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Short Communication

Validation of GDI, GPS and GVS for use in Parkinson's disease through evaluation of effects of subthalamic deep brain stimulation and levodopa

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ABSTRACT

The Gait Deviation Index (GDI), Gait Profile Score (GPS) and Gait Variable Scores (GVSs) have been proposed as measures of gait quality and validated for use with children with cerebral palsy. The aim of this study was to extend this validation to people with Parkinson's disease by evaluating the effects of subthalamic deep brain stimulation and levodopa on gait. 16 participants had their gait evaluated with stimulation, medication or a combination of both. The Unified Parkinson's Disease Rating Scale (UPDRS) showed statistically significant differences in agreement with previous studies. The GPS and GDI showed similar treatment effects as did GVS for hip and knee flexion/extension, as assessed with Cohen's d where medium or large. Overall the results suggest that these gait indices are sensitive to treatment in this group of patients and that their use in groups other than children with cerebral palsy is valid.

1. Introduction

Movement disorders, particularly locomotor deficits, are frequent and incapacitating characteristics of Parkinson's disease (PD) [1]. Three-dimensional gait analysis can characterize alterations in movement patterns, but results in a considerable amount of data that requires complex interpretation [2–5]. Gait indices such as the Gait Profile Score (GPS) [6] and Gait Deviation Index (GDI) [7] have recently been proposed and validated for different conditions. This study was designed to investigate their application to PD.

Validation is based upon the known response of people with PD to levodopa and high frequency deep brain stimulation (DBS) of the subthalamic nucleus. Studies show improvements in kinematic variables of gait after DBS [4,8] or in patients who use only levodopa [9,10]. We establish whether the GDI, GPS, and the Gait Variable Scores (GVSs) which comprise the Movement Analysis Profile (MAP) reflect this.

2. Methods

2.1. Participants

Participants were recruited from the Hospital das Clínicas (HCFMUSP, Brazil). Inclusion criteria were: an adult diagnosed with PD, implanted bilateral DBS at least 12 months prior to assessment (frequency > 100 Hz, pulse amplitude 60–120 μs, voltage 2.5–5 V), clinically stable, classified between levels 1 and 3 on the Hoehn–Yahr modified scale under the effect of medication and stimulation [11] with a Mini Mental State Examination score greater than 24 points [12], and able to walk independently without the use of antiparkinsonian medication and with the DBS switched off. Exclusion criteria were: uncontrolled infection or other pre-existing uncontrolled medical conditions, concomitant treatment with experimental drugs, a history of orthopedic surgery, and cognitive, visual, and auditory deficits. Sixteen individuals (11 male) were recruited (mean age

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Table 1
Descriptive and demographic characteristics of patients with DBS.

PD	Age (years)	Gender	Height (cm)	Body mass (kg)	H&Y	Duration of PD (years)	Levodopa (years)	Dosage levodopa (mg/day)	DBS (months)
Mean	58.31	11 M/5 F	168.31	68.34	2.22	20.63	17.81	456.25	20.18
SD	12.38		11.85	12.61	0.41	7.17	4.97	190.50	5.33

Abbreviations: PD, Parkinson's disease; M, male; F, female; cm, centimeters; kg, kilograms; H&Y, Hoehn and Yahr modified; mg/day, equivalent dosage of levodopa in milligrams per day. Values are expressed as mean and standard deviation (SD).

