnemius muscle activity during the stance phase of walking [18], and Shearin et al [20,21] showed that persons with PD with moderate impairment (stage of 2.5 H&Y) have significant modifications in step length and showed plantar-flexor weakness with lower gait velocity in both the on and off states [22].

In our study, persons with PD presented strong correlations between knee flexion muscle work/ body wearing and spatiotemporal gait parameters. Knee loading during the initial phase of gait is primarily caused by quadriceps muscle strength [19]. In the knee joint, a 'typical' moment pattern in the sagittal plane during the loading phase of gait comprises the internal knee extensor moment driven by eccentric contraction of the quadriceps muscle [23]. Consistently, lower extensor force generated by the quadriceps in persons with PD may directly affect the spatiotemporal gait parameters. This relationship, which has also been observed in this study, is supported by several authors, who have described similar correlations with functional ambulation [24], balance [25], or the ability to get up from a chair [2].

Previously, decreased quadriceps strength had been observed in PD [26], observed even in early stages, both on the affected and unaffected side, worsening with disease progression [27,28], correlating negatively with H&Y stage [24]. In addition, Allen et al [29] observed that persons with PD showed decreased leg extensor strength, which was associated with slower walking speed and increased risk of falls. These strength deficits and lower muscle activation correlated strongly with the UPDRS motor score [30]. Although isokinetic muscle strength is likely to be dependent on the speed of movement, as the disease progresses it may be influenced by bradykinesia [31] and therefore the speed-strength correlation observed in these individuals may provide clues to understanding the pathophysiology of this symptom. The speed dependence of weakness may represent bradykinesia itself, as demonstrated by Hallet and Khoshbin [32] in stating that bradykinesia is the inability to produce sufficient 'force' to generate the necessary speed. Throughout joint ROM in healthy subjects, muscle torque decreases as isokinetic velocity increases, however, in persons with PD, muscle weakness increases with gait speed, especially as the disease progresses [33], being a distinct manifestation of the disease itself [1].

The specific cause of muscle weakness in PD is unknown. It is debated whether its origin lies in the central or peripheral nervous system, or whether it is a secondary phenomenon [2]. The reduced force pro-duction may be due to reduced cortical activation of the muscles produced by the dopaminergic deficit in the nigrostriatal pathway, resulting in increased tonic inhibition of the thalamus [28,34].

Table III. Correlations for the more affected lower limb in persons with Parkinson's disease.

