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Research Article

Association between Parkinson's disease functional disability staging and gait kinematics parameters

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HIGHLIGHTS

- The assessment of functional decline in Parkinson disease is a routine in rehabilitation programs.
- Gait abnormalities may decline functional independence.
- There is an association between functional status decline and gait kinematics abnormalities.

ABBREVIATIONS

MDS-PD	Movement Disorder Society's Parkinson's Disease Diagnostic Criteria
MoCA	Montreal Cognitive Assessment
PD	Parkinson's disease
SPPB	Short Physical Performance Battery
TUG	Timed Up and Go
UPDRS	Unified Parkinson's Disease Rating Scale

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BACKGROUND: Parkinson's disease is one of the most common neurodegenerative diseases in the older adult's population. Clinical manifestations include motor and non-motor symptoms, which lead to functional loss and loss of independence.
AIM: To analyze the clarity between the functional staging of Parkinson's disease and gait kinematics in people with the disease.
METHODS: Fifteen (n=15) participants of both sexes participated in the study, 8 men and 7 women, with an average age of 74 years and a diagnosis of Parkinson's disease. Data collection was performed in a single visit to the collection environment. Functional status was assessed by the Unified Parkinson's Disease Rating Scale (UPDRS) and the Hoehn and Yahr Scale. Gait kinematics were recorded by an accelerometer fixed to the lateral malleolus. To collect the kinematic data, the participants walked on a 14-meter track at a self-selected gait speed.
RESULTS: Significant correlations were found between the Hoehn and Yahr stage and gait speed ($p < 0.001$; $r = -0.943$), stance time ($p < 0.001$; $r = 0.933$), cycle time ($p < 0.001$; $r = 0.966$), stance time variability ($p = 0.01$; $r = 0.785$), swing time variability ($p < 0.016$; $r = 0.766$) and cycle time variability ($p < 0.016$; $r = 0.761$).
INTERPRETATION: According to our results, a worse functional status is correlated with abnormalities in gait kinematics.

KEYWORDS: Shaking paralysis | Biomechanical phenomena | Gait analysis

INTRODUCTION

Parkinson's disease (PD) is a degenerative, idiopathic, chronic, and progressive neurological condition, classified as the second most prevalent neurodegenerative disorder among older adults. Its pathophysiology is characterized by the degeneration of dopaminergic neurons in the substantia nigra and alterations in the extrapyramidal system, which includes the basal ganglia and the thalamus, resulting in motor and non-motor symptoms that directly compromise functionality and quality of life [1-4]

Among the motor symptoms, tremor, rigidity, bradykinesia, akinesia, and biomechanical alterations of gait are frequently reported and are strongly associated with an increased risk of falls and loss of functional independence [2,5]. Furthermore, evidence shows that individuals with PD present joint rigidity, reduced trunk–hip mobility, and decreased activation of propulsive muscles, such as the gastrocnemius, which compromise both the efficiency and safety of locomotion [6,7].

The clinical progression of PD is usually monitored using scales such as the Hoehn and Yahr scale and the Unified Parkinson's Disease Rating Scale (UPDRS) [5,8]. These tools are widely applied and provide a global overview of disease severity, yet they have limitations in detecting specific and gradual changes in locomotor patterns. Gait kinematic analysis, on the other hand, allows for more objective and sensitive measurement of spatial and temporal parameters, such as reduced stride length and increased step frequency, thus accurately characterizing biomechanical modifications throughout disease progression [6,7-9].

In this context, the comparison between functional staging and gait kinematic parameters is justified as it enables a deeper understanding of how motor decline described by clinical scales is reflected in biomechanical gait alterations. This approach is relevant because it may provide objective evidence to complement traditional clinical assessments and support more targeted therapeutic

strategies. Therefore, the hypothesis of the present study is that individuals with higher functional staging of PD will present greater impairment in gait kinematic parameters, reflecting the progression of motor disability.

METHODS

Sample, eligibility criteria and ethics procedures

Fifteen older adults of both sexes participated in the study, all with a clinical diagnosis of Parkinson's disease. Diagnostic criteria were based on the Movement Disorder Society's Parkinson's Disease Diagnostic Criteria (MDS-PD), which require the mandatory presence of bradykinesia associated with either resting tremor or muscular rigidity[10].

Therefore, eligibility criteria include age 60 years or older; bradykinesia associated with resting tremor or muscle rigidity; no history of peripheral neuropathic diseases or other neurological disorders; no history of liver, kidney, respiratory, or cardiac disorders that could affect gait performance; ability to walk independently or with assistive devices; and normal vision or vision corrected with contact lenses[10,11]. Participants were recruited from a physical therapy facility. The sample size was determined using GPower 3.0 software (Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany) based on data from a pilot study. Gait speed was considered the primary outcome variable. The sample size calculation assumed an effect size of 0.9, a statistical power (1–β) of 0.8, and a significance level (α) of 0.05, using a two-tailed test. The procedure followed the guidelines for sample size estimation in GPower[12].

