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Gait dynamics in Pisa syndrome and Camptocormia: The role of stride length and hip kinematics

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ABSTRACT

This is an observational cross-sectional study evaluating gait dynamics in patients with Parkinson's Disease (PD) and severe postural deformities, PD without axial deviations and healthy subjects. Ten PS individuals with Pisa syndrome (PS) and nine subjects with Camptocormia (CC) performed 3-D Gait Analysis and were evaluated with walking and balance scales. Correlations with clinical and functional scales were investigated. Spatio-temporal and kinematic data were compared to ten PD subjects without postural deformities (PP) and ten healthy matched individuals (CG). Data obtained showed decreased walking velocity, stride and step length in PP, PS and CC groups compared to controls. The correlation analysis showed that stride and step length were associated with reduced functional abilities and disease severity in PS and CC groups. Kinematic data revealed marked reduction in range of movements (ROMs) at all lower-extremity joints in PS group. While, in CC group the main differences were pronounced in hip and knee joints. PS and CC groups presented a more pronounced reduction in hip articular excursion compared to PP subjects, revealing an increased hip flexion pattern during gait cycle. Moreover, the increased hip and knee flexion pattern adversely affected functional performance during walking tests. Results obtained provide evidence that step length, along with stride length, can be proposed as simple and clear indicators of disease severity and reduced functional abilities. The reduction of ROMs at hip joint represented an important mechanism contributing to decreased walking velocity, balance impairment and reduced gait performance in PD patients with postural deformities.

1. Introduction

Patients with Parkinson's Disease (PD) often present with abnormal posture, with a subset of patients showing severe postural deformities, including Pisa syndrome and camptocormia [1]. Pisa syndrome refers to a marked lateral trunk flexion of more than 10°, which is typically mobile and it resolves by passive mobilization or lying down [2]. It presents a prevalence of 8,8%, affecting predominantly patients with significantly longer disease duration, more severe disease and worse quality of life [3]. Camptocormia is used to describe a marked flexion of the thoraco-lumbar spine of at least 40–45°, appearing in standing position, increasing while walking and resolving in supine position [2]. At first, these abnormalities were described as truncal dystonia, analogous to that occurring in non-parkinsonian patient as a side-effect of neuroleptics' treatment [2,4]. Nowadays, the pathophysiology is very probably multifactorial, even if the bulk of the data supports central, rather than peripheral, hypotheses. Peripheral hypotheses take into account unspecific myopathic changes of paraspinal muscles: a focal myopathy has been demonstrated by EMG, CT and MRI scans and biopsy [5]. The central hypotheses, supported by both animal studies and clinical data, include an asymmetric functioning of basal ganglia output, leading directly to asymmetric regulation of postural muscle tone, inducing a misperception of body orientation and the adoption of an asymmetric posture [4]. Anyway, as far as the underlying pathophysiology of these postural deformities is still largely unknown and debated, their management remains difficult.

Marked alterations of gait are common in advanced PD, while perturbations of postural reflexes may be responsible for postural instability. Gait impairments, together with turning and balance disturbances, are the most important determinants of falls among people with PD. The negative impact of gait disorders on QoL is related to immobility and increased risk of falling [6]. Postural instability represents a disabling feature associated with difficulties in postural transfers, progressive loss of independence, immobility and high risk of

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sudden falls [7]. In this panorama, it is widely recognized that postural deformities may cause and worsen gait impairments, postural imbalance and functional disabilty [8], indipendently of others motor symptoms [1]. Therefore, the management of such abnormalities have recently attracted attention, even if it still remains a challenge. Recently, suggestions for clinical practice have been put forward, addressing the importance to consider both pharmacological and non-pharmacological interventions as integral parts of a comprehensive rehabilitative plan [4].

Current literature present a plenty of study aiming at objectively quantifying gait pattern in subjects with PD [9–11]. To our knowledge, only one study evaluated gait abnormalities in PD patients with Pysa syndrome, focusing almost on static postural control and balance [8]. Therefore, the characterization of gait abnormalities in PD patients with postural deviations could be relevant in order to describe distinctive walking patterns and direct specific rehabilitative strategies.

The purpose of our study is to quantitative assess gait dynamics in PD patients affected by postural deformities, Pisa syndrome and camptocormia, compared to a group of PD subjects without axial deviations and to a group of age-matched healthy subjects. Moreover, we try to reveal if disease severity is related to spatio-temporal and kinematic data in PS and CC groups. In the end, we evaluate if functional abilities during walking tests are related to spatio-temporal and kinematic data in the two groups of PD individuals with postural abnormalities.

2. Patients & methods

Twenty-nine subjects diagnosed with Parkinson's disease from the Unit of Neurology (University Hospital of Pisa, Italy) were recruited. Patients presented the following postural deformities: Pisa syndrome, defined as at least 10° of lateral trunk flexion, or camptocormia, defined as an anterior trunk flexion of at least 40°, reducible by passive mobilization or supine positioning. All participants (mean age 71 ± 6,4 years) were divided into three groups: Group PS, including 10 subjects with Pisa syndrome; Group CC, including 9 subjects with camptocormia; Group PP, including 10 subjects diagnosed with Parkinson's disease without postural deformities. Moreover, 10 healthy subjects (CG) were individualized to partecipate as a control group.

