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ORIGINAL RESEARCH

Swing time as a predictive variable for Parkinson's disease

O tempo de balanço como variável preditiva da doença de Parkinson

El tiempo de equilibrio como variable predictora de la enfermedad de Parkinson

Lucas Resende Sousa[1], Bárbara Crystian Rodrigues Martins[2], Lucyana Teodoro de Oliveira[3], Camilla Zamfolini Hallal[4]

ABSTRACT | Currently, Parkinson's Disease (PD) is diagnosed based only on the clinical observation of a combination of symptoms, which can lead to late diagnosis, since some individuals may have the disease for 5 to 10 years before being diagnosed. The aim was to identify temporal kinematic variables of walking, capable of discriminating elderly people with and without PD. 40 individuals were divided into two groups: elderly group without PD (n=21) and with PD (n=19). Ten consecutive gait cycles were obtained during walking at a preferred speed and used for data analysis. A discriminative analysis was performed to determine a predictor model of gait changes, characteristic of PD and calculated based on the specificity and sensitivity of each variable analyzed, using temporal kinematic variables. The variable with discriminative value of sensitivity and specificity was the time of balance, which can be classified as the variable with most predictive potential of the presence or not of PD, and the cut of found for this variable was 0,48 seconds. The kinematic gait analysis allows to discriminate a group of individuals with PD from a group of healthy individuals with high sensitivity and specificity, through the time of balance that is lower in the group affected by the disease (cut of 0,48 seconds).

Keywords | Parkinson's Disease; Gait; Kinematics; Early Diagnosis.

RESUMO | Atualmente, a doença de Parkinson (DP) tem seu diagnóstico baseado apenas na observação clínica de uma combinação de sintomas, o que pode levar ao diagnóstico tardio. Alguns indivíduos podem, em decorrência disso, ter a doença por 5 a 10 anos antes de serem diagnosticados. O objetivo deste estudo foi identificar as variáveis cinemáticas temporais da marcha, pois estas são capazes de discriminar idosos com e sem DP. Como método, 40 indivíduos foram divididos em dois grupos: grupo de idosos sem DP (n=21) e com DP (n=19). Foram obtidos dez ciclos de marcha consecutivos durante a marcha em velocidade de preferência, sendo utilizados para a análise dos dados. Realizou-se uma análise discriminativa para determinar um modelo preditor de alterações na marcha característico da DP. O modelo foi calculado com base na especificidade e sensibilidade de cada variável analisada, utilizando-se variáveis cinemáticas temporais. A variável com valor discriminativo de sensibilidade e especificidade foi o tempo de balanço, o que pode classificá-lo como a variável que possui grande potencial preditivo da presença ou não da DP, e o ponto de corte encontrado para essa variável foi de 0,48 segundos. A pesquisa concluiu que a análise cinemática da marcha permite discriminar um grupo de indivíduos com a doença de Parkinson de um grupo de indivíduos saudáveis, com alta sensibilidade e especificidade, por meio do tempo de balanço, visto que ele é menor no grupo acometido pela doença.

Descritores | Doença de Parkinson; Marcha; Cinemática; Diagnóstico Precoce.

[1]Universidade Federal de Uberlândia (UFU) – Uberlândia (MG), Brazil. E-mail: lucas.resende.sousa@hotmail.com. ORCID-0000-0002-0178-0534
[2]Universidade Federal do Triângulo Mineiro (UFTM) and Universidade Federal de Uberlândia (UFU) – Uberlândia (MG), Brazil. E-mail: barbaramfisio@gmail.com. ORCID-0000-0003-4434-5740
[3]Universidade Federal de Uberlândia (UFU) – Uberlândia (MG), Brazil. E-mail: lucyanat.oliveira@hotmail.com. ORCID-0000-0001-5168-1334
[4]Universidade Federal de Uberlândia (UFU) and Universidade Federal do Triângulo Mineiro (UFTM) – Uberlândia (MG), Brazil. E-mail: camillazhallal@ufu.br. ORCID-0000-0001-7414-7679

Correspondence address: Lucas Resende Sousa – Rua Benjamin Constant, 1286, Nossa Senhora Aparecida, Uberlândia – MG, Brazil – CEP 38400-678 – E-mail: lucas.resende.sousa@hotmail.com. Funding source: CNPq (459592/2014) and FAPEMIG (APQ 00327-14) – Conflict of interests: nothing to declare – Presentation Apr. 14th, 2021 – Accepted for publication May 5th, 2021 – Approved by the Ethics Committee: CAAE 43869315.2.0000.5152.

