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Axial and Appendicular Postural Abnormalities and Associations With Balance, Gait and Physical Function in Individuals With Parkinson's Disease

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ABSTRACT

Background: Individuals with Parkinson disease (PD) may have a flexed posture, but only axial postural abnormalities (PAs) are generally investigated. *Purpose:* The objective was to verify if PAs of the axial and appendicular skeleton observed in PD occur in an interrelated manner to maintain balance and physical function. *Methods:* A cross-sectional observational study. Sixty-nine individuals with PD were evaluated by computerized photogrammetry. The MDS-UPDRS scale was used to analyze the physical function and the Mini-BESTest to assess balance. To determine the relationship between PAs and clinical aspects, multiple linear regression analysis was performed, setting age and levodopa equivalent dose as covariates. *Results:* The anterior trunk inclination angles were significantly correlated with the flexion angles of the elbows, hips and knees (p<0.01). Larger head flexion was correlated with worsening physical function (p=0.013) and gait (p=0.043); greater trunk, hip and knee flexion were correlated with reduced postural instability (p<0.05), and greater knee flexion was correlated with improvements in gait deficits (p=0.013). Conclusion: Postural abnormalities in the axial and appendicular joints of people with PD appear to occur in an organized and interrelated manner as a body compensation used to improve physical function and reduce balance and gait deficits.

Keywords: Parkinson Disease; postural instability; computerized photogrammetry; motor disorders; posture.

ANORMALIDADES AXIAIS E APENDICULARES E ASSOCIAÇÕES COM EQUILÍBRIO, MARCHA E FUNÇÃO FÍSICA EM INDIVÍDUOS COM DOENÇA DE PARKINSON

RESUMO

Introdução: Indivíduos com Doença de Parkinson (DP) podem ter uma postura fletida, porém apenas Anormalidades Posturais (APs) axiais são geralmente investigadas. *Objetivo:* O objetivo foi verificar se APs do esqueleto axial e apendicular observadas na DP ocorrem de maneira inter-relacionada para manter o equilíbrio e a função física. *Métodos:* Estudo transversal. Sessenta e nove indivíduos com DP foram avaliados por meio de fotogrametria computadorizada. A escala MDS-UPDRS foi utilizada para analisar a função física e o instrumento Mini-BESTest para avaliar o equilíbrio. Para determinar a relação entre APs e aspectos clínicos, a análise de regressão linear múltipla foi realizada, definindo idade e dose equivalente de levodopa como covariáveis. *Resultados:* Os ângulos de inclinação anterior do tronco foram significativamente correlacionados com os ângulos de flexão dos cotovelos, quadris e joelhos (p<0.01). Flexão de cabeça aumentada foi correlacionada com piora da função física e marcha (p<0.05), e flexão de joelhos aumentada foi correlacionada com melhora nos déficits da marcha (p<0.05). *Conclusão:* APs nas articulações axiais e apendiculares de pessoas com DP parecem ocorrer de maneira organizada e inter-relacionada como uma compensação corporal utilizada para melhorar a função física e reduzir os déficits de equilíbrio e de marcha.

Palavras-chave: doença de Parkinson; equilíbrio; fotogrametria; alterações motoras; postura.

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INTRODUCTION

Postural abnormalities (PAs) are common in individuals with Parkinson disease (PD), but most studies focus only on the most severe abnormalities, such as camptocormia,[1,2,3,4] antecollis[5,6] and Pisa syndrome,[7,8] which occur in 6.9% (Triple et al, 2009)[1], 1.5%–6.3%[5,6] and 8.8%[7] of PD cases, respectively. Despite the great clinical importance of postural changes in the elbows, hips, and knees, they have not been completely investigated. Related studies on this topic present different methodologies for postural analysis, such as using a computer-assisted handheld device,[9] assessing the distance from an anatomical point to a wall,[10,11] or using different photographic analysis protocols with computerized photogrammetry.[12-14]

Although various types of postural deformities assessed by photogrammetry have been reported in PD patients, postural changes in the appendicular skeleton are rarely reported, [13,14] and there are no publications reporting elbow angles. In addition, a consistent definition of an abnormal posture in individuals with PD appears to have yet to be established. To our knowledge, only one study evaluated cutoff points for postural angular changes in people with PD, just exploring the trunk angles[15]. Thus, there is little data of the main axial and appendicular joints in the sagittal axis through photogrammetry to establish joint angles that are considered cutoff points that distinguish a normal overall posture from an altered posture.