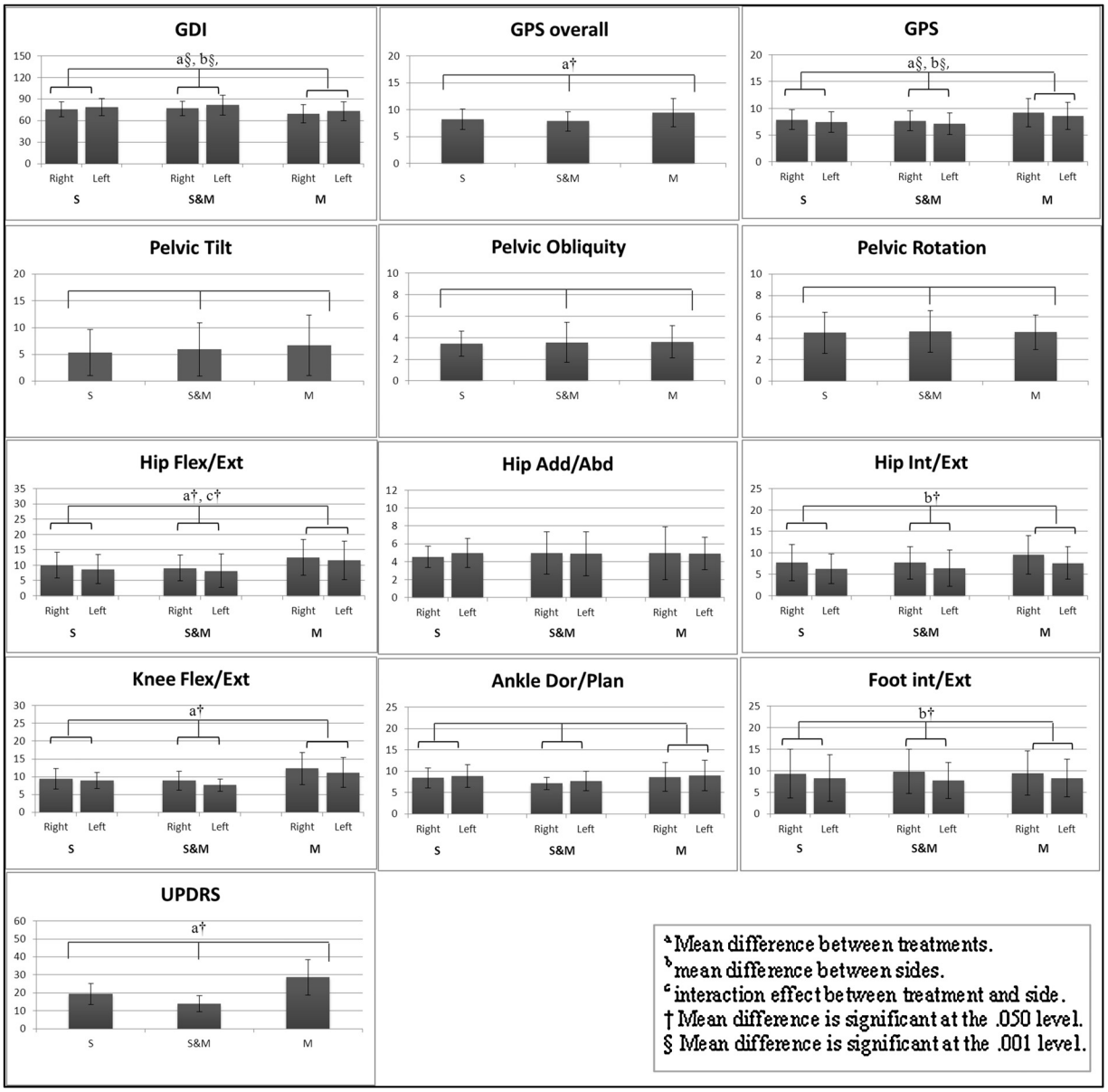

Fig. 1. Variables UPDRS, GDI and GPS/MAP during gait in patients with Parkinson's disease under treatment effects stimulation only (S), medication only (M) and both (S&M).

58.3 ± 12.3 years). This study received approval from the local ethics committee and all of the participants signed statements of informed consent.

2.2. Procedures

Assessments were performed in the Human Motion Analysis Laboratory at Universidade Nove de Julho under three conditions: Stimulation only (S), medication only (M), and both (S&M). Each patient attended on two days (randomized). On one day the patient arrived without having used medication for 12 h and underwent gait analysis (condition S). Forty minutes after taking medication another analysis was performed (condition S&M). On the other day, the patient took their medication as usual but a portable external programmer (Medtronic® Itrel model 3625, Minneapolis, USA) was used to switch off the DBS 3 h before the analysis (condition M).

Patients were instructed to walk barefoot on a track measuring 1.5 m × 4.0 m at a self-selected speed. Each gait analysis session consisted of at least ten trials. Six representative trials were selected for further analysis.

Under each condition, the patients were sent to another room and assessed by the same trained examiner using the Unified Parkinson's Disease Rating Scale (UPDRS, motor section III).

The examiner was blind as to which condition the patient was under. The score for each of the 27 items assessed ranged from 0 to 4, with the highest value indicating a greater influence of the disease and the lowest value indicating normality.

