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Kinematic angular parameters in PD: Reliability of joint angle curves and comparison with healthy subjects

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Abstract

Background: Most previous biomechanical studies of Parkinson's disease (PD) have been restricted to the description of spatiotemporal parameters and certain peak values for angular parameters. The reliability of joint angle curves and comparisons with control data are of major interest in PD, since variability in gait cycle timing is a feature of this pathology.
Methods: We used a video motion analysis system to record kinematic, spatiotemporal and angular parameters in 32 'off-drug' PD patients. The reliability of the patients' lower limb joint angle curves in the sagittal plane were analysed using the intra-class correlation coefficient (ICC), together with fast Fourier transform (FFT) analysis and hierarchical classification for discarding deviant curves. Lastly, we compared average curves (using a mixed model and the bootstrap method) for the less-affected and more-affected sides of PD patients and then compared the patient data with the results from 30 age-matched controls.
Results: The ICC-based procedure was easily applicable. Only 9.4% and 12.5% of the patients' hip and knee curves (respectively) were deemed to be unreliable. However, the PD patients' very high cycle-to-cycle variability in the sagittal plane ankle curves prevented us from applying to this joint. For the knee joint, the curves for the most disabled patients (who walked at below 0.5 m/s) were not reliable. We did not find any differences between the less and more disabled sides. The differences between patient and control curves concerned the double-support time during the stance phase and the time point for maximum knee flexion during the swing phase. Patients and controls differed in terms of the hip extension phase, with lower values in PD.
Conclusion: We have developed the use of validated statistic tools for unambiguously comparing PD patients and controls in terms of joint angle curve differences.

Keywords: Parkinson's disease; Gait; Reliability; Variability; Bootstrap

1. Introduction

Many biomechanical studies have reported on spatiotemporal gait parameters in Parkinson's disease (PD) [1–7] but only some have focused on angular parameters. A reduction in the angular excursion of lower limb joints was noted in parkinsonian syndromes [8,9]. These results have been confirmed by several studies in PD [3,10–15]. In the off-drug condition, the total sagittal plane excursions (TSPEs) were lower than control values, L-Dopa only improving the maximum knee joint flexion during the swing phase [3]. It has also been reported that the TSPEs in "on drug" severely impaired PD patients is about 70% of the control value [10]. In contrast, any significant decrease in TSPEs of proximal joints (hip and knee) was observed in 'on drug' patients with a mean UPDRS score of 16.1 [13]. The variability of angular gait parameters in PD has also been studied [14,16]. Patients

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showed great stride-to-stride variability in TSPEs [14]. This high variability makes it difficult to detect consistent trends when analysing several trials in a given patient [11].

The above-mentioned studies were limited to evaluation of certain numerical values that are supposedly representative of joint angle curves (e.g. initial contact, maximum extension and flexion, TSPE, etc.). This is important for a rapid overall evaluation but analysis of just a few points on the curve is not representative of the curve as a whole and some parts of the curve are thus not taken into account. Moreover, even though peak values simplify analysis and facilitate data interpretation, they usually occur at slightly varying times within the gait cycle (due to inter-individual variability) and thus can explain the observed discrepancies between the mean peak values and what is really present in the curve as a whole [17]. Variability in angle joint curves makes it difficult to draw any conclusions concerning analysis of a set of curves recorded in a given session. Hence, an 'average' curve which is representative of the patient would facilitate angular gait analysis. We have developed statistical tools for gait curve analysis [18,19]; our initial problem was to estimate the reliability of the curves recorded for a given subject and then select those which can legitimately be used to build an 'average' curve—a representative guide for a given patient and session. These tools were based on the use of intra-class correlation coefficients (ICCs) to assess curve reliability. In the present paper, we first focused on the application of this method to PD patients, in view of the significance of stride-to-stride variability in this pathology.

PD is clinically characterized by tremor, rigidity and akinesia that are generally asymmetric. Indeed, gait asymmetry itself could have a direct effect on joint angle curves but no significant differences were found between sides in 'on drug' patients [15]. In the second part of the present study, we sought to determine whether or not the more-affected and the less-affected sides in PD patients differed in terms of joint angle gait curves; this aspect is particularly important when seeking to compare curves between patients and control subjects. If the right and left curves indeed differ, one cannot legitimately pool the data and compare the resulting ''average'' PD patient curve with a control curve.

In the third and last part of the present study, we compared the average curve for the PD group to the average control curve and then sought to identify the parts of the gait cycle where there is a significant difference between PD patients and control subjects.

2. Patients and methods

2.1. PD patients

We studied 32 right-handed patients (20 men, 12 women) classified as suffering from PD according to the United Kingdom Parkinson's Disease Brain Bank (UKPDBB) 1989 criteria. The more-affected side (defined by tremor, rigidity and/or akinesia) was the right side for 12 patients and the left side for 16 patients. Four subjects did not show a lateral predominance. The characteristics of the patients are reported in Table 1. All patients had been medication-free for at least 12 h prior to testing.

Table 1
Characteristics and gait parameters in PD patients, compared with controls (using the Mann and Whitney U test for unpaired comparisons)

	PD		Controls		
	Mean	S.D.	Mean	S.D.	p
Age (years)	62.7	9.7	62.2	4.3	NS
Disease duration (years)	12.9	3.6			
UPDRS (motor)	45.3	11.7			
Walking speed (m/s)	0.67	0.25	1.26	0.16	<0.001
Cadence (steps/min)	104.46	18.63	115.18	8.31	<0.05
Stride length (m)	0.76	0.24	1.31	0.10	<0.001
Stride time (s)	1.19	0.25	1.05	0.08	<0.05
Single support/double-support	1.18	0.49	1.86	0.59	<0.001

2.2. Controls

Thirty healthy elderly control subjects (same gender ratio) were recruited from amongst the participants in a community project for senior citizens. A screening examination indicated that all control subjects were clinically normal, especially in terms of neurological and musculoskeletal parameters.

2.3. Methods

2.3.1. Gait data collection

Gait measurements were automatically recorded by means of a video motion system (the VICON system from Oxford Metrics, Oxford, England) featuring six infrared cameras and a sampling frequency of 50 Hz. Thirteen spherical, retro-reflective markers (2.5 cm in diameter) were used to define different segments of the pelvis and lower limbs. We used the VICON® software's lower body model (''Plug-in Gait'').

2.3.2. Assessment of gait function

The subjects (in underwear and bare-footed) walked at their normal speed. For each cycle, spatiotemporal gait measurements were determined. Joint angle curves in the sagittal plane were generated using VICON Polygon® software. For each subject and each body side, a minimum of seven gait cycles were obtained (mean $\pm$ S.D.: 14.3 $\pm$ 5.1). Data were expressed as a percentage of the gait cycle (from 0% to 100% in 2% steps, i.e. a total of 51 values).

2.4. Data analysis

2.4.1. Gait curve reliability in PD patients

By using a total of 64 curve beams (32 patients $\times$ 2 sides), we computed the ICC in order to determine whether or not the patients' gait curves were reliable [18]. Briefly, let r be the number of gait curves in the studied beam (r curves for a given patient and for a given side). The ICC of the r curves can be interpreted as the proportion of the variance due to the time-to-time variability in the total variance of the r curves. When the r curves are very similar, the ICC value is close to 1, indicating good reliability. In contrast, when the r curves are scattered, the ICC value is nearer to 0.