Recognition of the impact of postural changes on body physical function and stability is essential to establish therapeutic strategies, which can contribute to the improving the quality of life of these individuals. This research is justified by the fact that individuals with PD have important motor system impairments involving postural alignment, but it is not clear in the literature whether postural abnormalities observed in this population occur in an interrelated manner to maintain a balanced posture and whether PAs can influence the gait deficits and physical function of these individuals.

Therefore, the present study aimed to evaluate, through computerized photogrammetry, global parameters of body posture in the sagittal plane, not only of the trunk but also of the head, elbows, hips and knees, of individuals with PD and determine whether these PAs are related to each other and correlated with changes in physical function, balance and gait.

METHODS

This is a cross-sectional observational study with quantitative data analysis. This research was conducted in accordance with the principles presented in the Declaration of Helsinki and was approved by the research ethics committee of the Hospital de Clínicas de Porto Alegre (HCPA–UFRGS) with the following CAAE number: 67433517.5.0000.5327.

Sample

The convenience sample consisted of individuals of both sexes from the Movement Disorders Outpatient Clinic at the HCPA. The registration period was from May 2017 to December 2018. The clinical diagnoses of all PD participants were made according to the London Brain Bank Criteria (Calne, Snow, Lee and 1992).[16] All subjects were classified as having a disease severity between stages 1 and 4 according to the Hoehn & Yahr (HY) staging scale,[17] and were able to remain in orthostasis for approximately 10 seconds.

The exclusion criteria were orthopedic and/or rheumatological limitations or other neurological diseases, deep brain stimulation use, a previous surgery to correct a postural deformity and serious PAs, such as camptocormia, Pisa syndrome or antecollis.

A sample size calculation was performed based on the article by Yoshii et al.,[14] who observed a statistically significant correlation between the disease stage (according to the HY scale) and changes in cervical and thoracolumbar spinal postural alignment. The weaker correlation observed was between the disease stage and the degree of cervical flexion (r=0.350); thus, this correlation maximizes the size of our sample. With a power of 80% and a significance level of 5%, it was concluded that the minimum number of individuals required was 63 for this research. The sample size calculation was performed using WinPepi software version 11.65.

Procedures and Instruments for the Data Collection

All subjects who met the inclusion criteria received a free informed consent form, and the evaluations were performed only after they signed the consent form in the Clinical Research Center at the HCPA.

All eligible subjects were evaluated during the medication ON time. The evaluation began with an anamnesis to verify the sociodemographic data, clinical history of PD and drug therapy. The levodopa equivalent dose (LED) was calculated as suggested by Tomlinson et al,[18] and the motor subtype of the participants was classified according to the method presented by Stebbins et al.[19]

The participants were evaluated using the Portuguese version of the MDS-Unified Parkinson Disease Rating Scale (MDS-UPDRS)[20] to assess the nonmotor aspects of the disease (Part I), the physical function of individuals in performing activities of daily living (Part II), the motor aspects (Part III) and the motor complications (Part IV). The HY scale was used to verify the disease stages, and reduced version of Balance Evaluation Systems Test (Mini-BESTest)[21] as used for the balance assessments. For a specific analysis regarding balance deficits, the Mini-BESTest was stratified into four sections: anticipatory transitions (ATs), postural responses (PRs), sensory orientation (SO) and dynamic gait (DG) (Franchignoni et al., 2010)[21].