		Time self-selected speed			Steps self-selected speed			Velocity self-selected speed			Stride self-selected speed		
Knee		rho	CI	*p*	rho	CI	*p*	rho	CI	*p*	rho	CI	*p*
PT/BW 60°/s	Flexion	−0.536	−0.918; 0.364	0.215	0.036	−0.737; 0.768	0.938	0.536	−0.364; 0.918	0.215	−0.143	−0.809; 0.684	0.76
	Extension	−0.643	−0.941; 0.213	0.119	−0.346	−0.872; 0.55	0.448	0.643	−0.213; 0.941	0.119	0.286	−0.595; 0.855	0.535
Work/BW 60°/s	Flexion	−0.679	−0.948; 0.152	0.094	−0.346	−0.872; 0.55	0.448	0.679	−0.152; 0.948	0.094	0.25	−0.62; 0.844	0.589
	Extension	−0.607	−0.933; 0.269	0.148	−0.655	−0.943; 0.194	0.111	0.607	−0.269; 0.933	0.148	0.643	−0.213; 0.941	0.119
PT/BW 180°/s	Flexion	−0.286	−0.855; 0.595	0.535	0.364	−0.536; 0.877	0.423	0.286	−0.595; 0.855	0.535	−0.429	−0.893; 0.479	0.337
	Extension	−0.286	−0.855; 0.595	0.535	0.182	−0.662; 0.822	0.696	0.286	−0.595; 0.855	0.535	−0.214	−0.833; 0.643	0.645
Work/BW 180°/s	Flexion	−0.429	−0.893; 0.479	0.337	0.255	−0.616; 0.846	0.582	0.429	−0.479; 0.893	0.337	−0.357	−0.875; 0.542	0.432
	Extension	−0.357	−0.875; 0.542	0.432	−0.145	−0.81; 0.683	0.756	0.357	−0.542; 0.875	0.432	0.143	−0.684; 0.809	0.76
Ankle													
PT/BW 60°/s	Plantar Flexion	−0.464	−0.902; 0.444	0.294	−0.546	−0.921; 0.352	0.205	0.464	−0.444; 0.902	0.294	0.536	−0.364; 0.918	0.215
	Dorsal Flexion	−0.464	−0.902; 0.444	0.294	−0.145	−0.81; 0.683	0.756	0.464	−0.444; 0.902	0.294	0.036	−0.737; 0.768	0.939
Work/BW 60°/s	Plantar Flexion	−0.143	−0.809; 0.684	0.76	−0.509	−0.912; 0.396	0.243	0.143	−0.684; 0.809	0.76	0.571	−0.319; 0.926	0.18
	Dorsal Flexion	−0.036	−0.768; 0.737	0.939	0.291	−0.592; 0.856	0.527	0.036	−0.737; 0.768	0.939	−0.357	−0.875; 0.542	0.432
PT/BW 180°/s	Plantar Flexion	−0.487	−0.907; 0.42	0.268	−0.917[a]	−0.988; −0.53	0.004	0.487	−0.42; 0.907	0.268	0.955[a]	0.719; 0.994	0.001
	Dorsal Flexion	−0.536	−0.918; 0.364	0.215	−0.473	−0.904; 0.435	0.284	0.536	−0.364; 0.918	0.215	0.393	−0.511; 0.884	0.383
Work/BW 180°/s	Plantar Flexion	−0.487	−0.907; 0.420	0.268	−0.917[a]	−0.988; −0.53	0.004	0.487	−0.42; 0.907	0.268	0.955[a]	0.719; 0.994	0.001
	Dorsal Flexion	−0.357	−0.875; 0.542	0.432	−0.2	−0.828; 0.651	0.667	0.357	−0.542; 0.875	0.432	0.143	−0.684; 0.809	0.76
		Time Max speed			Steps Max speed			Velocity Max speed			Stride Max speed		
Knee		rho	CI	*p*	rho	CI	*p*	rho	CI	*p*	rho	CI	*p*
PT/BW 60°/s	Flexion	−0.714	−0.954; 0.084	0.071	−0.037	−0.769; 0.737	0.938	0.714	−0.084; 0.954	0.071	0.162	−0.673; 0.816	0.728
	Extension	−0.536	−0.918; 0.364	0.215	−0.441	−0.896; 0.467	0.323	0.536	−0.364; 0.918	0.215	0.505	−0.4; 0.911	0.248
Work/BW 60°/s	Flexion	−0.643	−0.941; 0.213	0.119	−0.477	−0.905; 0.431	0.279	0.643	−0.213; 0.941	0.119	0.577	−0.311; 0.927	0.175
	Extension	−0.357	−0.875; 0.542	0.432	−0.826[a]	−0.974; −0.193	0.022	0.357	−0.542; 0.875	0.432	0.847[a]	0.259; 0.977	0.016
PT/BW 180°/s	Flexion	−0.714	−0.954; 0.084	0.071	0.165	−0.671; 0.817	0.723	0.714	−0.084; 0.954	0.071	−0.018	−0.761; 0.745	0.969
	Extension	−0.5	−0.91; 0.406	0.253	0	−0.753; 0.753	1	0.5	−0.406; 0.91	0.253	0.09	−0.711; 0.79	0.848
Work/BW 180°/s	Flexion	−0.857a	−0.979; −0.293	0.014	0.018	−0.745; 0.761	0.969	0.857[a]	0.293; 0.979	0.014	0.162	−0.673; 0.816	0.728
	Extension	−0.357	−0.875; 0.542	0.432	−0.367	−0.878; 0.534	0.418	0.357	−0.542; 0.875	0.432	0.414	−0.493; 0.89	0.355
Ankle													
PT/BW 60°/s	Plantar Flexion	−0.321	−0.865; 0.57	0.482	−0.551	−0.922; 0.345	0.2	0.321	−0.57; 0.865	0.482	0.559	−0.335; 0.923	0.192
	Dorsal Flexion	−0.393	−0.884; 0.511	0.383	−0.128	−0.804; 0.692	0.784	0.393	−0.511; 0.884	0.383	0.198	−0.652; 0.828	0.67
Work/BW 60°/s	Plantar Flexion	−0.071	−0.782; 0.721	0.879	−0.753	−0.961; 0.001	0.051	0.071	−0.721; 0.782	0.879	0.739	−0.032; 0.959	0.058
	Dorsal Flexion	−0.357	−0.875; 0.542	0.432	0.092	−0.71; 0.79	0.845	0.357	−0.542; 0.875	0.432	0.018	−0.745; 0.761	0.969
PT/BW 180°/s	Plantar Flexion	−0.054	−0.776; 0.729	0.908	−0.982[a]	−0.997; −0.879	<0.001	0.054	−0.729; 0.776	0.908	0.927[a]	0.576; 0.989	0.003
	Dorsal Flexion	−0.393	−0.884; 0.511	0.383	−0.459	−0.901; 0.449	0.300	0.393	−0.511; 0.884	0.383	0.505	−0.4; 0.911	0.248
Work/BW 180°/s	Plantar Flexion	−0.054	−0.776; 0.729	0.908	−0.982[a]	−0.997; −0.879	<0.001	0.054	−0.729; 0.776	0.908	0.927[a]	0.576; 0.989	0.003
	Dorsal Flexion	−0.536	−0.918; 0.364	0.215	−0.404	−0.887; 0.502	0.369	0.536	−0.364; 0.918	0.215	0.505	−0.4; 0.911	0.248

