Two-dimensional posture evaluation in Parkinson's disease: effect of loads on the spinal angle during gait.

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Abstract.
Parkinson's Disease patients present diminished coordination caused by neural degeneration. This leads to large motor difficulties during gait such as balance loss and pronounced forward inclination of the upper body. This work assessed the spinal sagittal plane angle alterations in two groups: six parkinsonian patients and six control healthy subjects. This parameter was analyzed during gait under three conditions: without external loads and with external loads applied either on the chest or on the lower back area. Results were statistically compared by means of t-test of paired samples in both groups. For patients, a significant effect was found when loads were applied on the chest. On the other hand, healthy subjects showed no significant differences in either case.

1. Introduction

The arthro-osteo-muscular and nervous systems are closely interrelated in the complex dynamics and patterns present in the human gait. Therefore, neurodegenerative diseases, such as Parkinson's disease (PD), often cause movement disorders that could eventually affect the patient's gait. PD common symptoms are stiffness, tremor and bradykinesia (slowing down of voluntary movements).

In PD patients, it is observed a progressive loss of automatic movement patterns and postural reflexes, which leads to imbalance, diminished proprioception and festination (sequential effect of reducing consecutive footsteps length with accompanying reduction in gait speed).

Another motor sign present in PD patients is the tendency to tilt the torso forwards. The result is a bent posture and a displacement of the center of mass towards the front, ending up ahead of the ordinary center of pressure. These disorders not only affect the quality of life of PD patients, but also are often responsible for tripping and serious trauma [1, 2, 3, 4].

Moreover, some studies suggest that physical activities and muscular strengthening can help in the rehabilitation process [5]. In this way, PD patients who train postural maintenance related muscles tend to develop more control over their balance and gait.

The present work assessed the influence of a load over the posture of PD patients during gait. The chosen parameter to assess this influence was the Sagittal Plane Angle (SPA) described by the spine and the vertical axis, as shown in 1.

The proposed two-dimensional model is intended to compare the antero-posterior trunk inclination under different experimental conditions, which is the main cause of the forward displacement of the center of mass.

2. Materials and Methods

This study was approved by the bioethics committee of *Fundación para la Lucha contra las Enfermedades Neurológicas de la Infancia* (FLENI).

In order to evaluate whether the SPA varies significantly when the subjects walk carrying a standardized load, a paired two-sample t-test was calculated between PD patients and a control group. The sample size, experimental settings and numerical methods are described below.

2.1. Subjects

Two groups were evaluated: the control group was a sample of six healthy subjects between 22 and 75 years old, and the PD group consisted of six patients, between 50 to 75 years old, in third-stage Parkinson's disease according to the Hoehn and Yahr scale [6], diagnosed at the Rehabilitation and Educational Therapy Institute at FLENI.

All subjects signed informed consents, and patients were recruited from the out-patient clinic at the Movement Disorders section, FLENI.

Demographic data of both groups are presented in Table 1.

Table 1. Demographic data of healthy subjects (C) and PD patients.

Subject #	Gender	Group	Weight (Kg)	Height (m)	Body Mass Index (Kg/m^2)	Load Applied (Kg)
1	M	C	78	1.7	27	4.7
2	M	C	101	1.75	28	6.1
3	F	C	57	1.63	22	3.4
4	F	C	57	1.7	21	3.4
5	F	C	61	1.71	21	3.7
6	F	C	80	1.64	29	4.8
7	M	PD	92	1.66	31	5.5
8	M	PD	94	1.76	29	5.6
9	M	PD	100	1.7	33	6.0
10	F	PD	54	1.51	27	3.2
11	M	PD	82	1.72	24	4.9
12	M	PD	81	1.7	29	4.9

2.2. Experimental measurements

The gait assessments were performed at the FLENI Gait and Motion Laboratory. By using 17 sensors placed on the body of each subject (according to STCISB standards), the space-time coordinates were registered through a system of six ELITE optoelectronic cameras (BTS Bioengineering, Milan, Italy) with a sampling frequency of 100 Hz [7].

The subjects walked several times a distance of 10 meters in two different conditions:

(i) No load.

(ii) With load applied on the chest.

Loads were applied by means of a portable and noninvasive weighted backpack device capable of shifting the subjects' center off mass. Each load was calibrated to be 6% of the body weight of each corresponding subject [8] (see Table 1).

2.3. Statistical Analysis

In order to model the spinal angle, a straight line intersecting two dots was projected. The upper dot was located at the 7th cervical vertebrae and the other one at the sacrum bone. This is shown on figure 1.

The angle between this line and the vertical axis on the sagittal plane was the measurement used to evaluate the inclination. This SPA was calculated for each space-time stamp obtained by the camera along the 10 meters walk.

