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Swing time as a predictive variable for Parkinson's disease

O tempo de balanço como variável preditiva da doença de Parkinson

Tiempo de equilibrio como variable predictora de la enfermedad de Parkinson

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ABSTRACT | Currently, Parkinson's Disease (PD) is diagnosed based only on the clinical observation of a symptom combination, which can lead to late diagnosis, since some individuals have the disease for 5 to 10 years before diagnosis. The aim of this study was to identify temporal kinematic variables of gait, capable of discriminating older adults with or without PD. Forty individuals were divided into two groups: older adults without PD (n=21) and with PD (n=19). Ten consecutive gait cycles were obtained during gait at a preferred speed and then used in data analysis. Discriminative analysis was performed to determine a predictor model of gait changes, characteristic of PD, estimated based on the specificity and sensitivity of each analyzed variable, with temporal kinematic variables. The variable with discriminative value of sensitivity and specificity was swing time, which can be classified as the variable with most predictive potential of PD, and the cut-off point found for this variable was 0.48 seconds. Kinematic gait analysis allows discriminating a group of individuals with PD from a group of healthy individuals, with high sensitivity and specificity, through the swing time, which is lower in the group affected by the disease (cut-off=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, uma vez que alguns indivíduos podem ter a doença por 5 a 10 anos antes de serem diagnosticados. O objetivo do estudo foi identificar variáveis cinemáticas temporais da marcha capazes de discriminar idosos com e sem DP. 40 indivíduos foram divididos em dois grupos: grupo de idosos sem DP (n=21) e com DP (n=19). Dez ciclos de marcha consecutivos foram obtidos durante a marcha em velocidade de preferência, e utilizados para a análise dos dados. Realizou-se uma análise discriminativa para determinar um modelo preditor de alterações na marcha característico da DP e 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-la como a variável com grande potencial preditivo da presença ou não da DP; o ponto de corte encontrado para essa variável foi de 0,48segundos. A análise cinemática da marcha permite discriminar um grupo de indivíduos com DP de um grupo de indivíduos saudáveis com alta sensibilidade e especificidade, por meio do tempo de balanço, menor no grupo acometido pela doença (corte de 0,48segundos).
Descritores | Doença de Parkinson; Marcha; Cinemática; Diagnóstico Precoce.

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, ya que algunas personas pueden haber adquirido la enfermedad entre 5 y 10 años antes de

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la realización del diagnóstico. El objetivo del estudio fue identificar variables cinemáticas temporales de la marcha capaces de diferenciar a ancianos con EP y ancianos sin EP. Se dividieron los 40 participantes en dos grupos: ancianos sin EP (n=21) y ancianos con EP (n=19). Para el análisis de datos, se obtuvieron diez ciclos de marcha consecutivos durante la marcha a la velocidad preferida. Se realizó un análisis discriminante para determinar un modelo predictivo de cambios en la marcha característicos de EP que se calcula en base a 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 se puede clasificar como la variable con mayor potencial para predecir la presencia o no de EP; el punto de cohorte encontrado para esta variable fue de 0,48 segundos. El análisis cinemático de la marcha tiene una alta sensibilidad y especificidad en la identificación de individuos con EP comparados a individuos sanos por medio del tiempo de equilibrio, que es menor en el grupo afectado por la enfermedad (cohorte de 0,48 segundos).

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

INTRODUCTION

Parkinson's disease (PD) was first described by James Parkinson in 1817 and it is currently characterized by the presence of cardinal signs, such as resting tremor, bradykinesia, stiffness and postural instability[1]. Besides the characteristic motor impairments caused by PD, a considerable number of patients present some type of cognitive impairment[2].

The clinical manifestations appear because of a significant reduction of the neurotransmitter dopamine in the basal ganglia, due to the degeneration of dopaminergic neurons of the midbrain substantia nigra, which, in turn, is caused by the accumulation of alpha-synuclein protein in the cellular bodies of these neurons, in the form of intracellular filamentous aggregates (Lewy bodies)[3,4].

In this context, aging is strongly connected to PD development, due to accelerated loss of dopamine-producing neurons over time, which affects approximately 2% of 65-year-olds[5]. PD is considered the second most frequent neurodegenerative disease in older adults. It is estimated that more than 6.3 million people worldwide havethe diseas[6]; in the United States, it is estimated that more than one million people will be diagnosed with PD by 2030[7].

