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Comparative Analysis of Balance Control Strategies and Center of Pressure Complexity in Parkinson's Disease and Healthy Individuals

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ABSTRACT

Background: Balance impairment is a prominent and disabling feature of Parkinson's disease (PD), contributing to reduced mobility and increased fall risk. A clearer understanding of postural control strategies and the balance variables most sensitive to PD may help in designing targeted interventions. This study aimed to compare balance-related measures and postural regulation strategies between individuals with PD and neurologically healthy adults.

Methods: Using G*Power, the required sample size was estimated, and participants were recruited through purposive and convenience sampling. Fifteen individuals with PD and seventeen healthy controls completed the protocol. Postural control was assessed with a Kistler force platform across four standing conditions that manipulated surface stability and vision. Center of pressure (CoP) data were collected for 20 seconds at 1000 Hz. Variables in both AP and ML directions were analyzed, including spatial measures (CoP displacement, sway, RMS), quantitative measures (acceleration, velocity), and complexity (sample entropy). A sit-to-stand (STS) task was also evaluated.

Results: Manipulating the base of support (BoS) significantly affected spatial CoP measures and complexity in both groups ($p < 0.05$). During the STS task, quantitative variables were higher in controls compared to the PD group ($p < 0.05$). Complexity values were consistently higher in individuals with PD across all conditions ($p < 0.05$).

Conclusions: Overall, the increased sway magnitude and elevated irregularity in the PD group suggest reliance on more conscious and less automatic postural control strategies, reducing adaptability to environmental changes and potentially elevating fall risk under unstable conditions. Moreover, complexity and quantitative STS measures appear sensitive to PD, while spatial variables show strong responsiveness to BoS manipulation and visual dependence across balance tasks.

KEY WORDS : Parkinson's disease, Balance, Center of pressure, Complexity

Introduction

Parkinson's disease (PD) is a neurodegenerative disorder that affects millions of people worldwide [1]. It is characterized by motor symptoms, including postural instability, impaired balance control, freezing of gait, stooped posture, and difficulties with daily activities that worsen as the disease progresses [2, 3]. These symptoms increase instability, leading to a high number of falls in this population, with 61% reporting at least one fall per year [4-6]. Falls can result in injuries, fear of falling, and mortality, posing significant economic and societal burdens on healthcare systems worldwide [7].

Postural sway during quiet standing is commonly used to assess postural balance abilities [8]. Increased postural sway is often interpreted as weakened postural control [9] and has been observed in elderly individuals [10], as well as patients with neurological disorders such as stroke [11] and ataxia [12, 13]. Postural sway, measured using COP displacement, is divided into spatial variables, including sway amplitude, area, and root mean square distance (RMS), which quantifies the CoP variability around the mean CoP trajectory. Additionally, quantitative variables reflecting postural control strategy, such as mean velocity (MV), are assessed [14]. Postural control encompasses both voluntary and automatic control. The effects of both controls on spatial variables and quantitative variables reflecting postural control strategy of COP displacement have been reported.

Postural control in individuals with PD has been extensively studied [15, 16]. These studies indicate that the amount of sway and variability in individuals with PD is higher than in healthy individuals, and there is a significant correlation between these variables and falls. The conventional parameters of the center of pressure (CoP) have certain limitations in comprehending the sway and strategies of postural physiology during quiet stance. However, non-linear techniques take into account temporal organization, offering a deeper understanding of the mechanisms of postural control [17]. The use of non-linear techniques could enhance our understanding of deficits in postural control among individuals with Parkinson's disease, potentially reducing the incidence of falls [18, 19].

In recent years, there has been a growing appreciation for the variability and complexity of postural control in the study of the nervous system [20]. Nonlinear analysis of postural control has become increasingly adopted because it can assess the regularity and variability in a time series, providing insight into the degree of adaptation and maturity of motor control [21]. The progressive loss of complexity in physiological outputs has been repeatedly linked to aging and disease. This loss of complexity indicates a reduced ability to respond to perturbations or adapt to changes [22]. Additionally, researchers have demonstrated that lower values of complexity correspond to a more regular and predictable CoP pattern [23]. However, the complexity of posture control and the variability in balance among individuals with PD make the assessment of balance a challenging task [19]. This complexity is further compounded by the fact that PD is a heterogeneous disease, with variability in symptom severity and progression among individuals. As a result, more research is needed to better understand the mechanisms of balance impairment in PD and to develop more effective assessment tools that can capture this complexity.