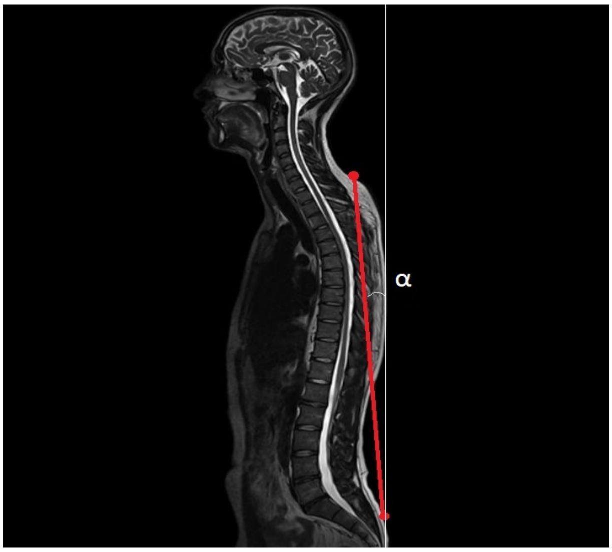

Figure 1. Spinal angle model (in red) and the SPA, (α). Drawn in white is the vertical axis reference.

SPA histograms for each subject were plotted . Figures 3 and 2 show plots for patient 12 and 8 respectively. It can be observed that mean SPA values under condition 2 were lower than under condition 1. However, this contrast was not observed in control subjects.

Normality test was performed by the qq-plot method [9, 10], shown in figure 4.

A paired sample t-test was run, comparing results for both conditions 1 and 2. Significance threshold was arbitrarily defined for $P < 0.05$, 2-tailed.

To take into consideration angular variability, the following variables were computed:

- $\bar{X}_i$ SPA average along the gait of the ith individual without load.
- $\bar{Y}_i$ SPA average along the gait of the ith individual with load.
- n_i^x Amount of measurements along the gait of the ith individual without load.

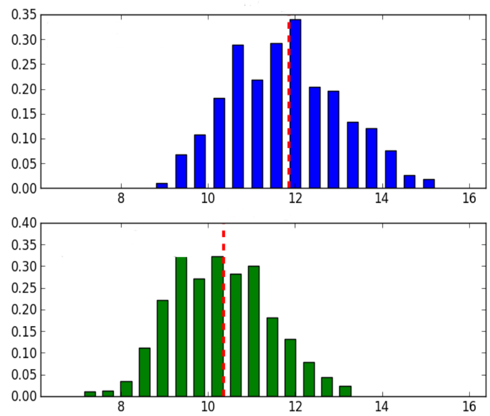

Figure 2. Histogram PD patient 12, upper panel without load and lower panel with load, red dotted lines are the means.

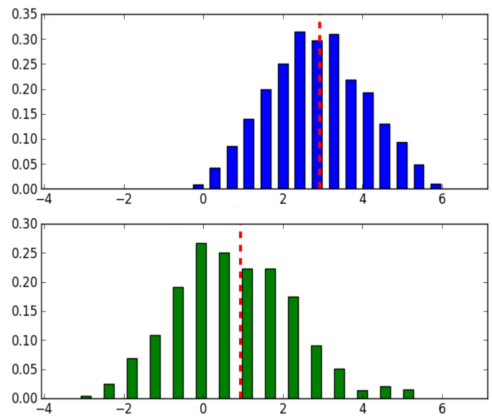

Figure 3. Histogram of PD patient 8, upper panel without load and lower panel with load, red dotted lines are the means.

- n_i^y Amount of measurements along the gait of the ith individual with load.
- σ_i^x Standard deviation of the SPA along the gait of the ith individual without load.
- σ_i^y Standard deviation of the SPA along the gait of the ith individual with load.

Statistical analysis was performed on the transformed variables according to the following expressions:

- $\widetilde{X}_i = \dfrac{\bar{X}_i}{\sqrt{\frac{(\sigma_i^x)^2}{n_i^x} + \frac{(\sigma_i^y)^2}{n_i^y}}}$
- $\widetilde{Y}_i = \dfrac{\bar{Y}_i}{\sqrt{\frac{(\sigma_i^x)^2}{n_i^x} + \frac{(\sigma_i^y)^2}{n_i^y}}}$

Software processing was calculated using packages NumPy and SciPy, with Python Language v2.7 [11], and statistical analysis was performed with R language [12].

3. Results

Statistical analysis showed a significant decrease on SPA measurements in condition 2 compared to condition 1, corresponding to straighter postures when subjects were loaded.

Despite this decrease, it was found no correlation between those variations and their initial or basal SPA (condition 1). The results are summarized in Table 2.

4. Discusion

The two-dimensional model of the spine projection in the sagittal plane (SPA) is a simplfied definition implemented to assess a specific parameter.

Nevertheless, the same model could be used in a further study to observe the effect of loads in lateral sways of the spine during gait.

