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Unraveling gait automaticity decline independent of cognitive decline in Parkinson's disease: A study using the new Parkinson's Affordable Neuro-movement Detection and Analysis (PANDA) system

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Abstract

The following protocol was used in the study: Unraveling gait automaticity decline independent of cognitive decline in Parkinson's disease: a study using the new Parkinson's Affordable Neuro-movement Detection and Analysis (PANDA) system. This cross-sectional study evaluated gait automaticity decline across Parkinson's disease (PD) stages, controlling for cognition, age, sex, and education. Participants, grouped by Hoehn and Yahr (H&Y) stages, completed gait tests under two dual-task conditions (verbal fluency and countdown tasks). The Gait Performance Index (GPI), calculated from gait parameters, revealed a progressive decline in automaticity starting in early PD stages, particularly during verbal fluency tasks. The study highlights the GPI, obtained via the cost-effective PANDA system, as a potential tool for early detection and monitoring of gait decline in clinical practice.

1 Abstract

The following protocol was used in the study: Unraveling gait automaticity decline independent of cognitive decline in Parkinson's disease: a study using the new Parkinson's Affordable Neuro-movement Detection and Analysis (PANDA) system. This cross-sectional study evaluated gait automaticity decline across Parkinson's disease (PD) stages, controlling for cognition, age, sex, and education. Participants, grouped by Hoehn and Yahr (H&Y) stages, completed gait tests under two dual-task conditions (verbal fluency and countdown tasks). The Gait Performance Index (GPI), calculated from gait parameters, revealed a progressive decline in automaticity starting in early PD stages, particularly during verbal fluency tasks. The study highlights the GPI, obtained via the cost-effective PANDA system, as a potential tool for early detection and monitoring of gait decline in clinical practice.

The following document describes in detail (step-by-step) the protocols used.

Study design and Ethic

- 2 A cross-sectional study in agreement with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (<https://www.equator-network.org/reporting-guidelines/strobe/>)

This study was approved by the proper Ethics Committee (#CAAE 67388816.2.0000.065) and conducted in accordance with the Helsinki Declaration.

Participants

3 Inclusion criteria:

- People aged between 35–85 years of age;
- With confirmed diagnosis of idiopathic PD according to the diagnostic criteria of the UK Parkinson's Disease Society Brain Bank (1);
- In stages I–III according to H&Y (1);
- Using dopaminergic medication;
- With the ability to ambulate independently;
- With no signs of dementia (determined by a Montreal Cognitive Assessment (MoCA) score ≥ 21) or major depression (determined by a Geriatric Depression Scale score ≤ 6) (2,3);
- Who agreed to participate in the study.

4 Non-eligibility criteria:

- The presence of neurological disorders other than PD;
- The presence of musculoskeletal, cardiovascular, or respiratory diseases or uncorrected visual/auditory disturbances that could interfere with gait performance.

Recruitment

- 5 Participants were recruited consecutively from the contacts of the AMPARO network (www.amparo.numec.prp.usp.br) between June 2018 and June 2020 using a non-probability sampling method. The AMPARO Network is Part of the Research, Innovation, and Dissemination Center for Neuromathematics (RIDC NeuroMat), and its main objective is to enhance the quality of life of people with PD in Brazil. This network comprises people with PD, their family members, caregivers, students, health professionals, and researchers who are interested in PD. To ensure group matching by H&Y stages, participants' age, sex, schooling, and MoCA scores were controlled. Initially, eligibility criteria were verified. Subsequently, information about the study procedures was passed on, and those selected were asked to consent to participate.

Procedures

- 6 All participants were tested 40 to 120 minutes after their L-dopa dose (ON period) during a single individual session conducted by a physiotherapist who specialized in movement disorders and trained to apply all tests and scales.
- 6.1 **Movement Disorder Society-sponsored Unified Parkinson's Disease Rating Scale – Section III (MDS-UPDRS III).**
The severity of motor symptoms was assessed using MDS-UPDRS III. This section comprises 18 tests scored on an ordinal scale from 0 (low severity) to 4 (high severity) and was treated as a continuous variable. The MDS-UPDRS III has

demonstrated excellent factor validity, test-retest reliability (ICC $\frac{1}{4}$ = .93), high internal consistency, and responsiveness (4).

Available: movementdisorders.org

6.2 **Montreal Cognitive Assessment (MoCA)**

Global cognitive capacity was evaluated using the MoCA, a widely recognized tool for detecting cognitive symptoms, including mild ones. The MoCA effectively distinguishes PD patients in different cognitive states (no cognitive impairment, mild cognitive impairment, or dementia) from healthy controls (2,4,5), and it can detect changes even in the early stages of the disease (6). This tool has been used in several studies to investigate DT performance (7,8,9).