RESUMEN | Actualmente, el diagnóstico de la enfermedad de Parkinson (EP) se obtiene desde la observación clínica de una combinación de síntomas, lo que puede llevar a un diagnóstico tardío. Como resultado, algunas personas pueden haber adquirido la enfermedad entre 5 y 10 años antes de que fuesen diagnosticadas. El objetivo de este estudio fue identificar las variables cinemáticas temporales de la marcha, ya que son capaces de diferenciar a los ancianos con EP y a los ancianos sin EP. Se dividieron los 40 participantes en dos grupos: ancianos sin EP (n=21) y ancianos con EP (n=19). Se obtuvieron diez ciclos de marcha consecutivos durante la marcha a la velocidad preferida para el análisis de datos. Se realizó un análisis discriminante para determinar un modelo predictivo de cambios en la marcha característicos de la EP. El modelo se calculó con base en la especificidad y sensibilidad de cada variable analizada, utilizando variables cinemáticas temporales. La variable con valor discriminante de sensibilidad y especificidad fue el tiempo de equilibrio, que puede clasificarse como la variable con mayor potencial para predecir la presencia o no de EP; y el punto de cohorte encontrado para esta variable fue de 0,48 segundos. Se concluye que el análisis cinemático de la marcha puede discriminar a un grupo de individuos con enfermedad de Parkinson de un grupo de individuos sanos, con alta sensibilidad y especificidad, por medio del tiempo de equilibrio, que fue menor en el grupo afectado por la enfermedad.

Palabras clave | Enfermedad de Parkinson; Marcha; Cinemática; Diagnóstico Precoz.

INTRODUCTION

Parkinson's disease (PD) was first described by James Parkinson in 1817 and is contemporarily characterized by the presence of cardinal signs, such as resting tremor, bradykinesia, rigidity and postural instability[1]. In addition to the motor impairments typical of PD, a considerable number of patients also have some type of cognitive impairment[2].

Clinical manifestations are caused by an expressive reduction in dopamine in the basal ganglia. This occurs due to the degeneration of dopaminergic neurons in the substantia nigra of the midbrain by the accumulation of alpha-synuclein protein, in the form of intracellular filamentous aggregates (Lewy bodies)[3,4], in the cell bodies of these neurons.

In this context, the aging of the individual is strongly linked to the development of PD, since the acceleration of the loss of dopamine-producing neurons affects approximately 2% of people at the age of 65[5]. PD is considered the second most frequent neurodegenerative disease in the older population; it is estimated that more than 6.3 million people worldwide have the disease[6] and that, by 2030, more than one million people will be diagnosed[7] in the United States.

Among the impairments caused by the disease, changes in gait are especially limiting to the patient's functionality[8]. Factors such as difficulty in spatiotemporal regulation, reduced stride length (SL), higher stride frequency (SF), longer double foot support on the floor and greater variability in spatiotemporal parameters interfere in the functionality of the older population[9]. The variability of spatiotemporal parameters has an inverse relationship with the dynamic stability of gait. In individuals affected by PD, there is an alteration in the center of mass, caused by postural instability, which is often evident in situations of changes in direction and speed[10]. These changes lead patients to greater energy expenditure, compared to the gait situations of young and healthy individuals, which predisposes them to falls with serious outcomes, such as fractures and deaths[11].

Currently, the diagnosis of PD is based on observation of symptoms, but the disease is commonly diagnosed late; by the time of diagnosis, up to 70% of the substantia nigra dopaminergic neurons may have been lost[12,13].

Considering that the diagnosis is generally late, simultaneously to the important gait alterations that accompany the disease progression, it is of great importance to identify biomechanical gait variables capable of discriminating older adults with and without PD. Thus, it is possible to implement early physical rehabilitation and fall prevention strategies, ensuring greater safety, quality of life and independence for Parkinson's patients.

The objective of this study was to identify temporal kinematic variables of gait capable of discriminating older adults with and without PD. Our hypothesis is that, due to the notorious gait alterations present progressively in PD, there are temporal kinematic variables capable of discriminating older patients with and without the disease with high sensitivity or specificity and identifying which variable would be more predictive.

METHODOLOGY

Sample selection

The study included 40 individuals divided into two groups: older adults without Parkinson's disease (n=21) and with Parkinson's disease (n=19). A convenience sample was determined according to the number of participants in the university extension project developed for patients with Parkinson's disease. Individuals without the disease were participants in a physical activity program for the older population.

The study respected the confidentiality of the identity of the research subjects, as well as the guarantees provided for in the free and informed consent form, signed by all participants.

Eligibility criteria common to the groups were: age between 60 and 80 years, absence of pain, fracture, or severe soft tissue injury in the six months prior to the study; as well as a history of cardiovascular, respiratory (information reported by the participants) or cognitive changes, requiring a score above 24 in the application of the mini mental state examination (MMSE). Table 1 demonstrates the characterization of the sample.