Based on research, it has been found that individuals with PD exhibit greater CoP sway and displacements, which tend to decrease with age and disease severity [24, 25]. Conversely, an increase in CoP sway accompanied by a decrease in irregularity may indicate poor postural control, while a decrease in CoP sway and diminished irregularity suggests good postural control performance [26]. The aim of this study was to determine whether increased CoP sway is associated with decreased irregularity in individuals with PD. Therefore, we hypothesized that increased CoP sway in individuals with PD would be accompanied by decreased irregularity. Given the numerous balance variables, one objective of this study was to determine which of these variables are more sensitive to Parkinson's disease (PD). Taken together, these studies highlight the complexity of postural control in individuals with PD and the challenges that this complexity presents for the assessment and management of balance impairment in this population. The objective of this study was to compare balance variables and postural control strategies in individuals with PD and a control group by investigating the sensitivity of balance variables to manipulation of the proprioceptive and visual systems in controlling posture.

Material and Methods

The statistical population of this study comprised elderly residents of Hamadan. Using the G*Power software with $\alpha=0.05$ and a statistical power of 80%, a minimum of 24 participants was required. This led to the selection of 15 patients with Parkinson's disease (8 males and 7 females) from the specialized neurology clinic at Be'sat Hospital in Hamadan as the experimental group, and 17 neurologically healthy elderly volunteers (9 males and 8 females) as the control group, all chosen using convenience sampling. Written informed consent was obtained from all participants according to the protocol approved by the Ethical Committee Board of the Islamic Azad University, Hamedan Branch (IR.IAU.H.REC.1401.001) in accordance with the ethical standards of the Declaration of Helsinki, 1983. The inclusion criteria for individuals with Parkinson's disease were: a diagnosis of early PD, being at stage II or III of the disease according to the Hoehn and Yahr scale, using medication (being in the ON phase), and not having any implanted devices or deep brain stimulation [27]. Additionally, the inclusion criteria for healthy individuals were: no history of major surgery or any significant walking problems such as neurological, muscular, or skeletal abnormalities, and having a healthy vestibular, auditory, and visual system. Both the control and Parkinson's groups were selected from individuals aged 50 to 70 years old, and both groups had the ability to walk independently without any assistive devices.

All participants in the study underwent the Mini-Mental State Examination (MMSE), and in addition to that, patients with Parkinson's disease also underwent the Montreal Cognitive Assessment (MoCA) and the Parkinson's Disease Quality of Life Questionnaire (PDQL). The exclusion criteria for individuals with Parkinson's disease were: atypical or secondary PD, diseases that affect balance, a history of orthopedic surgery in the lower extremities during the past year, severe cognitive impairment, the use of psychotropic substances or drugs, the use of a cane or walking aid, and obtaining a score below 17 in the cognitive tests of MMSE and MoCA in illiterate and low-educated individuals, and obtaining a score below 100 on the PDQL [27].

The Kistler force platform (Type 9281, Kistler Instrument AG, Winterthur, Switzerland) was used to evaluate postural control. COP data were recorded for 20 seconds at a sampling frequency of 1000 Hz. Then, resulting force platform data were processed with a fourth-order, zero-lag, low-pass Butterworth filter with a 10 Hz cutoff frequency [28]. To assess postural control, each participant completed four quiet standing trials, which involved standing upright with feet together, maintaining a neutral and comfortable stance, and keeping arms relaxed at their sides. The trials were conducted on either a firm or foam surface with eyes open or closed, and their order was randomized.