The postural evaluation was performed using a photogrammetry protocol based on that proposed by Ferreira et al.[22] on the development of Postural Assessment Software (PAS/SAPO).[23] Some precautions were taken to ensure photo quality, such as the use of well-configured and calibrated photographic equipment, a comfortable space and temperature, privacy for the subject, and adequate lighting to allow precise focus. In addition, all participants wore bathing suits during the photographic recording session, and the photos were taken after the previously selected anatomical points were located and marked.

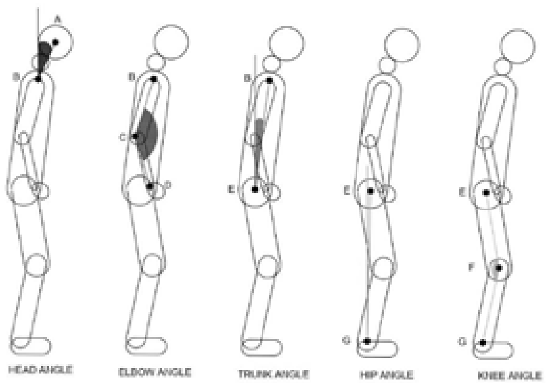
The anatomical references, which served as guides for the photographic analyses, were marked with 15 mm reflective Styrofoam spheres, placed bilaterally on each individual at the following anatomical points:[22] A- tragus; B- acromium; C- lateral epicondyle; D- midpoint of the wrist (midpoint between the styloid process of the radius and the head of the ulna); E- greater trochanter; F- knee joint line and G- lateral malleolus. There was a total of 14 anatomical points.

After the reflective markers were placed, the subjects remained standing, relaxed, looking straight ahead. To ensure that they were within 10 cm of the wall and the plumb line, a black mat was placed, marking the place where they should be positioned in orthosis. The verbal command given to participants was "you should stand on this mat in a comfortable and habitual position and position your feet in a way that is normal for you" so that the postural recordings would resemble the participants' daily life as closely as possible. All participants were photographed in the left lateral and right lateral profile postures. Both the placement of the anatomical markers and the recording of the photographs were performed by a trained evaluator.

A camera (Sony H Series Dsc-h300 20.1mp) without zoom was used to capture images of the individual according to the protocol recommended by SAPO Software,[22] with a plumb line attached to the ceiling and two markers placed one meter apart on a wire, for an additional image calibration. The participants were positioned such that they were in the same plane as the plumb line, perpendicular to the axis of the digital camera, which was located 2.3 meters away from the subject and was supported by a tripod that was one meter tall. Bubble levels were attached to the top of the camera and to the front of the lens to confirm the camera's horizontal and vertical alignments, respectively.

After the images were acquired, they were transferred to a computer and analyzed using ImageJ software. These analyses were performed by a single researcher blinded to the other evaluations who received comprehensive training in performing the test protocol of this study. The following points were used to assess joint angles,[22] as illustrated in Figure 1.

The joint angles were measured in degrees, and we adopted the positive sign for the anterior inclination angles (flexion joint) and the negative sign for the posterior inclination angles (extension joint). To obtain the final values, we used the average of the angles obtained in the right and left sagittal profile photos of each participant.



Statistical analysis of the data

Qualitative characteristics were described as frequencies and percentages, and quantitative characteristics were described as the means and standard deviations (SDs). The angles evaluated by photogrammetry were also described as quartiles, minimums, maximums and 95% confidence intervals (95% CIs).

The normality of the angles evaluated by photometry was verified by the Shapiro-Wilk test and normal probability graphs. The relationships between the angles were evaluated using Pearson's correlation coefficient. To determine the relationship between the PAs and the clinical, sociodemographic, motor, physical function and balance aspects, multiple linear regression analysis was performed, with age and LED as covariates, as they have been described in the literature as factors that interfere with motor aspects and the postures of individuals with PD.[12,13] The analyses were performed using the PASW v18.0 application. The adopted significance level was 5%.