2.3. Equipment, processing and data analysis

Sixteen retro-reflective spherical markers were placed according to the conventional gait model [13,14]. Three-dimensional marker trajectories were captured with an eight-camera SMART-D® BTS system (Milan, Italy) at 100 Hz and then filtered (fourth-order Butterworth filter, cut-off frequency 8 Hz). These were exported to C3D format using SMART-Tracker® software and then labeled and processed in Vicon Nexus® software (VICON, Oxford, UK) using the Plug-in Gait® model. GDI [7] and GPS [7] indices were then calculated for each limb in relationship to normal data for 24 healthy age- and gender-matched subjects (60 ± 5 years; 14 men), provided by the motion analysis laboratory at the Hospital Israelita Albert Einstein, São Paulo. Neither the GPS nor the MAP components were normally distributed; thus, logarithmic transformations were performed before applying parametric statistics.

The power of the sample was calculated using the variance between repeated measurements (repeated-measures ANOVA), based on the minimal clinically significant difference of 2.3–2.7 points found in the UPDRS [15]. The values obtained were $\alpha = 0.05$ and power = 90%. The descriptive variables and all measurements were expressed as means and standard deviations. Analysis of repeated-measures ANOVA was used to compare the means of the three conditions for each of the variables studied. Tukey's multiple comparison test was used when differences were found. Interactions between the variables and treatments were also analyzed.

Cohen's d was used to measure the effect size of treatments, for power analysis purposes [16]. The effect size was classified as small when $d \geq 0.2$, medium when $d \geq 0.5$, and large when $d \geq 0.8$. Statistical significance in all tests was set at 5% ($P < 0.05$). The Statistical Package for Social Sciences, version 15, was used for the analysis (SPSS Inc., Chicago, USA).

3. Results

Table 1 displays the descriptive and demographic characteristics of the patients. Fig. 1 summarizes the results using the means and standard deviations of the variables for each treatment type. UPDRS scores were considerably lower (better) under condition S, and there was only a modest improvement under condition S&M. These patterns were seen in both the overall GPS and the GPS and GDI at the limb level and in the flexion/extension components of the GPS in the hip and knee. There were also statistically significant differences between sides (left or right) for the GDI, GPS, and GVS components for hip internal rotation and foot internal progressions. There was a significant interaction between condition and side for hip flexion/extension GVS. Table 2 shows the effect sizes for those variables showing statistically significant changes.

Table 2
Effect size of the variables UPDRS, GDI and GPS/MAP during gait in patients with Parkinson's disease under treatment effects stimulation only (S), medication only (M) and both (S&M).

	Effect size S vs. M		Effect size S&M vs. M	
UPDRS	1.125		1.932	
GPS overall	0.55		0.72	
	Right	Left	Right	Left
GDI	0.49	0.45	0.62	0.60
GPS	0.55	0.51	0.63	0.62
Hip Flx/Ext	0.50	0.51	0.68	0.57
Knee Flx/Ext	0.78	0.64	0.93	1.10

Effect size: small $d \geq 0.2$; medium $d \geq 0.5$; large $d \geq 0.8$.

4. Discussion

The effect of stimulation and medication in people with PD is well established. Stimulation gives marked improvements compared to medication, but the combination is little better than stimulation only as assessed by UPDRS for walking speed and stride/step length [1–5,8,17–20] and joint range of movement [2–5]. UPDRS data in this study agrees. The GDI and GPS data followed similar patterns, giving strong evidence that they would be meaningful measures in patients with PD as well as the populations for whom they were originally developed. As remarked by Baker et al. [6] there is a strong mathematical relationship between GDI and GPS, so qualitative agreement is inevitable. Inclusion of data from both allows comparison of absolute scores.

Differences in the GVS for hip and knee flexion/extension followed the same pattern. Differences are known to exist in ankle range of motion [2–5], but this study did not find a statistically significant difference, possibly because the GVS used data from the entire gait cycle rather than at only maximum dorsiflexion and plantarflexion. There was a statistically significant difference between left and right sides for the GPS and GDI, which was unexpected. The importance of the GVS was illustrated here because it allowed identification of this phenomenon primarily in the transverse plane at the hip and foot. There appeared to be an interaction between treatment and side for hip flexion/extension which agrees with the findings of Johnsen et al. [2].

The overall conclusion of this study is that the GDI, GPS, and GVS follow the known responses to medication and stimulation of people with PD. This strongly suggests that the measures are valid for use on people with this condition and further suggests a general validity of using the measures on populations other than those for whom they was designed, which was children with cerebral palsy.

Conflict of interest statement

The authors declare that there are no conflict of interest.

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