Considering that postural instabilities or falls could have predominance in either direction, it might be useful to analyze whether loads placed on the anterior-posterior plane, could

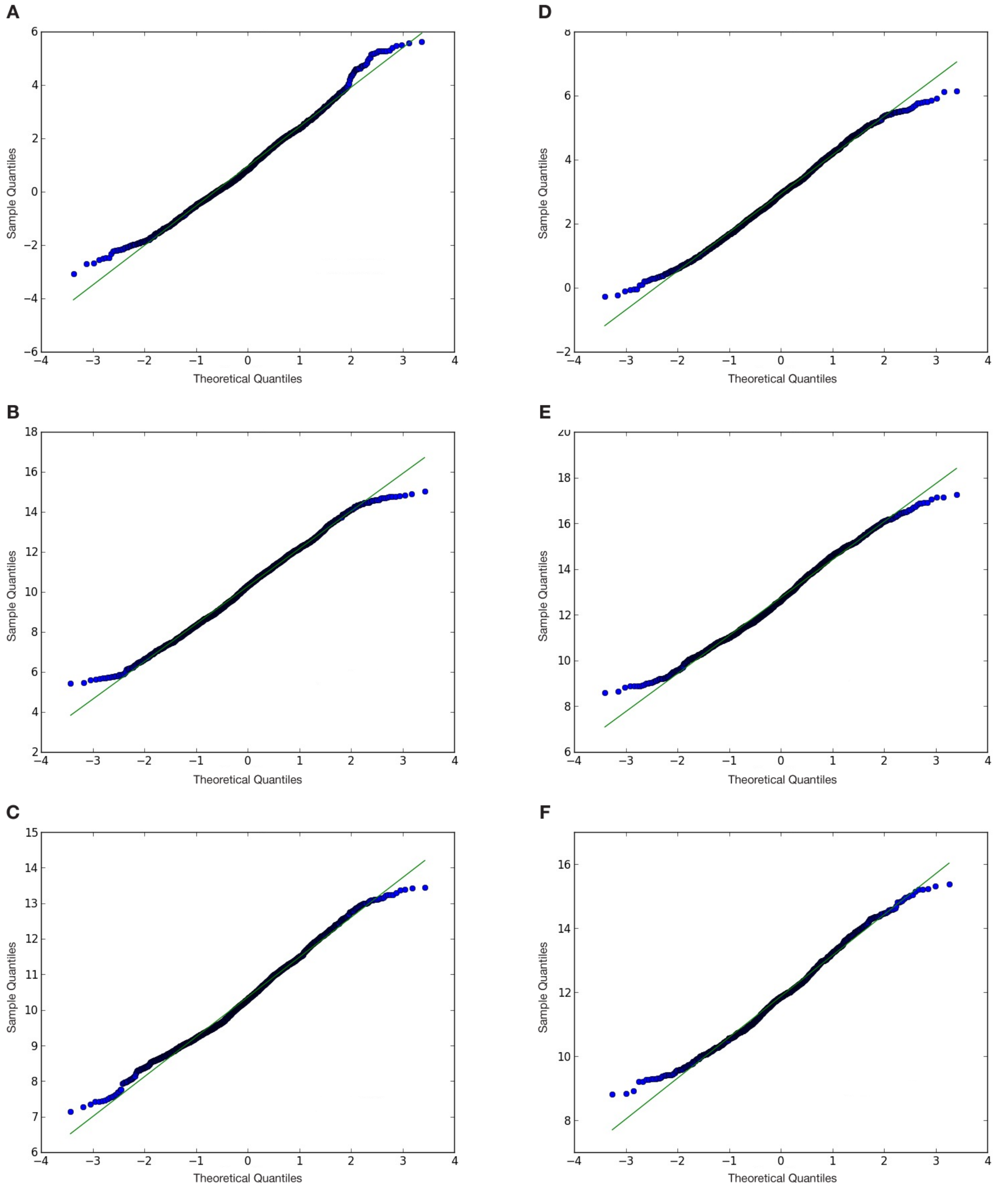

Figure 4. Q-Q plots of PD patients 8 (A and D), 9 (B and E) and 12 (C and F), where panels on the left are for condition 2, and panels on the right are for condition 1.

Journal of Physics: Conference Series **705** (2016) 012017 doi:10.1088/1742-6596/705/1/012017

Table 2. Statistical results for each group

Group	Difference of means	Statistic t	df	P
PD	1.74°	8.86	6	0.0001
C	4.36°	1.86	6	0.11

alter lateral components of gait patterns that might have a deleterious effect on overall gait performance.

This study was limited due to age variability in control subjects and sample sizes. Further research is needed in order to support these preliminary results.

The results suggest that the incorporation of loads in the treatment of the instability and posture in patients in the third stage of Parkinson Disease could influence the clinical results.

Several researches have determined that therapeutic techniques could lead to determine the real impact of the rehabilitation exercises with loads applied, and eventually include them in the corresponding protocols.

5. Acknowledgments
The authors would like to thank Marcos Crespo (FLENI) and Franka van Velthoven (University of Twente), for their assistance in the assembly of all the experimental settings.

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