RESULTS

Sample characteristics

A total of 79 participants were included in this study. Out of those, 10 were unable to complete all stages of the clinical evaluation; thus, they were excluded from the study (four were excluded because they were not able to remain standing when the photographic records were taken, three were excluded because they had large dyskinetic movements when the photos were taken, which invalidated the records, and two individuals were excluded because they presented with severe cognitive deficits and were unable to understand the questions for the anamnesis). Thus, the analyses were performed with a total of 69 individuals of both sexes aged between 40 and 79 years. Table 1 describes the sociodemographic and clinical characteristics of the included individuals.

Table 1 – Sample characterization (N = 69)

Variables	Mean (SD) or n (%)
Age (years)	62.55 (9.94)
Diagnostic Time (years)	9.59 (4.94)
Age of onset of symptoms (years)	50.59 (10.02)
Age of diagnosis (years)	52.46 (9.85)
Sex	
Male	36 (52.2)
Female	33 (47.8)
Motor subtypes	
Dominant Tremor	27 (39.1)
Postural instability and gait disorder	34 (49.3)
Indeterminate type	8 (11.6)
Hoehn & Yahr	
1	10 (14.5)

2	39 (56.5)
3	15 (21.7)
4	5 (7.2)
Total MDS-UPDRS (points)	82.46 (28.87)
LED (mg/d)	1163.71 (460.49)

Age, diagnostic time, age of onset of symptoms, age of diagnosis, total of Unified Parkinson Disease Rating Scale (MDS-UPDRS) and Levodopa equivalent dose (LED) were described as means and standard deviations (SD). Sex, motor subtypes and stages of Hoehn & Yahr Scale were described as frequencies and percentages.

Axial and appendicular angles

The results of the photogrammetric analysis are described in Table 2, which presents the distribution of the angular values of each joint analyzed. To verify the severity of the PAs of the individuals with PD who were evaluated, we included in this same table the reference angular values considered normal for healthy adult women (Macedo Ribeiro et al, 2017)[24].

Table 2 – Angular values of the evaluated joints

Angles Evaluated	Average (95% CI)	Median (min- max)	Q1	Q3	Normality Reference Average (95% CI)#
Head	22.96 (20.12- 25.80)	20.90 (0.74- 53.38)	16.16	29.27	12.66 (-6.07 – 31.39)
Trunk	3.77 (2.66- 4.89)	3.41 (-5.71- 15.14)	0.62	6.25	-1.41 (-7.62 – 4.80)
Elbow*	31.18 (29.48- 32.88)	31.64 (11.64- 54.09)	27.41	35.81	-----
Hip	3.28 (2.24- 4.33)	3.43 (-9.44- 12.05)	1.56	5.68	-5.99 (-15.51 – 3.53)
Knee*	10.44 (9.08- 11.79)	9.38 (2.06- 28.46)	6.44	13.5	-3.72 (-14.32 – 6.88)

*Values subtracted from 180º to represent flexion angles. #Ribeiro et al. (2016).

We found that angular measurements, except the elbow joint angle, found in PD participants presented means above the values considered normal for the healthy population. The elbow angle could not be compared because we did not find a reference value in the current literature. According to the 95% CI overlap in the PD and healthy groups, there was a difference in knee angle, and on average, PD participants presented a flexion angle that was greater than twice that of healthy individuals.

Regarding the anterior head tilt angles, 16 (23%) of the participants presented angles higher than those described as normal in the healthy population; for the trunk, hip and knee angles, 26 (38%), 29 (42%) and 49 (71%) individuals, respectively, had values that exceeded the reference values. When we performed a new analysis, including only the individuals with trunk extension, we found that 15 participants (22% of the sample) presented this PA, with a minimum angle of -5.71º and a maximum angle of -0.29º. There was no significant difference between this group and the group with trunk flexion in the clinical variables.

To verify the relationships between the global postural changes, the correlations between all body angles were evaluated (Table 3). Most angles were positively correlated with each other, except for the head anteriorization angle with the trunk and knee flexion angles.