During the tests, the subjects were instructed to stand barefoot on the platform and maintain a steady gaze on a black point located on a paper sheet placed 2 meters away in open eyes condition [29]. Each test was conducted three times, and the average of the measured values was calculated for each subject. To ensure consistency across trials and participants, the feet position was standardized on the surface with a separation of 5 cm [30].

The next test was the sit-to-stand (STS) test. In this test individuals were seated barefoot on a sturdy chair lacking armrests, back support, or wheels. The chair's height was customized to match each subject's leg length, which was measured by the distance from the lateral femoral condyle to the ground. In this case, the subject's foot was placed on the bar that connected the two front legs of the chair. When the start of the movement was announced, the subject got up from the chair at the desired speed with their arms folded across their chests and put his feet on the force plate and stood in this position for 3 or 4 seconds [31]. Prior to the recorded trials, each participant underwent three practice trials and subsequently performed three STS trials, with 30 seconds of rest between each trial.

In this research, three categories of variables were evaluated in anterior-posterior (AP) and medial-lateral (ML) directions: spatial (the amount of CoP displacement, postural sway, and RMS), quantitative (acceleration and velocity), and complexity of CoP movements during the time period (sample entropy). Postural sway refers to the total distance traveled by the CoP during the trial, representing the overall movement of the body to maintain balance. It is calculated by summing the absolute values of the CoP displacement over time. RMS (Root Mean Square) represents the variability of the CoP displacement and is calculated as the square root of the average of the squared deviations from the mean CoP position. RMS provides a measure of the magnitude of sway, indicating the consistency of postural control. The Bioware software v3,5,2 (Kistler Nordic AB, Sweden) was used to extract spatial and quantitative data.

As a complexity of postural control, the sample entropy is mathematically computed as follows:

First, from a vector $X_N = \{x_1, x_2, \dots, x_N\}$, two sequences of consecutive points $X_m(i) = \{x_i, \dots, x_{i+m-1}\}$ and $X_m(j) = \{x_j, \dots, x_{j+m-1}\}$ ($i, j \in [1, N - m], i \neq j$) are selected to compute the maximum distance and to be compared with the tolerance γ for counting the repeated sequences, based on Equation (1). For the sequence $X_m(i)$, its count is defined as $B_i^m(\gamma)$.

$$d [X_m(i). X_m(j)] = \max [|x_{i+k}. x_{j+k}|] \\ \leq \gamma (k \in [0. m - 1] . \gamma \geq 0) \quad (1)$$

where the tolerance γ equals to $0.35 \cdot \text{SD}$ [32], and SD is the standard deviation of XN.

$B^m(\gamma)$ is the average amount of $B_i^m(\gamma)$ for $i \in [1, N - m]$, and $B^{m+1}(\gamma)$ is the average of $m + 1$ consecutive points. Thus, SE is obtained using the Equation (2) [33-35].

$$SE(N. m. \gamma) = -\ln \left[\frac{B^{m+1}(\gamma)}{B^m(\gamma)} \right] \\ = -\ln \left[\frac{(N-m-1)^{-1} \sum_{i=1}^{N-m-1} B_i^{m+1}(\gamma)}{(N-m)^{-1} \sum_{i=1}^{N-m} B_i^m(\gamma)} \right] \quad (2)$$

The Shapiro–Wilk test was used to assess the normality of the outcome measures. Descriptive statistics were computed for all demographic and outcome measures. As the data for balance variables had a normal distribution, parametric statistics were utilized for analysis. The balance variables in this study involved two within-group factors: eye condition (open eyes/closed eyes) and surface (firm/foam), along with a between-group factor (PD/control group). Hence, a three-way repeated measures ANOVA was employed for comparisons. The assumption of sphericity was tested using Mauchly's test. An a priori alpha level of $\alpha = 0.05$ was established for this study. All statistical analyses were conducted using SPSS 25.0 (IBM, Armonk, New York) and SPSS 21.0 (SPSS Inc., Chicago, IL, USA).

Results

In Table 1, the demographic characteristics of the participants and the comparison between the two groups in these characteristics are shown.