The table shows the correlation between gait parameters at self-selected speed and maximum speed, and isokinetic measurements for the most affected lower extremity in patients with PD. PT/BW: peak torque/body wearing, for 60° and 180°. [a] Statistical significance <0.05.

Table IV. Correlation for the less affected lower limb in persons with Parkinson's disease.

		Time self-selected speed			Steps self-selected speed			Velocity self-selected speed			Stride self-selected speed		
Knee		rho	CI	*p*	rho	CI	*p*	rho	CI	*p*	rho	CI	*p*
PT/BW 60°/s	Flexion	−0.786[a]	−0.967; −0.081	0.036	−0.2	−0.828; 0.651	0.667	0.786[a]	0.081; 0.967	0.036	0.071	−0.721; 0.782	0.879
	Extension	−0.75	−0.961; 0.007	0.052	−0.655	−0.943; 0.194	0.111	0.75	−0.007; 0.961	0.052	0.571	−0.319; 0.926	0.18
Work/BW 60°/s	Flexion	−0.893[a]	−0.984; −0.427	0.007	−0.309	−0.862; 0.579	0.5	0.893[a]	0.427; 0.984	0.007	0.143	−0.684; 0.809	0.76
	Extension	−0.75	−0.961; 0.007	0.052	−0.655	−0.943; 0.194	0.111	0.75	−0.007; 0.961	0.052	0.571	−0.319; 0.926	0.18
PT/BW 180°/s	Flexion	−0.714	−0.954; 0.084	0.071	−0.236	−0.84; 0.629	0.61	0.714	−0.084; 0.954	0.071	0.107	−0.703; 0.796	0.819
	Extension	−0.429	−0.893; 0.479	0.337	−0.273	−0.851; 0.604	0.554	0.429	−0.479; 0.893	0.337	0.214	−0.643; 0.833	0.645
Work/BW 180°/s	Flexion	−0.607	−0.933; 0.269	0.148	−0.255	−0.846; 0.616	0.582	0.607	−0.269; 0.933	0.148	0.143	−0.684; 0.809	0.76
	Extension	−0.464	−0.902; 0.444	0.294	−0.436	−0.895; 0.472	0.328	0.464	−0.444; 0.902	0.294	0.393	−0.511; 0.884	0.383
Ankle													
PT/BW 60°/s	Plantar Flexion	0.107	−0.703; 0.796	0.819	−0.236	−0.84; 0.629	0.61	−0.107	−0.796; 0.703	0.819	0.357	−0.542; 0.875	0.432
	Dorsal Flexion	−0.5	−0.91; 0.406	0.253	−0.073	−0.783; 0.72	0.877	0.5	−0.406; 0.91	0.253	−0.036	−0.768; 0.737	0.939
Work/BW 60°/s	Plantar Flexion	−0.25	−0.844; 0.62	0.589	−0.618	−0.936; 0.253	0.139	0.25	−0.62; 0.844	0.589	0.679	−0.152; 0.948	0.094
	Dorsal Flexion	−0.143	−0.809; 0.684	0.76	−0.309	−0.862; 0.579	0.5	0.143	−0.684; 0.809	0.76	0.321	−0.57; 0.865	0.482
PT/BW 180°/s	Plantar Flexion	−0.631	−0.938; 0.233	0.129	−0.752	−0.961; 0.002	0.051	0.631	−0.233; 0.938	0.129	0.739	−0.032; 0.959	0.058
	Dorsal Flexion	−0.714	−0.954; 0.084	0.071	−0.618	−0.936; 0.253	0.139	0.714	−0.084; 0.954	0.071	0.5	−0.406; 0.91	0.253
Work/BW 180°/s	Plantar Flexion	−0.559	−0.923; 0.335	0.192	−0.807[a]	−0.97; −0.138	0.028	0.559	−0.335; 0.923	0.192	0.811[a]	0.149; 0.971	0.027
