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Use of the Gait Profile Score for the quantification of the effects of Robot-Assisted Gait Training in patients with Parkinson's Disease

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Abstract— **The recovery of walking is a crucial aspect in rehabilitation of patients with Parkinson's disease (PD). The aim of this research was to quantify the effects of an end-effector robotic rehabilitation locomotion training in a group of PD patients using 3D gait analysis (GA). In particular, spatio-temporal parameters and kinematics variables by means of synthetic indexes (Gait Profile Score, GPS, and its Gait Variable Scores GVSs) were computed from GA at baseline, before the treatment (T0), and at the end of the rehabilitative program (T1). At T1 statistically significant improvements were found particularly in terms of spatio-temporal parameters (velocity, step length and cadence). No changes were observed as for GPS, while a trend towards improvement was found in terms of GVSs of pelvis and hip on the frontal plane. From these results, the use of Gait analysis has allowed to provide quantitative data about the end-effector robotic rehabilitation evidencing those joints more sensible to the treatment. The robotic locomotion training seems to improve gait pattern in patients with PD and in particular, the effect is on spatio-temporal parameters.**

***Keywords*: Gait Analysis; Gait Profile Score; Parkinson's disease; robotic rehabilitation.**

I. INTRODUCTION

In Parkinson's disease (PD) gait disorders are among the most common and disabling symptoms [1, 2], which may manifest in a variety of clinical involvements of body segments. Thus, the gait recovery represents an important goal of rehabilitation in PD patients. Recently, robotic assisted devices have been used for gait training in PD, with good results [3, 4, 5, 6].

Most of these analyses have been conducted mainly in terms of clinical evaluations and questionnaire and only two studies quantified the outcomes of this treatment using Gait Analysis (GA) [5, 7]. However, these studies assessed only spatio-temporal parameters, without evaluating lower limb kinematics. In this study, the effects of gait kinematics of an end-effector robotic rehabilitation locomotion training in patients with PD were quantified.

II. METHODS

A. Subjects

Twenty-three PD patients were recruited for this study (age: 68.6 ± 6.2 years). They were in a stable doses of Parkinson's medications for at least 4 weeks prior to study and showed independent walking ability (without aids).

The examination included GA at baseline, before the treatment (T0), and at the end (T1) of the robot-assisted therapy.

This study was approved by the ethics committees of IRCCS San Raffaele Pisana, Roma and informed consent was obtained from all subjects enrolled in this study.

B. 3D-Gait Analysis and clinical evaluation

All participants were assessed using an optoelectronic system (BTS, Milan, Italy). For the evaluation of the gait kinematics passive markers were placed on the subject's skin, according to Davis [8]. After collecting some anthropometric measures (height, weight, tibial length, distance between the femoral condyles or diameter of the knee, distance between the malleoli or diameter of the ankle, distance between the anterior iliac spines and thickness of the pelvis), passive markers were placed at special points of reference, directly on the subject's skin, and in particular at C7, sacrum and bilaterally at the ASIS, greater trochanter, femoral epicondyle, femoral wand, tibial head, tibial wand, lateral malleolus, lateral aspect of the foot at the fifth metatarsal head and at the heel (only for static offset measurements). All acquisitions were acquired by the same operator to assure reproducibility of the acquisition

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technique and to avoid the introduction of errors due to different operators.

Five trials were acquired asking the participants to walk at their self-selected velocity and barefoot. In terms of clinical evaluation, they were assessed by UPDRS III score. A control group of 15 healthy subjects (Control Group: CG; age: 70.9±5.5) were used as normality group.

The patients' evaluations were performed in two different sessions: at baseline, before starting with the treatment (T0) and at the end of the treatment (T1).

C. Therapeutic intervention

Patients underwent a cycle of out-patients rehabilitation treatment, consisting of at least a daily 3-hour cycle, divided into 45 minutes of treatment for lower limb with robotic device and a treatment of occupational therapy for the upper limb.

As concerns robot-assisted therapy each subject was asked to perform 20 sessions (5 days a week for 4 weeks) of robot assisted gait training, using the end effector system machines G-EO system device (Reha Technology AG; Olten, Switzerland) [9]. The engineering characteristic of G-EO robot is based on end effector device with Body Weight Support (BWS) and a footplate placed on a double crank and a rocker gear system, and with 3 DoF each, which allows the control of the length and the height of the steps. The footplate angles can be used to simulate a real over-ground high repetitive walk [10] (Figure 1).

Figure 1: G-EO system device

The trajectories of the footplates and the vertical and horizontal movements of the centre of mass are fully programmable, enabling wheelchair-bound subjects not only for the repetitive practice of simulated floor walking, but also to climb up and down the stairs. The parameters of the treatment were noted for each session, and the steps taken during the simulated walking were converted into the distance covered, based on the step length previously chosen [11]. The practice included a robot-assisted walking therapy, at variable speeds, for 45 minutes, with a partial BWS. All participants started with 30-40% of BWS and an initial speed of 1.5 km/h; afterwards, speed was increased to a range of 2.2 to 2.5 km/h maximum and initial BWS was decreased [9].