Postural Balance

complexity

The results of the factor analysis revealed that the main effect of group ($F=4.81$, $p=0.036$) and BoS had a significant impact on complexity ($F=9.12$, $p=0.005$). Pairwise comparisons indicated a significant increase in complexity when standing on an unstable foam surface. Furthermore, the complexity level was higher in the PD group compared to the control group. Other factors, such as visual ($F=1.44$, $p=0.24$) and direction ($F=3.83$, $p=0.06$), did not exhibit a significant effect on CoP complexity.

Table 1. Baseline characteristics in the control and PD groups.

	groups		Sig.
	PD	Control	
N (female, male)	15 (7,8)	17 (8,9)	
Age (year)	61.60±6.23	60.52±6.17	0.62
Mass (Kg)	67.60±10.56	68.88±11.60	0.75
Height (cm)	1.64±0.10	1.64±0.09	0.86
BMI	25.13±3.39	25.71±3.45	0.64
MMSE	23.00±3.74	27.07±2.40	0.002
MoCa	22.80±3.14	NA	
PDQL	112.40±12.63	NA	

Note: Values are mean $\pm$ standard deviation. Abbreviations: PD, Parkinson's disease; N, number of participants; BMI, body mass index; MMSE, Mini-Mental State Examination; MoCa, Montreal Cognitive Assessment; PDQL, Parkinson's disease quality of life; NA, not applicable. * Significance level $p < 0.05$.

Spatial variables

Postural displacement: The results indicated that the main effect of group did not significantly impact the amount of postural displacement ($F=2.64$, $p=0.11$) (Table 2). However, the main effects of BoS ($F=4.38$, $p=0.04$) and direction ($F=17.24$, $p=0.000$) significantly influenced postural displacement. Mean comparisons revealed that postural displacement increased in the foam condition, with a higher magnitude observed in the AP direction compared to the ML direction.

Postural sway: The main effect of group did not significantly affect the amount of postural sway ($F=0.17$, $p=0.68$). However, the results demonstrated significant main effects of visual condition ($F=100.8$, $p=0.000$), BoS ($F=23.91$, $p=0.000$), and direction ($F=25.23$, $p=0.000$) on sway. Mean comparisons showed that postural sway increased in the closed eyes and foam conditions, with a greater magnitude observed in the AP direction compared to the ML direction (Table 2, Figure 1).

RMS: The results revealed that the main effect of direction ($F=18.74$, $p=0.000$) was significant for this variable, with a higher magnitude observed in the AP direction compared to the ML direction.

Quantitative variables

The results regarding of speed and acceleration of CoP, showed that changes in the visual and BoS factors did not have a significant effect on them. However, the main effect direction factor had a significant effect on the amount of acceleration ($F=6.37$, $p=0.017$) and speed ($F=8.16$, $p=0.008$). The pairwise comparisons showed that these variables were significantly higher in the AP direction than the ML direction. The between group comparison showed in table 2 and figure 1.

Table 2. Between-group comparison of static balance variables in different posture conditions.

