Parkinsonism and Related Disorders

Short communication

Computerized assessment of handwriting in de novo Parkinson's disease: A kinematic study

Lola Diaz-Feliz [a,d,*], Pilar Sanz-Cartagena [b], Marcos Faundez-Zanuy [c], José Arbelo-Gonzalez [d], Pedro Garcia-Ruiz [a]

[a] *Neurology Department. Jim´enez Díaz Foundation University Hospital, Spain*
[b] *Neurology Department. Matar´o Hospital, Spain*
[c] *Tecnocampus Matar´o, Spain*
[d] *Neurology Department. University Hospital San Roque. Fernando Pessoa University, Spain*

A R T I C L E I N F O

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A B S T R A C T

Introduction: Dysgraphia, a recognized PD motor symptom, lacks effective clinical assessment. Current evaluation relies on motor assessment scales.
Computational methods introduced over the past decade offer an objective dysgraphia assessment, considering size, duration, speed, and handwriting fluency. Objective evaluation of dysgraphia may be of help for early diagnosis of PD.
Objective: Computerized assessment of dysgraphia in de novo PD patients and its correlation with clinical scales.
Methods: We evaluated 38 recently diagnosed, premedication PD patients and age-matched controls without neurological disorders. Participants wrote "La casa de Pamplona es bonita" three times on paper and once on a Wacom tablet under the paper, totaling four phrases. Writing segments of 5–10 s were analyzed. The Wacom tablet captured kinematic data, including mean velocity, mean acceleration, and pen pressure. Data were saved in.svc format and analyzed using specialized software developed by Tecnocampus Mataro´. Standard clinical practice data, Hoehn & Yahr staging, and UPDRS scales were used for evaluation.
Results: Significant kinematic differences existed; patients had lower mean speed (27 ± 12 vs. 48 ± 18, $p < 0.0001$) and mean acceleration (7.2 ± 3.9 vs. 15.01 ± 7, $p < 0.0001$) than controls. Mean speed and mean acceleration correlated significantly with UPDRS III scores (speed: $r = -0.52$, $p < 0.0007$; acceleration: $r = 0.60$, $p < 0.0001$), indicating kinematic parameters' potential in PD evaluation.
Conclusions: Dysgraphia is identifiable in PD patients, even de novo, indicating an early symptom and correlates with clinical scales, offering potential for objective PD patient evaluation.

1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disease, and its prevalence is projected to double over the next 30 years [1]. Early-stage diagnosis primarily relies on clinical assessment by a neurologist [1].

Handwriting involves the integration of cognitive, kinesthetic, and perceptual-motor skills, making it a complex task easily affected by neurological disorders [2]. Although not a diagnostic criterion for PD, altered handwriting is frequently observed as an initial symptoms [3]. Therefore, handwriting impairments have been explored as potential diagnostic signals for developing an independent and reliable diagnostic support system for early PD detection [2].

Dysgraphia, a well-established motor symptom of PD, manifests as difficulties in writing, often preceding other motor symptoms. Micrographia, characterized by abnormally small handwriting, occurs in about 5 % of PD patients before the onset of classical motor symptoms [4].

Evaluating dysgraphia is challenging, as current clinical assessments rely on subjective motor rating scales [2]. Letanneux et al. proposed the term Parkinsonian dysgraphia based on four variables: duration, speed, fluency, and size, to study graphomotor impairment in PD. Alterations in

* Corresponding author. Neuroscience UAM-Cajal, Neurology Department, Movement Disorder Unit. University Hospital San Roque, Fernando Pessoa University, Las Palmas. Dolores de la Rocha 5, 35001, Las Palmas, GC, Spain.
E-mail address: lola.diaz@estudiante.uam.es (L. Diaz-Feliz).

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handwriting kinematics are among the recently proposed biomarkers for PD, offering a potential objective measure for early diagnosis and disease progression [2,4–6].

Assessing the improvement of motor symptoms in response to dopaminergic treatment is crucial for differential diagnosis and tracking disease progression [9,10].