D. Data analysis

In this analysis, spatio-temporal parameters and kinematic data were considered. As concerns spatio-temporal parameters, we considered the followings: % stance (as % of the gait cycle), mean velocity (m/s), step length (m), step width (mm) and cadence (steps/min).

From the kinematic data, the Gait Profile Score (GPS) was computed. The GPS is a single index outcome measure that summarises the overall quality of the patient's kinematics. In addition to a global measure of the overall gait quality, it can be deconstructed to provide the gait variable score (GVS) (an index that measures single gait variable deviation) for nine key relevant kinematic variables (the pelvis and hip in three planes, the knee and ankle on the sagittal plane and the foot progression) [12]. The higher the GPS value is, the less physiological gait pattern is.

E. Statistical analysis

The parameters were not normally distributed, subsequently the median and quartile range (IQR) of all indexes were calculated. The Wilcoxon paired test was used to compare the baseline (T0) and endpoint (T1), in order to determine whether the treatment introduced statistically significant changes. The T0 and T1 data of patients and CG were compared with Mann-Whitney U test. P-values less than 0.05 were considered significant.

III. RESULTS

As concerns spatio-temporal parameters, the results showed statistical improvements in terms of mean velocity, step length and cadence (Table I). No changes occurred as for the other spatio-temporal parameters.

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Table I: Spatio-temporal parameters for the patients and the Control Group (CG). *= p-value < 0.05, T0 vs. T1; += p< 0.05, T0/T1 compared with CG.

	PD patients		Control group
	T0 session	T1 session	
% stance (%gait cycle)	62.1 (3.6)+	61.9 (3.9)+	58.9 (1.2)
Mean velocity (m/s)	0.3 (0.2)+	0.7 (0.2)+,*	1.2 (0.1)
Step length (m)	0.2 (0.1)+	0.4 (0.1)+, *	0.7 (0.1)
Step width (mm)	144.4 (39.1)+	139.8 (20.1)+	115.5(25.9)
Cadence (step/min)	98.1 (15.9)+	101.1 (12.7)+,*	118.1 (6.1)

The kinematic data showed that while globally no differences were found in terms of GPS (T0: 10.3±2.1 degrees vs. T1: 10.9±3.0 degrees; p> 0.05; CG: 6.5±1.2 degrees), some significant improvements were displayed by GVSs, and in particular by Pelvic Up/Down (T0: 4.4±1.8 degrees vs. T1: 3.1±0.8 degrees; p< 0.05; CG: 1.4±0.6 degrees) and Hip Ab-Adduction (T0: 6.3+3.4 degrees vs. T1: 4.8+1.8 degrees; p<0.05; CG: 4.7±3.7 degrees).

As concerns clinical evaluation, the score of UPDRS III improved significantly (T0: 36.9 vs. T1: 31.9; p < 0.05).

IV. DISCUSSION

The data obtained by this study showed that after the robot-assisted gait training, significant changes were observed in PD patients both in terms of spatio-temporal parameters and in terms of some features of gait kinematics. As concerns spatio temporal parameters, we observed significant improvements as for velocity, step length and cadence, confirming literature [9]. Data obtained by kinematics showed that globally no changes occurred after robot training, as demonstrated by GPS; a trend towards improvement appeared at GVS of pelvis and hip on the frontal plane. Even if an improvement of velocity appeared, no significant changes occurred in terms of angular displacement. This result could be in agreement with literature, which showed that the peak sagittal plane kinematic parameters have poor relationships with gait speed [13].

From a clinical point of view, these results are important because showed that the use of GVSs let possible to evidence the joints more involved in the changes induced by the therapy. Besides this robot-assisted gait training used in this study, based on an end effector system machine, has had significant effects on gait strategy in particular in terms of spatio-temporal parameters. Thus, the robot training based on an end effector system seems to be a promising technique for rehabilitation in patients with PD; the positive results from patients support the recommendation to extend the study to a larger cohort. This type of intense stereotyped somatosensory cueing and stimulation could help in fact the functional recovery of the gait automatism and speed. Our results showed how this robot made a significant gain, in gait recovery especially of spatio-temporal parameters, with an important patient's safety, confirming previous research [9]. This approach can contribute to increase a short time lower limb motor recovery in PD patients.

Further researches should be conducted in future considering a larger number of patients, so to confirm our results, and comparing the results of this treatment obtained in this study with other rehabilitative treatments for PD patients. In addition, a limit of the use of a summary parameter, such as GPS and its GVSs, to quantify the gait patterns of a subject or the effects of a treatment is that favourable and adverse changes might be masked when using a single number; so, further researchers could be performed considering an in-depth analysis of GA plots, so to have the correct overview of the patient's gait pattern.

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