All the participants were oriented towards the study's procedures and after that they signed the informed consent form. Also, the study was approved by the local Ethics Committee, by Plataforma Brasil (process number: 2.107.552), with no conflict of interest and with its own financing.

Procedures

Data collection was performed at the physical therapy clinic of the Sagrado Coração University Center (UNISAGRADO), located in Bauru, São Paulo. A single visit to the data collection site was made. Participants initially completed a sample characterization form. Subsequently, a physical therapist performed the functional assessment, which included the following tests: UPDRS; Hoehn and Yahr scale; *Short Physical Performance Battery* (SPPB); and *Timed Up and Go* (TUG). A 3D accelerometer (Noraxon®, Arizona, USA) was fixed on the lateral malleolus of the dominant limb for kinematic data collection. Data from the accelerometer were sampled at a frequency of 120 Hz. Gait kinematics were analyzed in the dominant lower limb in order to standardize data collection across participants and reduce variability between measurements.

The UPDRS aims to assess the progression of Parkinson's disease and identify potential limitations and disabilities developed by the patient. It is divided into four sections: mental state, behavior, and mood; activities of daily living; motor examination; and therapy complications. The UPDRS consists of approximately 42 questions. The score for each item ranges from 0 to 4, with higher values indicating greater disease impairment and lower values indicating a greater tendency toward normality [13].

The Hoehn and Yahr scale aims to classify the staging of Parkinson's Disease simply through motor symptoms and disabilities. Subdivided into 7 stages, the modified scale qualifies mild disabilities in stages 1 to 3, and severe disabilities in stages 4 to 5 [7,8].

The Short Physical Performance Battery assesses lower limb function through three tasks: balance (feet together, semi-tandem, tandem), 4-meter gait speed, and the chair stand test performed five times. Each test is scored from 0 to 4 points based on performance; the scores are summed to a maximum of 12 points. Scores classify functional capacity as follows: 0–3 = disability, 4–6 = low, 7–9 = moderate, 10–12 = good [14].

The Timed Up and Go (TUG) test aims to assess mobility and balance. To perform the test, the patient must be seated and then stand up with their arms crossed in front of the body, walk three meters, turn around, return to the chair, and sit down again [15].

The assessment consists of recording the time, in seconds, taken to complete the task. The gait assessment was performed on a 14-meter-long walkway, where the strides taken in the first and last two meters were discarded for data analysis. The participants were instructed to walk at their preferred gait speed, and 50 strides were considered for analysis [16,17]. All tests were made during the T-off of the medication. The physical therapist who performed the assessments has several years of experience in neurological rehabilitation.

Data analysis and statistics

The accelerometry data were analyzed in a MATLAB (MathWorks, Natick, USA) environment to determine the phases of stance, swing, and stride. For the kinematic analysis, the following parameters were considered: walking speed, stance time, swing time, stride time, as well as the variability of these parameters.

Temporal kinematic parameters, including stance time, swing time, and stride time, were calculated for each stride. For statistical analyses, the mean values obtained across 50 strides were considered. Variability of temporal parameters was assessed using the standard deviation of the 50 strides [18]. The walking speed was calculated based on the distance covered and the time required to complete the trial.

The PASW 18.0 statistical package (SPSS Inc.) was used for statistical analysis. Means and standard deviations were presented as descriptive measures. The normality of the data was tested using the Shapiro-Wilk test. Pearson correlation coefficients

were calculated to verify associations between the scales and gait kinematics. The significance level was set at $p < 0.05$.

RESULTS

Fifteen older adults, eight men and seven women, aged 74.4 (8.33) years, who scored an average of 30 (16.49) points on the UPDRS, participated in the study. Table 1 presents the sample characteristics.

Table 1. Sample characterization

Variables	Mean (SD)
Age (years)	74.4 (8.33)
Mass (kg)	75.7 (12.17)
Height (m)	1.69 (0.1)
Body mass index ($kg.m^{-2}$)	26.51 (4.63)
Diagnosis time (years)	9.12 (6.53)
Stages in Hoehn e Yahr Scale	Stage 1 – n = 4 Stage 2 – n = 3 Stage 3 – n = 4 Stage 4 – n = 4
UPDRS Score (points)	30 (16.49)
Short Physical Performance Battery score (points)	7.88 (1.61)
Time to perform Timed Up and Go test (s)	21.49 (8.58)

Table 2 presents the kinematic gait parameters of the participants.

Table 2. Gait kinematic parameters.