		SO			SC			FO			FC		
		PD	Control	P.value	PD	Control	P.value	PD	Control	P.value	PD	Control	P.value
Entropy	AP	0.60± 0.4	0.36± 0.1	0.051	0.71± 0.5	0.42± 0.2	0.034	0.60± 0.5	0.36± 0.1	0.071	0.61± 0.2	0.53± 0.1	0.207
	ML	0.61± 0.3	0.33± 0.1	0.082	0.77± 0.3	0.40± 0.2	0.033	0.42± 0.2	0.32± 0.1	0.110	0.44± 0.2	0.42± 0.2	0.796
Displacement	AP	4.19±2.4	3.29± 1.6	0.214	4.31± 2.4	3.40± 1.7	0.216	2.88± 1.8	2.21± 1.2	0.232	3.13± 1.9	2.46± 1.8	0.246
	ML	1.81± 1.1	1.26± 0.7	0.211	1.88± 1.2	1.76± 0.9	0.770	1.81± 1.2	1.56± 1.1	0.540	2.2± 1.6	2.64± 1.3	0.604
Sway	AP	0.51± 0.2	0.45± 0.1	0.313	0.57± 0.2	0.61± 0.2	0.668	0.74± 0.2	0.80± 0.2	0.487	1.12± 0.2	1.18± 0.5	0.697
	ML	0.48± 0.2	0.32± 0.1	0.009	0.40± 0.2	0.37± 0.2	0.687	0.72± 0.3	0.71± 0.3	0.991	0.99± 0.4	0.87± 0.4	0.428
RMS	AP	4.31± 2.2	3.38± 1.5	0.175	4.41± 2.3	3.65± 1.5	0.277	3.35± 1.5	2.49± 1.1	0.074	3.47± 1.6	2.49± 1.1	0.284
	ML	2.2± 1.5	1.90± 1.3	0.557	2.12± 1.3	1.89± 0.9	0.573	2.3± 1.2	1.88± 1.0	0.279	2.67± 1.4	2.88± 2.8	0.793
Acceleration	AP	0.04± 0.01	0.03± 0.02	0.543	0.03± 0.02	0.01± 0.01	0.017	0.05± 0.02	0.02± 0.01	0.127	0.04± 0.01	0.03± 0.02	0.361
	ML	0.02± 0.01	0.03± 0.02	0.183	0.02± 0.01	0.01± 0.01	0.203	0.03± 0.01	0.02± 0.01	0.151	0.02± 0.01	0.02± 0.01	0.308
Velocity	AP	0.25± 0.2	0.25± 0.1	0.996	0.27± 0.2	0.14± 0.01	0.016	0.28± 0.2	0.21± 0.1	0.254	0.34± 0.1	0.29± 0.2	0.737
	ML	0.16± 0.1	0.25± 0.2	0.261	0.22± 0.1	0.12± 0.1	0.153	0.23± 0.1	0.17± 0.1	0.398	0.33± 0.2	0.20± 0.1	0.239

Note: Values are mean ± standard deviation. Abbreviations: SO: standing on a firm surface with open eyes; SC: standing on a firm surface with closed eyes; FO: stance on foam with open eyes; FC: stance on foam with closed eyes. P.value: compared between groups.

Table 3. Between-group comparison of static balance variables in Sit-to-Stand test.

		Groups		
		PD	Control	P.value
Entropy	AP	1.5±0.1	1.1±0.1	0.119
	ML	1.8±0.2	1.6±0.2	0.431
Displacement	AP	5.88±2.6	4.39±2.5	0.107
	ML	1.58±1.4	1.25±0.3	0.496
Sway	AP	4.84±2.3	4.46±1.2	0.616
	ML	6.33±3.8	4.98±1.8	0.474
RMS	AP	8.02±2.4	6.90±1.9	0.157
	ML	6.61±2.2	5.57±2.7	0.557
Acceleration	AP	0.07±0.04	0.12±0.03	0.002
	ML	0.03±0.02	0.2±0.02	0.403
Velocity	AP	0.19±0.1	0.34±0.1	0.001
	ML	0.05±0.03	0.05±0.02	0.714