Among the impairments caused by the disease, changes in gait significantly limit functionality[8]. Difficulty of spatiotemporal regulation, reduced stride length (SL), higher stride frequency (SF), increase double support time and greater variability of spatiotemporal parameters interfere in functionality in Parkinson's disease[9]. The variability of spatiotemporal parameters has an inverse relationship with the dynamic stability of gait. In individuals affected by PD, the center of mass changes due to postural instability, often evident in many situations such as alterations in direction and speed[10]. These alterations make PD patients expend more energy when compared with the gait of young and healthy individuals, which predispose them to falls with severe outcomes, such as fractures and death[11].

Currently, PD diagnosis is based on the observation of symptoms. However, PD is commonly late diagnosed; some individuals may have the disease from five to ten years before reaching diagnosis[12,13] and, at that time, up to 70% of dopaminergic neurons of the substantia nigra may have already been lost[14,15].

Given the generally late diagnosis, concomitantly with the important gait changes that accompany the progression of this disease, it is of great importance to identify biomechanical variables of gait that can discriminate older adults with and without PD. As to implement early strategies of physical rehabilitation and prevention of falls, ensuring greater safety, quality of life and independence to PD patients.

The aim of this study was to identify temporal kinematic gait variables capable of discriminating older adults with and without PD. Our hypothesis is that, due to the notorious gait changes progressively present in PD, temporal kinematic variables can discriminate older adults with and without PD, with high sensitivity or specificity, and identify which variable would be more predictive.

METHODOLOGY

Sample selection

Forty individuals participated in the study, divided into two groups: older adults without Parkinson's disease (n=21) and older adults with Parkinson's disease (n=19).

The sample was of convenience and determined according to the number of participants of the university extension project for patients with Parkinson's disease. Individuals without the disease participated in a physical activity program for older adults.

The study respected the identity confidentiality of the research subjects, as well as the guarantees in the Free and Informed Consent Form, signed by all participants.

The eligibility criteria common to both groups were age between 60 and 80 years; absence of pain, fracture or severe soft tissue injury in the six months before the study; as well as a history of cardiovascular, respiratory (information reported by participants) or cognitive alterations, and a score greater than 24 in the application of the mini mental state examination (MMSE). Table 1 shows the characterization of the sample.

Table 1. Characterization of the sample, described by mean and standard deviation

Characteristics	without Parkinson's (n=21)	with Parkinson's (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 of classification and progression of Parkinson's disease.

Participants without PD met the following criteria: absence of history of neurological diseases; and physical activity practice for at least six months before the study, at least three times a week. For 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)[16]. Patients in these early stages of the disease classification are still functionally active and perform independent gait, i.e., individuals without late impairments, allowing early identification.

The research subjects should perform physiotherapy for at least six months before the study, at least three times a week. The physiotherapy activity was controlled, focused on balance training, gait in various situations, stretching and muscle strengthening. In addition, they could not be in the pharmacological adaptation phase and all collection procedures were performed in the "on" phase of PD medications.

Instruments

To collect kinematic data, the *foot switch* contact sensor system (Noraxon®) was used, placed in the calcaneus and on the basis of the halux of the participants, bilaterally. Figure 1 shows the location of the sensors.

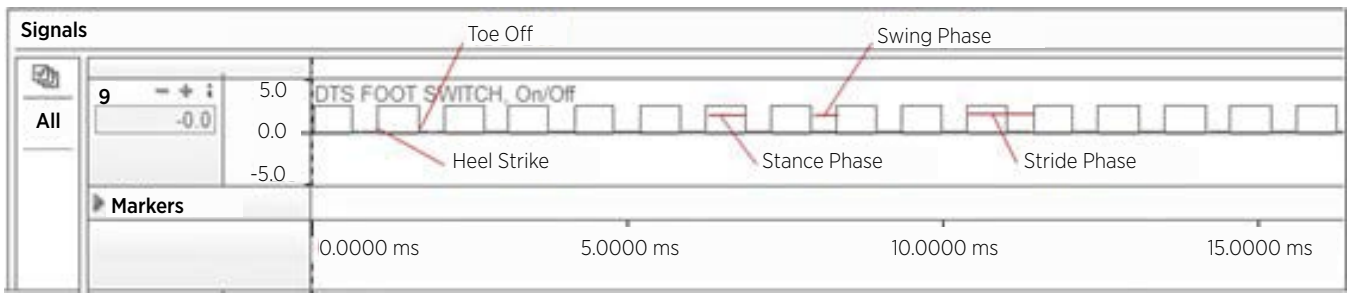

Figure 1. Signal of the pressure sensors used for determining the beginning and end of the support phase, swing phase, step and stride

Data collection procedures

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

The volunteers were instructed, by verbal stimulus, to walk on the catwalk at the speed they routinely walk.

Gait activity was performed three consecutive times, under this condition, and the mean of these attempts was used for data analysis.