Gait speed ($m{\cdot}s^{-1}$)	1.07 (0.19)
Stance time (s)	0.5 (0.07)
Swing time (s)	0.61 (0.02)
Stride time (s)	1.12 (0.06)
Stance time variability (s)	0.04 (0.09)
Stride time variability	0.02 (0.03)

Associations were found between Hoehn and Yahr score and gait speed ($p < 0.001$ and $r = -0.943$), stance time ($p < 0.001$ and $r = 0.933$), stride time ($p < 0.001$ and $r = 0.966$), variability of stance time ($p = 0.01$ and $r = 0.785$), and with the variability of stride time ($p < 0.016$ and $r = 0.761$). Table 3 presents the results. Table 3 presents the results.

Table 3. Correlations between Hoehn and Yahr scale and gait kinematic parameters.

	Disease staging according to Hoehn and Yahr Scale	
	p	r
Gait speed ($m{\cdot}s^{-1}$)	> 0.001	-0.943*
Stance time (s)	> 0.001	0.933*
Swing time (s)	0.76	-0.16
Stride time (s)	> 0.001	0.966*
Stance time variability (s)	0.016	0.785*
Stride time variability (s)	0.016	0.761*

* $p < 0.05$ means significant difference.

DISCUSSION

The present study aimed to analyze the correlation between the staging of Parkinson's disease and gait kinematic parameters in older adults with the condition. According to our results, more advanced stages of Parkinson's disease were associated with reduced gait speed, longer stance and swing times, and greater variability of temporal gait parameters. These associations suggest that disease progression may be linked to alterations in motor control, which in turn contribute to modifications in gait and reduced mechanical efficiency of locomotion. However, it is important to note that correlation does not imply causation, and our findings should be interpreted within the limitations of the study design and sample size.

Previous studies have reported that individuals with Parkinson's disease exhibit reduced muscle activation and weakness in stabilizing and propulsive muscles, such as the gluteus medius, soleus, gastrocnemius, and tibialis anterior, when compared with healthy controls [6]. These deficits may contribute to compromised temporal and spatial gait variables, postural imbalance, and bradykinesia, which can manifest as gait phenomena such as festination and freezing [6,19]. Impaired activation of propulsion muscles, including the gastrocnemius, has also been linked to slower gait speed [6,19]. Similarly, an increase in stance time has been associated with greater energy expenditure and an elevated risk of falls [6,20]. Our results are consistent with these reports, indicating that advanced stages of Parkinson's disease may be associated with motor impairments that influence gait kinematics.

Motor control deficits in Parkinson's disease have been closely related to altered gait kinematics [21-23]. Weakness in stabilizing and propulsive muscles reduces the ability to maintain the center of mass within the base of support, increasing step variability and instability [22,20]. These motor impairments reflect not only neurological deficits but also musculoskeletal adaptations that interfere with gait patterns. In advanced stages of the disease, executive function decline has been shown to exacerbate variability in gait parameters, further contributing to irregularity and instability [20,22-24]. Cognitive assessments such as the Montreal Cognitive Assessment (MoCA) provide additional evidence that reduced executive function is associated with slower gait speed and increased variability, reinforcing the link between cognitive decline, instability, and fall risk [24].

Although scales such as the UPDRS and Hoehn & Yahr staging are valuable for assessing disease severity, they were not directly analyzed in relation to gait parameters in this study. Therefore, associations with these scales should be interpreted cautiously and limited to the available data. Future studies should combine clinical motor scales with objective gait measures to provide a more comprehensive understanding of disease progression.

This study also presents limitations, including the absence of joint angular kinematics and kinetic data, which could have provided additional insights into compensatory patterns and locomotor dynamics in Parkinson's disease. Additionally, gait analysis was performed only on the dominant lower limb, which may not fully capture the asymmetrical characteristics of gait observed in people with Parkinson's disease [25]. Although this methodological choice aimed to standardize data collection and reduce interindividual variability, it may have introduced bias and limited the generalization of the results. Furthermore, the small sample size restricts the generalizability of the findings. Future investigations with larger cohorts and more detailed biomechanical analyses are warranted to clarify the relationship between disease staging and gait kinematics.

In summary, this pilot study provides initial evidence that gait kinematic parameters, including stance time, stride, gait speed, and temporal variability, are associated with the clinical progression of Parkinson's disease. These findings highlight the relevance of gait analysis in understanding functional decline in older adults with Parkinson's disease, while emphasizing the need for cautious interpretation and further research.

CONCLUSION

Functional decline in Parkinson's disease increases the occurrence of gait abnormalities, such as reduced gait speed, prolonged stance time and stride length, and greater variability of temporal gait parameters. These gait alterations have important clinical implications, as they can elevate the risk of falls and compromise functional independence, highlighting the need for targeted therapeutic interventions to maintain mobility and ensure safety during locomotion.

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