Table 3 – Correlations between the evaluated body angles

Angles evaluated	**Trunk**		**Elbow**		**Hip**		**Knee**	
	Correlation coefficient	p	Correlation coefficient	p	Correlation coefficient	p	Correlation coefficient	p
Head	0.221	0.067	0.329	0.006*	0.266	0.027*	0.128	0.293
Trunk	.....	.....	0.382	0.001*	0.513	0.000*	0.307	0.010*
Elbow	.....	.....	.....	.....	0.430	0.000*	0.372	0.002*
Hip	.....	.....	.....	.....	.....	.....	0.739	0.000*

*$p \leq 0.05$.

Posture, balance and gait

The analyses show that the participants with lower degrees of trunk flexion (r=-0.769) have higher postural instability, as assessed by the Pull Test (p=0.044). Multiple regression analysis have not demonstrated a relationship between the Mini-BESTest total score and trunk flexion angles. However, there was a significant correlation between balance improvement (represented by higher scores on this scale) and larger hip and knee flexion angles (p=0.001 and p=0.015, respectively).

Knee flexion also correlated with was related to lower gait deficits (p=0.013), as assessed by item 3.10 of the MDS-UPDRS. In addition, vertical head alignment had a statistically significant positive correlation with worse gait analysis scores across this MDS-UPDRS item in the population evaluated (p=0.043).

Posture and physical function

Table 4 presents the results of the multiple regressions performed. Higher anterior head was associated with worse physical function, as verified by an increase in the MDS-UPDRS part II score (p=0.013) and worsened gait (p=0.043) in these individuals. The other clinical variables (MDS-UPDRS total part I, III and IV score) studied did not present a statistically significant correlation with the posture analyzed by sagittal axis photogrammetry of the participants in this research.

Table 4 – Correlation between body angles and analyzed variables

Clinical Variables	Head		Trunk		Elbow		Hip		Knee	
	Coefficient	p	Coefficient	p	Coefficient	p	Coefficient	p	Coefficient	p
Age [a]	0.462	0.000*	0.245	0.043*	0.234	0.053	0.266	0.027*	0.189	0.120
LED [a]	0.001	0.753	0.002	0.054	0.002	0.081	0.002	0.158	0.003	0.049*
Hoehn & Yahr [b]	0.103	0.399	-0.118	0.335	0.030	0.809	-0.102	0.405	-0.072	0.556
Sex[b] M vs F	6.286	0.016*	2.246	0.042*	0.978	0.568	0.384	0.720	-1.034	0.450
Functionality [b]	0.377	0.013*	0.048	0.457	0.026	0.795	0.001	0.981	0.008	0.919
Motor Aspects [b]	0.136	0.190	0.042	0.334	0.024	0.716	0.019	0.659	-0.017	0.753
Total MDS-UPDRS [b]	0.075	0.108	0.02	0.315	-0.007	0.818	0.003	0.888	0.001	0.977
Pull Test [b]	0.534	0.560	-0.769	0.044*	-0.214	0.718	-0.530	0.149	-0.284	0.549
Total Mini BESTest [b]	0.050	0.834	0.012	0.902	0.230	0.110	0.277	0.001*	0.262	0.015*
Anticipatory transitions	0.604	0.381	0.243	0.404	0.522	0.217	0.722	0.006*	0.729	0.025*
Postural responses	0.198	0.702	0.070	0.748	0.406	0.199	0.530	0.007*	0.486	0.047*
Sensory orientation	-0.567	0.541	0.509	0.192	0.257	0.653	0.355	0.329	0.238	0.594
Dynamic gait	0.202	0.742	-0.570	0.025*	0.076	0.840	0.020	0.933	-0.001	0.998
Gait [b]	1.858	0.043*	-0.058	0.931	-0.776	0.451	-1.156	0.070	-1.998	0.013*

*p ≤ 0,05; a= variables analyzed by Spearman correlation Test; b= variables analyzed by Multiple regression. LED= Levodopa equivalent dose; M= Male; F= Female; MDS-UPDRS= Unified Parkinson Disease Rating Scale.