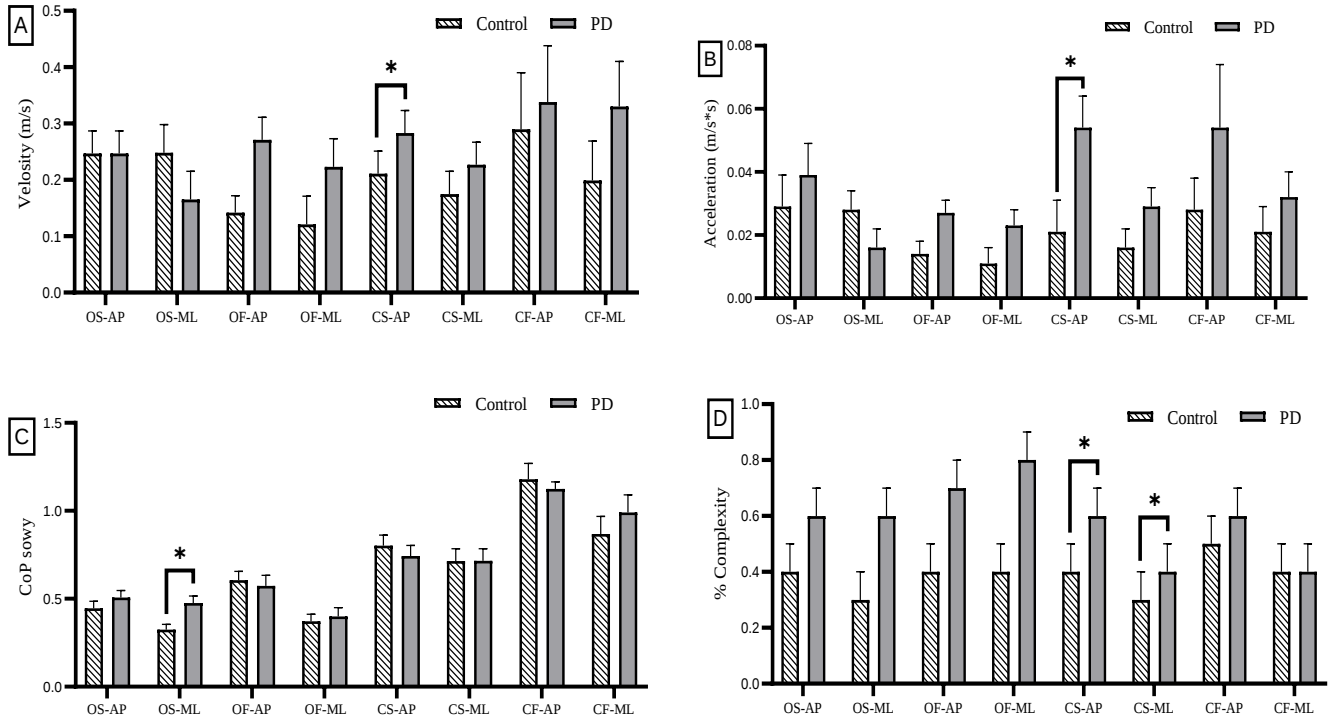


Figure 1. Mean and standard deviation of the A) velocity, B) acceleration, C) sway and D) complexity of the center of pressure (COP) displacement in the PD and control groups in Postural Balance tasks. OS-AP: standing on a firm surface with open eyes in anteroposterior direction; OS-ML: standing on a firm surface with open eyes in mediolateral direction; OF-AP: standing on a foam with open eyes in anteroposterior direction; OF-ML: standing on a foam with open eyes in mediolateral direction; CS-AP: standing on a firm surface with closed eyes in anteroposterior direction; CS-ML: standing on a firm surface with closed eyes in mediolateral direction; CF-AP: standing on a foam with closed eyes in anteroposterior direction; CF-ML: standing on a foam with closed eyes in mediolateral direction.

Sit-to-stand (STS)

The results regarding of STS test showed that the main effect of groups was not significant in the COP displacement ($F=3.38$, $p=0.076$), sway ($F=0.45$, $p=0.51$), RMS ($F=0.34$, $p=0.93$) and complexity ($F=1.78$, $p=0.192$) (Table 3, Figure 2). But in quantitative variables, the main effect of group was a significant effect in the acceleration ($F=7.29$, $p=0.011$) and speed ($F=14.42$, $p=0.001$) of COP movements. The pairwise comparison showed that in the PD group the amount of them were lower compared to the control group.

Discussion

The aim of this study was to investigate balance variables and postural control strategies in individuals with Parkinson's disease (PD) and compare them with a control group. Results from the static balance test showed that spatial variables such as postural sway and CoP displacement were more sensitive to changes in visual input and BoS. Additionally, in both spatial variables, CoP movements were greater in the AP direction than in the ML direction.