Available: mocacognition.com

6.3 **Geriatric Depression Scale (GDS)**

Depressive symptoms were assessed using the Geriatric Depression Scale (GDS), a standard self-report rating scale for depression in PD (10). The GDS short form includes 15 dichotomous questions (YES or NO) regarding the participant's mood, with higher scores indicating a greater likelihood of depression.

Available: <https://integrationacademy.ahrq.gov/>

6.4 **Gait assessments**

Following the clinical evaluation, participants performed three gait tests under single task (ST) and DT conditions. Visual markers indicating each test's start and end positions were placed on the floor. The use of assistive devices was not permitted.

The order of the gait test, conditions, and cognitive task parameters was randomized. The randomization process involved drawing pieces of paper, each specifying details about the gait test, conditions, and cognitive task parameters.

1) Gait test order: 10-meter walk test (10mWT), Timed Up and Go (TUG), and 6-meter walk test using PANDA system (see below).

2) Conditions order for each gait test: Single Task (ST), i.e., without a concomitant task, DT with the Countdown task (DTc), and DT with the Verbal Fluency task (DTv).

3) Parameters for cognitive tasks: numbers (90-100) for the Countdown task and letters (A-N-O-R-S) for the Verbal Fluency task.

The instruction for ST in all tests was to "walk at your usual speed". For DTc, the instruction was to "walk at your usual speed while counting down as many numbers as possible from X." For DTv, participants were instructed to "walk at your usual speed while saying as many words as possible starting with the letter X, avoiding repetition."

Task prioritization for the DT condition was not applied, as it reduces the ability to discriminate group differences(10).

6-meter walk test using the PANDA system and GPI calculation

The 6-meter walk test using the PANDA system was performed using the following instruments:

- 01 GoPro™ Hero4 Silver camera
- 01 pair of non-slip black socks
- 01 yellow sticker 19 mm in diameter
- 01 calibration paper containing two reference points positioned 20 cm apart
- 01 tripods for the camera with height adjustment GoPro™ application
- CvMob™ software, version 3.6 (<http://cvmob.ufba.br>)

The software's video guide included the camera positioned perpendicular to the plane to be analyzed (0.80 meters high from the ground and 5.70 meters perpendicular), with the evaluator using a caliper positioned sagittally to the movement to be accomplished.

The camera parameters used for filming contained the following configuration:

1. Control via wireless (connected to a Motorola™ Moto X Style smartphone);
2. Field of View (Narrow);
3. 120 frames per second;
4. 720 bpi resolution;
5. The low Light option is turned off.

Participants were instructed to walk in a straight line for 6 meters in a flat, well-lit space free from excessive noise. They wore a pair of non-slip black socks, each featuring a yellow sticker on the left foot's lateral malleolus. The videos were recorded as each participant walked from right to left, which allowed the software to visualize and read the sticker (see Figure 1). Participants were instructed to begin walking as soon as they heard the command "Go" and to stop in the same place when they heard the command "Stop."

The gait stages were identified based on two key moments: when the heel made contact with the ground (initial contact) and when the first toe lifted off the floor (last contact). Participants were instructed to ensure that their left foot, which had a sticker, walked directly along the longitudinal line marked on the floor from the start to the end of the course at a normal pace.

The kinematic gait variables were measured using the CvMob™ movement analysis system. Among the variables analyzed in the study, only the velocity in the Y-axis (VyMedio) was directly extracted from the CvMob™ program. The remaining variables were derived using the Movement Element Decomposition (MED) method, previously described in another article (11). The method analyzed the trajectory and

velocity data of a selected marker (sticker) to break down the movement into distinct elements, defined by periods of zero velocity at both the start and end. From these elements, several variables were estimated: the number of strides (Nx), average stride length (RmX), average stride height (RmY), average stance time (DuPar—the duration during which the foot remained at zero velocity), vertical average swing phase velocity (VmY), average foot swing ascent velocity (VyPos—estimated between the initial and average swing phases), and average foot swing descent velocity (VyNeg—estimated between the mid and final swing phases).

To develop the Gait Performance Index (GPI), three physiotherapists specializing in Parkinson's Disease (PD) and a physicist with expertise in movement analysis examined the behavior of all variables collected by the CvMob[®] system and their connection to the progression of PD. They considered factors that were either directly or inversely related to symmetry, as the analysis tool is two-dimensional and uses only one limb as the primary reference. From this evaluation, five key variables were chosen to represent gait efficiency in terms of energy and stability effectively: Nx, RmX, RmY, VyNeg, and DuPar. The GPI was then defined using these variables in the following equation:(1):

$$GPI = (RmX \bullet RmY \bullet VyNeg) / (DuPar \bullet Nx)$$

A higher Gait Performance Index (GPI) value indicates better gait performance, which is characterized by symmetrical and longer steps in both vertical and horizontal directions, as well as less time spent in double support.