The gait was evaluated on a 10-meter-long by 2-meter-wide carpet. The first two meters and the last two meters of the catwalk were disregarded in data analysis, to avoid possible influences of the acceleration and deceleration processes of gait.

Data analysis

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

Discriminative analysis was performed using PASW statistics 18.0® software (SPSS), to determine a predictive model of changes characteristic of PD in gait, using the variables step time, stride time, support time, swing time, step time variability, stride time variability, support 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 represented in Figure 2 and it was obtained by the representation of sensitivity×specificity. High sensitivity and specificity values, represented by a greater graphical area of sensitivity×specificity, result in a more significant predictor model. The cut-off point of the most predictive variable was estimated by discriminative statistical analysis with coefficients, which indicates the limit value to determine the presence of PD. The established significance level was $p<0.05$ for all tests.

RESULTS

The results showed that the variable with the highest sensitivity and specificity value was the swing time, which makes it the studied variable with the highest predictive capacity of the presence or not of PD. The most significant predictor model is represented by the larger graphic area (sensitivity×specificity) among the analyzed variables (Figure 2). The cut-off point for the predictive swing time variable was 0.48 seconds. Table 2 presents the data for the ROC curve area.

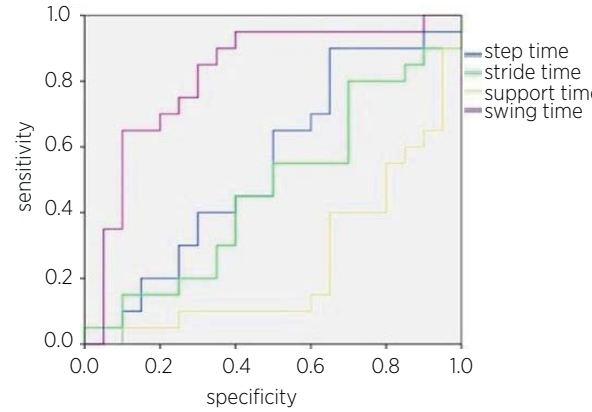

Figure 2. Roc curve of specificity and sensitivity

Table 2. ROC curve data

Variables	Area	SE	p	95%CI	
				LL	UL
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; LL: lower limit; UL: upper limit.

DISCUSSION

The aim of this study was to identify temporal kinematic gait variables capable of discriminating older adults with and without PD. This identification is relevant, because, today, Parkinson's Disease is usually late diagnosed, when the individual already presents motor impairments that are identifiable in an evaluation[17]. With the early identification of PD, it is possible to program early therapeutic intervention, which can help prevent or minimize disease complications[18,19].

The results showed that the 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 older adults without PD, whose cut-off point was 0.48 seconds.

In the study by Pistacchi et al.[18], spatiotemporal and kinematic gait parameters were quantified and identified in healthy individuals with PD. The swing phase and swing time differed considerably ($p<0.05$), while the support phase was not statistically significant compared with healthy individuals. The swing time indirectly represents stability and functional balance,

since it shows the capacity of the individual to remain in single support during a gait cycle. Therefore, the longer the individual needs to remain on a stable or double support basis, the lower is his/her ability to remain balanced during the performed activity[19-21].

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

The balance deficit in Parkinson's disease displaces the center of mass forward, which makes it difficult to perform compensatory movements to regain balance[22,23]. However, gait stability ensures the ability to maintain functional locomotion despite the presence of external disturbances or internal control errors. The difficulty in adapting gait in PD populations is a considerable risk, especially regarding falls and serious consequences[24].

According to the H&Y scale, balance disorders only occur in the third stage of PD. This scale, widely used in clinical practice, was not developed to identify kinematic changes in gait and, therefore, it is not sensitive to changes in swing time[16]. In this regard, in a review, Kamieniarz et al.[25] identified that postural instability may already appear in early stages of the disease, even before the onset of clinical symptoms, which corroborates the results of our study.

It is important to clarify, however, that this study has some limitations to be considered when interpreting its results. Kinematic analysis was performed in a laboratory environment and with the dominant lower limb as reference; however, motor manifestations are not bilaterally symmetrical in early stages of Parkinson's disease. In addition, all subjects were physically active because they participated in extension projects and this is not the reality of most older adults, with or without PD.

CONCLUSION

Kinematic gait analysis allows discriminating a group of individuals with PD from a group of healthy individuals, with high sensitivity and specificity, through the swing time, which is lower in the group affected by the disease (cut-off=0.48 seconds). The identification of abnormal gait characteristics can help predict the evolution of the disease, especially regarding kinematic parameters related to dynamic balance, such as reduced swing time, already in the early stages of PD.

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