	Dorsal Flexion	−0.393	−0.884; 0.511	0.383	−0.455	−0.9; 0.453	0.305	0.393	−0.511; 0.884	0.383	0.429	−0.479; 0.893	0.337
		Time Max speed			Steps Max speed			Velocity Max speed			Stride Max speed		
Knee		rho	CI	*p*	rho	CI	*p*	rho	CI	*p*	rho	CI	*p*
PT/BW 60°/s	Flexion	−0.893[a]	−0.984; −0.427	0.007	−0.22	−0.835; 0.639	0.635	0.893[a]	0.427; 0.984	0.007	0.36	−0.539; 0.876	0.427
	Extension	−0.643	−0.941; 0.213	0.119	−0.698	−0.951; 0.116	0.081	0.643	−0.213; 0.941	0.119	0.775a	0.053; 0.965	0.041
Work/BW 60°/s	Flexion	−0.893[a]	−0.984; −0.427	0.007	−0.239	−0.841; 0.627	0.606	0.893[a]	0.427; 0.984	0.007	0.378	−0.524; 0.88	0.403
	Extension	−0.643	−0.941; 0.213	0.119	−0.698	−0.951; 0.116	0.081	0.643	−0.213; 0.941	0.119	0.775[a]	0.053; 0.965	0.041
PT/BW 180°/s	Flexion	−0.857[a]	−0.979; −0.293	0.014	−0.257	−0.846; 0.615	0.578	0.857[a]	0.293; 0.979	0.014	0.396	−0.509; 0.885	0.379
	Extension	−0.607	−0.933; 0.269	0.148	−0.404	−0.887; 0.502	0.369	0.607	−0.269; 0.933	0.148	0.505	−0.4; 0.911	0.248
Work/BW 180°/s	Flexion	−0.714	−0.954; 0.084	0.071	−0.33	−0.867; 0.563	0.469	0.714	−0.084; 0.954	0.071	0.45	−0.458; 0.899	0.31
	Extension	−0.536	−0.918; 0.364	0.215	−0.587	−0.929; 0.298	0.166	0.536	−0.364; 0.918	0.215	0.667	−0.173; 0.945	0.102
Ankle													
PT/BW 60°/s	Plantar Flexion	0.036	−0.737; 0.768	0.939	−0.532	−0.917; 0.369	0.219	−0.036	−0.768; 0.737	0.939	0.505	−0.4; 0.911	0.248
	Dorsal Flexion	−0.679	−0.948; 0.152	0.094	−0.257	−0.846; 0.615	0.578	0.679	−0.152; 0.948	0.094	0.396	−0.509; 0.885	0.379
Work/BW 60°/s	Plantar Flexion	−0.107	−0.796; 0.703	0.819	−0.863[a]	−0.979; −0.314	0.012	0.107	−0.703; 0.796	0.819	0.847[a]	0.259; 0.977	0.016
	Dorsal Flexion	−0.143	−0.809; 0.684	0.76	−0.514	−0.913; 0.39	0.238	0.143	−0.68; 0.809	0.76	0.541	−0.358; 0.919	0.21
PT/BW 180°/s	Plantar Flexion	−0.45	−0.899; 0.458	0.31	−0.926[a]	−0.989; −0.571	0.003	0.45	−0.458; 0.899	0.31	0.964[a]	0.770; 0.995	<0.001
	Dorsal Flexion	−0.5	−0.91; 0.406	0.253	−0.532	−0.917; 0.369	0.219	0.5	−0.406; 0.91	0.253	0.595	−0.286; 0.931	0.159
Work/BW 180°/s	Plantar Flexion	−0.27	−0.85; 0.606	0.558	−0.926[a]	−0.989; −0.571	0.003	0.27	−0.606; 0.85	0.558	0.927[a]	0.576; 0.989	0.003
	Dorsal Flexion	−0.393	−0.884; 0.511	0.383	−0.642	−0.940; 0.215	0.12	0.393	−0.511; 0.884	0.383	0.703	−0.106; 0.952	0.078