During the last decade, computational methods have been introduced to evaluate dysgraphia objectively [5–7]. Kinematic variables such as speed and fluency of writing allow differentiation between patients and controls, as well as between and on- and off-medication treatment situations [8].

Recent advances in digital tablet technology have been revolutionary in the study of various handwriting components [2]. These technologies enable the measurement of handwriting speed and fluency, and the quantification of letter size, which are not possible to study objectively using the traditional paper and pencil method. The aim of this work was to evaluate computerized handwriting impairments in patients with newly diagnosed PD.

2. Methods

We evaluated 38 recently diagnosed, premedication PD patients (per UK Brain Bank Criteria) and age-matched controls without neurological disorders. Handwriting recording sessions involved instructed writing tasks. Participants were asked to write a standard phrase in Spanish, "La casa de Pamplona es bonita," three times on paper and once on a Wacom tablet placed under the paper. Participants were instructed to write the phrase as they normally would. In total, they wrote four phrases. Writing segments of 5–10 s were analyzed.

The Wacom tablet captured kinematic data, including X and Y coordinates, pen pressure, and azimuth and altitude angles. The data was saved in.svc format and analyzed using SVC ANALYTICS, a specialized software developed by engineers at Tecnocampus Mataro´. This program visualizes both on-surface and in-air trajectories and calculates relevant measures such as entropy and fractal dimensions. The extracted data was provided in Excel files for further statistical analysis.

Statistical analysis focused on kinematic parameters such as mean velocity and mean acceleration. Parametric measures were evaluated using paired t-tests for these measures. Non-parametric measures, such as UPDRS scores, were analyzed using Mann-Whitney tests. Correlations between handwriting measures and UPDRS scores were assessed using Spearman's rank correlation. Baseline handwriting variables between patients and controls were compared using Student's t-tests.

Standard clinical practice epidemiological data, Hoehn & Yahr staging, and UPDRS scales were used for patient evaluation.

2.1. Ethical compliance

This study was approved by Comit`e d'E`tica d'Investigacio´ Clínica amb Medicaments del Consorci Sanitari del Maresme with the reference number Code CEIm 29/20.

Informed consent was obtained from all participants included in this study.

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this work is consistent with those guidelines.

3. Results

Our investigation revealed significant kinematic differences between patients and controls. Patients exhibited a lower mean speed compared to the controls (27 ± 12 vs 48 ± 18, $p < 0.0001$, *t*-test) as well as a lower mean acceleration (7.2 ± 3.9 vs 15.01 ± 7, *t*-test, $p < 0.0001$, Fig. 1). In contrast, no differences in pressure were found.

Spearman Rank correlations between the UPDRS III and handwriting parameters: mean pressure, mean speed, and mean acceleration were calculated. The results are described in Table 1.

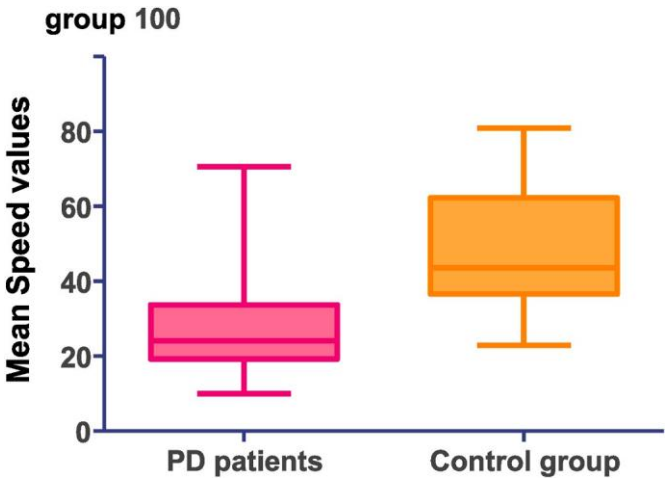

Fig. 1. This graphic illustrates the comparison of mean speed between Parkinson's patients and healthy controls. Observable differences in speed distribution underscore potential distinctions between the two groups. The variation in the box's spread and the presence of outliers highlight disparities in handwriting speed dynamics among the studied groups.