Conversely, a lower GPI value suggests decreased gait performance, marked by a more asymmetrical gait, shorter step height and length, and increased time in double support (12).

The GPI was calculated for ST, DTc, and DTV conditions.

Available:<https://cvmob.wordpress.com/>

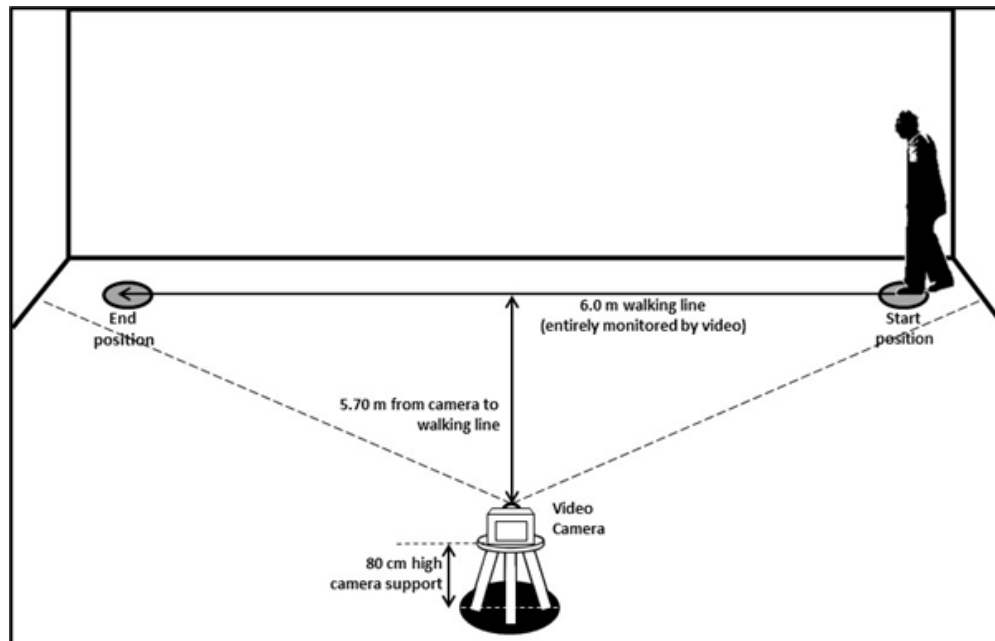


Figure 1: Film recording environment.

10-Meters Walk Test under DT (10mWT-DT)

The 10-Meter Walk Test (10mWT) assesses walking speed over a short distance, expressed in meters per second. Participants were instructed to walk a defined distance, and the time was recorded (13). All participants were evaluated under ST, DTc, and DTv conditions, consistent with other studies that evaluated DT performance in PD (14,15). The time taken to complete the test was measured using a digital stopwatch by a research assistant.

Timed Up & Go Test under DT (TUG-DT)

The TUG test is valuable in an outpatient setting due to its brevity, minimal equipment requirements, and ease of administration. The TUG test correlates strongly with functional mobility and gait velocity in PD patients (16,17). Additionally, it has demonstrated high test-retest and inter-rater reliability in PD populations (18). During the TUG test, participants were instructed to rise from a chair, walk forward at their normal speed for three meters, turn around, walk back to the chair, and sit down. The TUG test under dual-task conditions (TUG-DT) has been utilized to evaluate people with PD (19,20).

All participants were assessed under three conditions: ST, DTc, and DTv. The time taken to complete the test was measured using a digital stopwatch by a research assistant.

Statistical Analysis

- 7 The normal distribution of the samples was assessed using the Kolmogorov-Shapiro test. For variables that demonstrated a normal distribution homogeneity of variance was tested using Levene's test.

Variables that exhibited a normal distribution and homogeneity of variance, including age and years of schooling, were analyzed using One-Way ANOVA, with the groups (H&YI, H&YII, H&YIII) considered as factors. Effect sizes were calculated for each factor that reached a statistically significant level. When statistically significant differences were detected, the Tukey post-hoc test was applied for pairwise comparisons between the groups.

Variables that did not exhibit a normal distribution, including MoCA scores, UPDRS-III scores, GDS scores, TUG-DT, 10mWT-DT, and GPI-DT, were analyzed using Kruskal-Wallis ANOVA (KW-ANOVA), with the groups (H&YI, H&YII, H&YIII) considered as factors. When statistically significant differences were observed, multiple comparisons of the average ranks for each pair of groups were conducted. Normal z-values were computed for each comparison, and post-hoc probabilities were corrected for the number of comparisons for a two-sided test of significance.

Additionally, the Wilcoxon test was used to compare the conditions (ST, DTc, and DTv) for the three gait tests for all participants.

Differences were considered significant when $p < 0.05$. Statistical analyses were performed using Statistica Version 13 (TIBCO Software Inc. USA).

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