In addition, participants without PD met the following criteria: absence of a history of neurological diseases and practitioners of physical activities for at least six months prior to the study, at least three times a week. For the group of older adults with PD, the criteria were: diagnosis of idiopathic Parkinson's disease classified in stages I to II of the Hoehn-Yahr scale (HY)[14]. Patients in these early stages of disease classification are still functionally active and walk independently, that is, individuals without late impairments, which allows for early identification.

Table 1. Sample characterization, described by mean and standard deviation

Characteristic	without Parkinson's (n=21)	with Parkinson (n=19)	*P*
Age (years)	69±2	69±2	0.942
Men/women (n)	10/11	9/10	-
H&Y I / H&Y II (n)	-	9/10	-
Weight (kg)	71±3	73±3	0.648
Height (cm)	161±2	160±2	0.877

H&Y: Hoehn-Yahr Scale for Rating and Progression of Parkinson's Disease.

Research subjects underwent physical therapy for at least six months prior to the study, at least three times a week. The physiotherapy activity was controlled, with attention to balance training, gait in different situations, stretching and muscle strengthening. In addition, they could not be in the pharmacological adaptation phase and all collection procedures were carried out in the *on* phase of PD medications.

Instruments

For the collection of kinematic data, the *foot switch* contact sensor system (Noraxon®) was used, placed on the calcaneus and at the base of the hallux bilaterally of the participants. Figure 1 shows the location of the sensors.

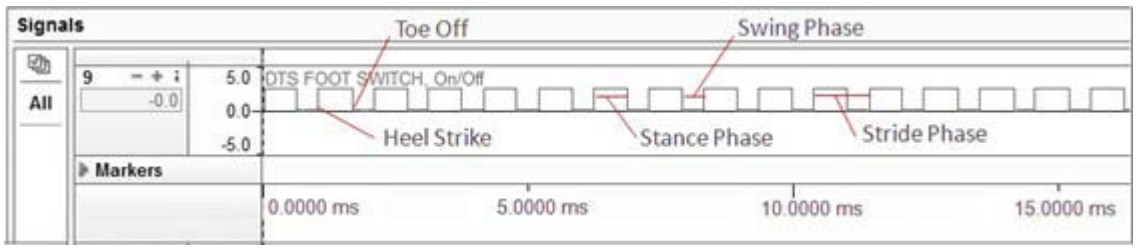

Figure 1. Signal from the pressure sensors used to determine the start and end of the stance phase, swing phase, step and stride

Procedures for data collection

Before the gait assessment procedures, volunteers were instructed about all assessment procedures and familiarized with the collection environment, equipment and task on the same day of collection.

The volunteers were instructed, through verbal stimulation, to walk on the walkway at the speed they routinely walk. The gait activity in this condition was performed for three consecutive times, and the average of the attempts was used for data analysis.

The gait assessment was performed on a mat ten meters long and two meters wide. The first and last two meters of length of the walkway were disregarded in the data analysis, to avoid possible influences from the process of acceleration and deceleration of the gait.

Data analysis

Ten gait cycles obtained at the preferred speed were used for data analysis. The determination of the step time, the stride time, the support time and the swing time was performed using the signal from the pressure sensors, based on the voltage of the signal from the pressure sensors (5mV or 0mV). Thus, it was possible to obtain the variability values of the respective variables, which were calculated from the standard deviation.

Discriminative analysis was performed using the PASW statistics 18.0® (SPSS) software, in order to determine a predictor model of changes in gait characteristic of PD using the variables step time, stride time, support time, swing time, stride time variability, stride time variability, stance time variability and swing time variability.

The specificity and sensitivity of each analyzed variable and the receiver operating characteristic (ROC) curve were also calculated. The ROC curve is shown in Figure 2 and is obtained by representing the sensitivity×specificity. High sensitivity and specificity values, represented by a larger graphic area of sensitivity×specificity, result in a more significant predictor model. The cutoff point for the most predictive variable was calculated using a discriminative statistical analysis by coefficients, which indicates the threshold value capable of discriminating older adults with and without PD. The level of significance was set at $p < 0.05$ for all tests.

RESULTS

The results showed that the variable with the highest sensitivity and specificity value was swing time, which may classify it as the variable studied with the greatest predictive capacity for the presence or absence of PD. The most significant predictor model is represented by the largest graphic area (sensitivity×specificity) among the analyzed variables (Figure 2). The cutoff point found for the predictive variable of swing time was 0.48 seconds. Table 2 shows the ROC curve area data.