The table shows the correlation between gait parameters at self-selected speed and maximum speed, and isokinetic measurements for the most affected lower extremity in patients with PD. PT/BW: peak torque/body wearing, for 60º and 180º. [a] Statistical significance <0.05.

Table V. Isokinetic strength data of persons with PD and healthy controls.

		PD More Affected LL	Healthy non-dominant LL	p	PD less affected LL	Healthy dominant LL	p
	Knee	Median (IR)			Median (IR)		
PT/BW 60°/s	Flexion	50.8 (15.4)	83.4 (22.1)	0.073	47 (28.8)	82 (33)	0.018[a]
	Extension	110 (38.1)	153.7 (69.8)	0.064	86.7 (53.9)	165.3 (46.8)	0.025[a]
Work/BW 60°/s	Flexion	42.4 (22.3)	101.2 (38.6)	0.048[a]	40.1 (38.4)	91.2 (39.6)	0.025[a]
	Extension	114.1 (49.2)	170.5 (76.8)	0.048[a]	98.1 (73.2)	178.5 (52.2)	0.018[a]
PT/BW 180°/s	Flexion	37.2 (23.7)	61 (40.8)	0.11	31.3 (20)	64.3 (49)	0.064
	Extension	65.3 (25.6)	98.5 (78.5)	0.064	69 (33)	103.5 (83.7)	0.064
Work/BW 180°/s	Flexion	32.4 (15.6)	75.3 (52.9)	0.048[a]	27.3 (32.1)	70 (71.1)	0.048[a]
	Extension	63 (23.9)	118 (82.2)	0.048[a]	79.8 (40.8)	120 (25.1)	0.048[a]
	Ankle						
PT/BW 60°/s	Plantar flexion	19.5 (12.1)	23.6 (22.1)	0.11	22 (11.2)	27 (20.9)	0.142
	Dorsal flexion	22 (20.6)	68.5 (70)	0.018[a]	30.1 (10.8)	59.6 (22.6)	0.002[a]
Work/BW 60°/s	Plantar flexion	7.7 (6.1)	10.1 (12.8)	0.035[a]	8 (8.1)	14 (11.1)	0.047[a]
	Dorsal flexion	7.4 (7.1)	25.4 (35.3)	0.025[a]	10.1 (3.6)	25.5 (23.7)	0.018[a]
PT/BW 180°/s	Plantar flexion	13.2 (20)	26.6 (7.7)	0.006[a]	15.8 (24.8)	26.7 (13.2)	0.015[a]
	Dorsal flexion	12.7 (6.4)	47.4 (53)	0.002[a]	20 (16.8)	48.8 (44.6)	0.002[a]
Work/BW 180°/s	Plantar flexion	5 (7.9)	12.4 (5.4)	0.005[a]	5.3 (10.5)	11.8 (6.3)	0.018[a]
	Dorsal flexion	3.1 (2.3)	23.7 (25.8)	0.004[a]	5.7 (7.2)	15.2 (31.3)	0.009[a]

IR: Interquartile range; LL: Lower Limb; PD: Parkinson's disease; PT/BW: Peak Torque/body wearing. [a] Statistical significance <0.05.