DISCUSSION

As expected, there were postural alterations in the participants, and these axial and appendicular PAs were associated with each other. Our study found that most PAs visualized in the sagittal axis in individuals with PD were significantly correlated; that is, the participants with a larger anterior trunk inclination angle also presented significant flexion angles in the elbows, hips and knees. The axial and appendicular PAs correlated with symptoms of postural instability and gait deficits, as well as a worsening of the physical function of these individuals with PD.

These findings corroborate with the hypothesis that PAs in individuals with PD are part of a cascade of compensatory mechanisms to counteract sagittal misalignment in order to remain balanced, maintain proper gait and have their ability functional preserved. Such changes have previously been reported in healthy elderly people, as in the study by Gong et al,[25] who confirmed that a close interaction between the spine and the lower extremities is used to maintain balance in the elderly population, as these PAs can displace the center of mass. Another result of our study that reaffirms our hypothesis that trunk and limb PAs are part of a body compensation mechanism to maintain balance in individuals with PD is the significant positive correlation between a better Mini-BESTest score and larger hip and knee flexion angles (both in the total test score and in the subsystem categories: anticipatory transitions and postural responses).

The age of the individuals was a factor that correlated positively with an increase in the anterior inclination angles of the head and trunk and greater hip flexion, demonstrating that, as expected, older participants have higher postural deformities[13]. We believe that as individuals age, these postural changes become increasingly evident, as indicated by Gong et al[25] when reporting changes in the parameters that describe body posture during aging, emphasizing that to perform an individualized functional analysis, it is essential to consider age. Some authors argue that elderly individuals, whether they are healthy or have PD, develop an adaptive capacity for body changes that occur during their lifetime, including the optimization of an erect posture. Muscle chains are active; initial tension is responsible for the succession of associated tension, leading to PAs that act as a predisposing form of disability with advancing age, resulting in reduced quality of life.[25,26]

The consequence of accentuated trunk flexion is the extension of the cervical region, which is a compensatory adjustment in head posture to preserve the forward position of the head, facilitating gait and performance of the activities of daily living (ADLs); this adjustment may explain why we found no correlation between greater cervical flexion and trunk flexion.[25] On the other hand, we found a significant correlation between the anterior inclination angle of the head and gait deficits of the participants in our study. We did not find any other study that assessed gait and cervical postural changes.

There are few studies about PAs in individuals with PD focusing on the physical function and performance of ADLs. Recently, Geroin et al[15] found an association between motor impairment and degree of trunk inclination;

however, the authors did not identify an association with ADLs and falls. In our sample, when we evaluated the physical function of these individuals through part II of the MDS-UPDRS, we verified that the participants with the largest anterior inclination of head had a worse ability to perform ADLs, even after we corrected for age and LED in the statistical analyses. This finding may suggest the influence of head posture on physical function, and it can be explained by the fact that larger anterior head tilt angles reduce the visual field of the surrounding environment and make it difficult to perform tasks requiring above-shoulder view.

Although PAS/Sapo photogrammetry is considered a reliable diagnostic tool that is widely used to assess posture, there was a lack of data regarding normal reference values of body angles in the sagittal axis in the elderly population assessed by PAS/Sapo photogrammetry. This leads to an important limitation when interpreting these data since normal parameters are not available for comparison, which is why we used the values resulting from a systematic review of healthy adult females as the reference parameters.[24]

Finally, we suggest that additional studies using the same postural assessment protocol[22] are conducted with a larger sample size and a control group of healthy elderly individuals matched by age and sex. We also suggest that a correlation analysis of PAs with kinematic gait parameters and an analysis of postural instability through stabilometry be performed for a better understanding of the influence of PAs on these motor aspects in the PD population.

CONCLUSION

Individuals with PD have a flexion pattern evident on the global level in the sagittal axis. PAs are more evident in individuals with PD than in the healthy population and occur interconnectedly between the axial and appendicular skeletal joints to reduce balance deficits and consequently improve physical function and risk of falling. On the other hand, we found that increase in the anterior inclination angle of the head influencing a worse gait pattern in this population.

All the authors declared to have no conflict of interests.

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