The mean speed and mean acceleration in PD patients showed significant correlations with UPDRS III scores (speed: $r = -0.52$, $p < 0.0007$; acceleration: $r = 0.60$, $p < 0.0001$, Spearman). This underscores the potential of handwriting parameters as valuable indicators of motor impairment in PD patients.

4. Discussion

Altered handwriting is a very well-known motor element in PD. The writing impairments of these patients consist of a reduction in the size of the written letter (micrographia) and difficulty controlling and executing fine motor movements (dysgraphia). The clinical evaluation of handwriting up to the present has been neglected, despite that PD patients complain of poor handwriting, and a progressive deterioration of penmanship is evident over time. Clinical visual evaluation of handwriting is quite subjective and automatic computerized writing analysis has been proposed as a diagnostic method. These studies often use data from online handwriting acquisition devices such as digitizing tablets [5,8]. The pressure of the pen, the speed of handwriting, as well as the azimuth and altitude angles, are some of the attributes that are commonly retrieved from the on-surface dynamics [5].

In this study, obtained using Intuos (Wacom) tablets for handwriting assessment, clear statistical differences were noted between de novo PD

Table 1
UPDRS values correlated slightly and positively with the mean pressure values. In contrast there were strong inverse correlations between the UPDRS III scores with the mean speed values as well as with acceleration mean values.

	Pressure_mean	Speed_mean	Acceleration_mean
N	38	38	38
Spearman r	0,3535	−0,5258	−0,6060
95 % confidence interval	0.02825 to 0.6111	−0.7285 to −0.2385	−0.7794 to −0.3464
P value (two-tailed)	0,0295	0,0007	<0.0001
P value summary	*	***	***
Exact or approximate P value?	Gaussian Approximation	Gaussian Approximation	Gaussian Approximation
Is the correlation significant? (alpha = 0.05)	Yes	Yes	Yes

and controls in the main parameters such as mean velocity and mean acceleration. In addition, these parameters correlated with clinical scales (motor UPDRS). Patients with higher UPDRS scores showed poorer writing performance evidenced by significantly slower speed and acceleration in the writing exercise.

Sarbaz et al. [11] examined 17 healthy subjects and 13 PD patients' handwriting for parameters related to the speed power range. Further, the authors classified PD patients versus healthy individuals using a neural network and found a precision of up to 86.2 % [11]. In another study, Rosemblun et al. [12] measured kinematic characteristics of handwriting in 20 healthy subjects and 20 PD patients who were asked to write their address and full name. Among the properties estimated by the authors were mean time on the tablet surface, average time the pen spends off the surface, trajectory speed and mean pen pressure. The diagnostic accuracy using this approach reached 97 %. In a more recent study, characteristics based on kinematic, geometric, and nonlinear dynamics analyses were evaluated to distinguish between PD and healthy subjects. Study participants were categorized based on K-NN algorithm, support vector machines and random forests. A precision around 93.1 % were obtained in the differentiation of patients from healthy control subjects. Further examination indicated that parameters related to velocity, acceleration and pressure were the most discriminating [5]. These outcomes support the results obtained in this study regarding speed and acceleration, nevertheless, in the current work the mean pressure values did not differ significantly between PD patients and healthy controls.

Overall, the results of this work indicate that dysgraphia is an easily identifiable abnormality in PD, even in the novo patients, and may be one of the initial symptoms. This motor impairment correlates with clinical scales, discriminating between healthy and PD patients, and may be another valuable element to objective assessment of PD patients.

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CRediT authorship contribution statement

Lola Diaz-Feliz: Writing – review & editing, Writing – original draft, Methodology, Investigation. **Pilar Sanz-Cartagena:** Validation, Supervision. **Marcos Faundez-Zanuy:** Software, Resources. **Jose´ Arbelo-Gonzalez:** Visualization, Validation, Supervision. **Pedro Garcia-Ruiz:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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