These findings show the relevance of early rehabilitation treatment in PD, starting in the early stages of the disease, when motor symptoms are mild. To prevent deficiencies in advanced stages, rehabilitation therapy should be started even before motor symptoms limit the subject's independence [35,36]. In this regard, several studies have shown how an exercise program focused on improving lower limbs strength might ameliorate the motor impairments associated with PD [37], improving symptoms such as gait, balance, or the risk of falls, which are related to the independence and quality of life of these persons [38].

The present pilot study was limited by the small sample size. Our results cannot be extrapolated to other stages of PD, as persons with PD included were between II-III H&Y stages, or during the 'off' phase of the medication cycle, since all persons with PD were evaluated in the 'on' phase of medication. Future studies should include PD-related assessment (i.e., UPDRS) for a better understanding of the motor impairment (UPDRS III) of the persons with PD. Gait was evaluated using the 10MWT, which although a valid test, the use of instrumental systems such as three-dimensional gait analysis is a more objective system and can provide kinetic and kinematic data.

Conclusions

Our results showed correlations between both lower limbs muscle isokinetic strength and spatio-temporal gait parameters in persons with PD and II-III H&Y stages, suggesting a possible rehabilitation target for functional objectives. In addition, our results showed significant differences in lower limbs strength-related measures and gait parameters at self-selected speed and at maximum speed between persons with PD and age-matched healthy controls.

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Fuerza muscular y parámetros espaciotemporales de la marcha en personas con enfermedad de Parkinson. Un estudio piloto

Introducción. La debilidad muscular en personas con enfermedad de Parkinson (EP) ha sido frecuentemente reconocida como un síntoma inespecífico. En otras patologías neurológicas, la debilidad de las extremidades inferiores, específicamente la debilidad de los cuádriceps, es el factor que causa mayor incapacidad para caminar. Pocas investigaciones han evaluado la relación entre la fuerza muscular de los miembros inferiores, utilizando herramientas objetivas en personas con EP y el desempeño de la marcha. El objetivo de este estudio fue analizar la correlación entre la fuerza muscular de los miembros inferiores, utilizando un dinamómetro isocinético, y los parámetros espaciotemporales de la marcha en la EP, en comparación con controles sanos emparejados por edad y sexo.

Sujetos y métodos. El estudio se llevó a cabo con siete personas con EP –Hoehn y Yahr (HY) entre II y III– y siete controles sanos. Se realizaron pruebas isocinéticas de rodilla y tobillo a 60 y 120°/s y la prueba de marcha de 10 metros, a velocidad de marcha cómoda y rápida, en todos los sujetos reclutados.

Resultados. Se observaron diferencias significativas en las medidas relacionadas con la fuerza de las extremidades inferiores y en los parámetros de la marcha entre las personas con EP y los controles. Los parámetros de la marcha mostraron excelentes correlaciones (rho ≥ 0,7) para ambas extremidades inferiores: trabajo de flexión plantar de tobillo/desgaste corporal a 180°/s con número de pasos (indirecto) y zancada (directa) a ambas velocidades, y entre pico de torsión de flexión plantar de tobillo/desgaste corporal a 180°/s con número de pasos (indirecto) y zancada (directa) a velocidad máxima; y entre trabajo de extensión de rodilla/desgaste corporal a 60°/s con zancada (directa) a velocidad autoseleccionada.

Conclusiones. La fuerza muscular de las extremidades inferiores de las personas con EP (estadios de HY II-III) se correlaciona excelentemente con el patrón de la marcha, mostrando una fuerza isocinética inferior a la de sujetos sanos de la misma edad y sexo. Este protocolo mostró seguridad para ser realizado en una muestra mayor.

Palabras clave. Análisis de la marcha. Enfermedad de Parkinson. Fuerza muscular. Parámetros de la marcha. Patología neurológica. Trastornos del movimiento.