Inclusion criteria were:

- diagnosis of Parkinson's disease, according to the United Kingdom Parkinson's Disease Society Brain Bank criteria [12]
- postural deformities (Pisa syndrome or camptocormia);
- walking ability for a short distance (10 m) without use of device;
- age over 18 years.

Exclusion criteria were:

- severe dyskinesia or "on-off" fluctuations;
- need for assistive devices to rise from a chair or bed;
- severe cardiopulmonary disease;
- severe lower limbs arthritis;
- severe motor disability due to other neurological or orthopedic diseases;
- other vertebral diseases (scoliosis, spondiloartrosis) evaluated with X-ray;
- important cognitive deficit (MMSE < 24).

Anthropometric data of parkinsonian patients are summarized in Table 2. All subjects underwent functional evaluations and gait analysis, after giving their informed consent to partecipate in the study.

The disease duration (DD) and the time of postural deviation's onset (PO) were determined for all parkinsonian patients with axial deviations, (Table 2). Moreover, all PD patients were classified with the Hoehn and Yahr disease rating scale (HY) [13] and examined according to the motor section of the Unified Parkinson's Disease Rating Scale (UPDRSIII) [14], (Table 2). Patients also performed the following functional evaluations: Six-minute walk test (6MWT), 10-m Walking Test (10mWT), Timed Up and Go Test (TUG) and Berg Balance Scale (BBS) [15–17].

The study was carried out according to the Declaration of Helsinki and was approved by the Local Ethics Committee.

2.1. Gait analysis

All subjects underwent 3-D Gait Analysis performed at Motion Analysis Laboratory of Neurorehabilitation Unit of the University Hospital of Pisa, using the ELITE System (BTS Bioengineering, Milan, Italy). Before the recordings, general and anthropometric data were collected. The gait tests were performed during the on-phase of the medication cycle (1–2 h after intake of their morning dose). Then, spatio-temporal and kinematics data were acquired through six photogrammetric system infrared cameras acquiring at a sampling frequency of 100 Hz 18 reflective markers were placed on definite anatomical landmarks for kinematic acquisitions, according to Davis protocol [18]. Acquisitions were made in standing position and during barefoot walking at self-selected speed, recording at least three trials for each limb.

2.2. Data analysis

Spatio-temporal and kinematic parameters analysis for the hip, knee, and ankle joints were performed by using BTS Elite Clinic software. The following spatio-temporal parameters were analyzed: walking velocity, cadence, stride time, stride length, step time, step length, step width and the percentages of stance and swing phases compared to the total duration of gait cycle.

As regard the kinematic pattern, a body model accounting for each body segments was used to calculate articular angular excursions along the gait cycle. In the sagittal plane, the value of the maximum and the minimum angle reached in each joint (hip, knee, ankle) was calculated. Furthermore, the dynamic range of motion (ROM) of each joint was determined. Further analysis were performed using MATLAB.

2.3. Statistical analysis

Variables across groups were tested for normality with Shapiro-Wilk test. The four groups were matched for anthropometric variables such as age, sex, height, weight and BMI as confirmed with Kruskal-Wallis H test for non-parametric samples (Table 1). Data were analyzed non-parametrically with the Mann-Whitney *U*-test for independent group comparisons. Further, Spearman's coefficient was used to analyze the correlations between disease severity and spatio-temporal data (step and stride length) and kinematic data (knee ROM, hip ROM, hip flexion in stance phase of gait cycle) in PS and CC groups. Moreover, the correlations between functional tests (6MWT, 10 MWT, TUG, BBS) and spatio-temporal data (step and stride length) and kinematic data (hip ROM, knee ROM, hip flexion in stance phase of gait cycle) were

Table 1
Groups' characteristics.

	PS	CC	PP	CG	*p*
Age (years)	67,7 ± 4,3	72,2 ± 5,2	73,2 ± 8,1	68,8 ± 10	0,24
Sex (F/M)	5F/5M	2F/7M	4F/6M	7F/3M	0,21
Height (m)	1,67 ± 1,07	1,73 ± 0,09	1,66 ± 0,08	1,65 ± 0,08	0,29
Weight (Kg)	72,6 ± 10,8	77,6 ± 15,2	61,4 ± 11,8	66,4 ± 8,8	0,06
BMI	25,8 ± 3,1	25,6 ± 3,8	22,1 ± 3,1	24,3 ± 4,3	0,07

NOTE. Values are mean ± standard deviation (SD). Abbreviations: BMI, Body Mass Index; PS, Pysa syndrome; CC camptocormia; PP, Parkinson disease without postural deformities; CG, healthy subjects. *Significant at $p < 0.05$.