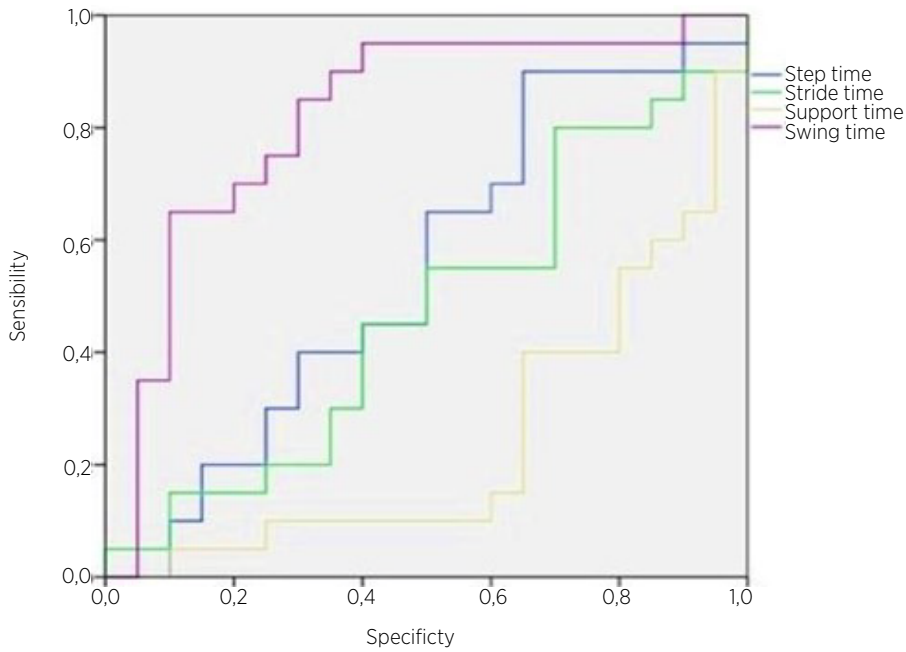

Figure 2. Specificity and sensitivity ROC curve

Table 2. ROC curve data

Variables	Area	SE	*p*	CI 95%	
				LB	UB
Step time	0.545	0.093	0.626	0.362	0.728
Stride time	0.470	0.093	0.745	0.288	0.652
Support time	0.245	0.078	0.006	0.092	0.398
Swing time	0.818	0.072	0.001	0.677	0.958

SE: standard error. CI: confidence interval. LB: lower bound UB: upper bound

DISCUSSION

The objective of this study was to identify, among temporal kinematic variables of gait, those capable of discriminating older adults with and without PD. Such identification is relevant because, currently, the diagnosis of PD is usually late, when the individual already has

motor impairments identifiable by an assessment[15]. With early identification of PD, it is possible to program an early therapeutic intervention, which can help prevent or minimize complications resulting from the disease[16,17].

The results showed that swing time is a variable of high sensitivity and specificity and, therefore, capable of discriminating older adults with and without PD. Older adults with PD have a shorter swing time than those without PD, whose cutoff point was 0.48 seconds.

In the study by Pistacchi et al.[16], spatiotemporal and kinematic gait parameters were quantified and identified in individuals with and without PD. The swing phase and swing time differed considerably ($p<0.05$), while the stance phase was not statistically significant in patients compared to healthy individuals. Swing time indirectly represents stability and functional balance, given that it shows how much the individual is able to remain on unipodal support during a gait cycle. Therefore, the longer the individual needs to maintain a stable or bipedal support base, the lower their ability to remain balanced during the activity performed[17,18,19].

Gait instability is an important sign in PD, as most patients do not have an adequate interaction of systems that influence dynamic balance, such as gait.

The balance deficit in PD causes the center of mass to move forward, which makes it difficult to perform compensatory movements as a way to regain balance[20,21]. However, gait stability guarantees the ability to maintain functional locomotion despite the presence of external disturbances or internal control errors. The greater difficulty in adapting to gait in the population with PD is a considerable risk, especially with regard to falls and serious consequences[22].

According to the H&Y scale, swing disorders only occur in the third stage of PD. However, this scale – widely used in clinical practice – was not developed to identify kinematic changes in gait, that is, it is not sensitive to changes in swing time[14]. In this regard, the review by Kamieniarz et al. in 2018 identified that postural instability may appear in the early stages of the disease, even before the onset of clinical symptoms, which corroborates our results[23].

It is important to clarify, however, that this study has some limitations to be considered when interpreting the results. The kinematic analysis was performed in a laboratory environment, with the dominant lower limb as reference. However, it is known that in the early stages of PD, motor manifestations are not bilaterally symmetric. Furthermore, all participants were physically active because they were part of extension projects, but this is not the reality for most older adults with or without PD.

CONCLUSION

The kinematic gait analysis makes it possible to discriminate a group of individuals with Parkinson's disease from a group of individuals without it, with high sensitivity and specificity, more specifically in swing time, which is shorter in the group affected by the disease (cutoff of 0.48 seconds). The identification of abnormal gait characteristics, especially with regard to kinematic parameters related to dynamic balance, such as reduced swing time in the early stages of PD, can help predict the clinical evolution of the disease and enable an early diagnosis.

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