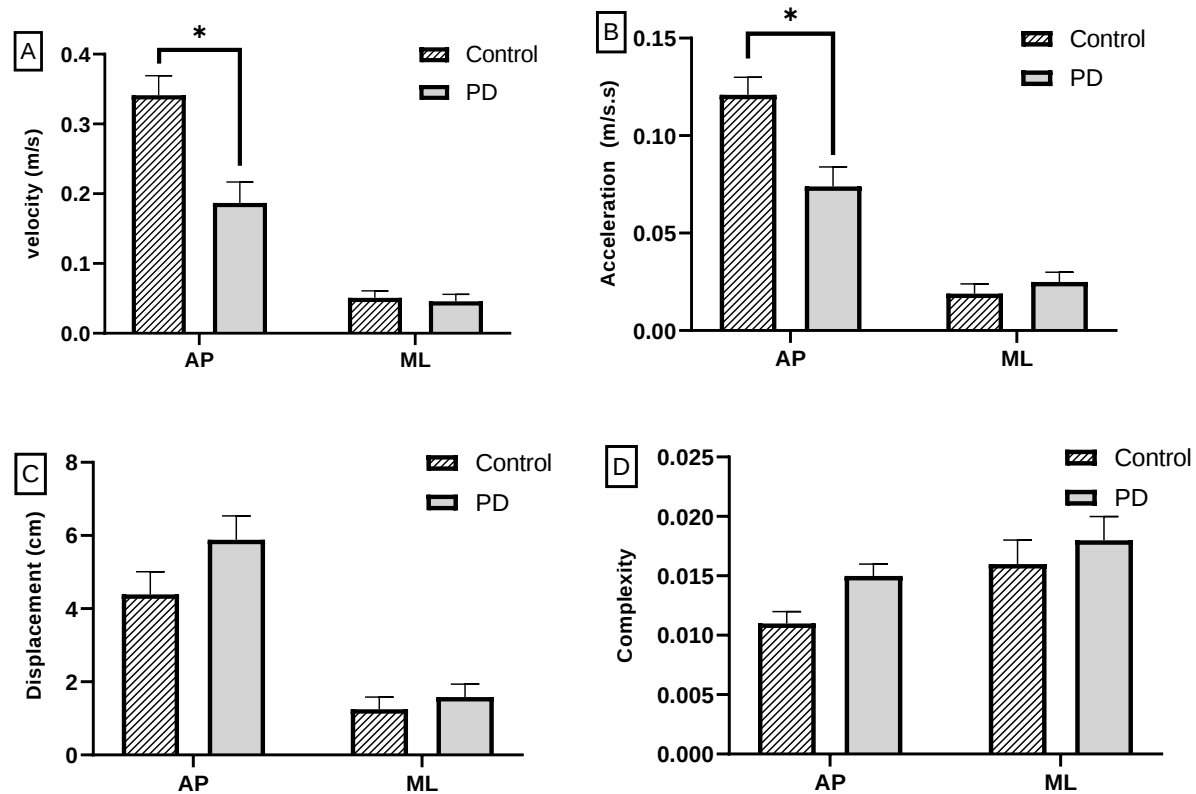


Figure 2. Mean and standard deviation of the A) velocity, B) acceleration, C) sway and D) complexity of the center of pressure (COP) displacement in the PD and control groups in STS task. OS-AP: AP: anteroposterior direction; ML: mediolateral direction; *P < 0.05.

These findings align with previous studies that have demonstrated significant increases in postural sway when visual information is removed [36] or when BoS is manipulated [37]. In the presence of visual cues, the balance control system is automatically regulated, resulting in reduced sway, as observed in prior research [38]. However, with eyes closed, the balance control system may rely more on voluntary mechanisms, leading to increased sway.

Contrary to previous studies [39, 40] indicating that individuals with PD exhibit greater oscillations compared to healthy individuals, especially in more challenging tasks, this study did not observe a significant difference between the two groups in spatial variables. One possible reason for this discrepancy may be the severity of the disease or the absence of freezing of gait (FOG) among PD participants in this study. Additionally, the control group in this study consisted of elderly individuals who may have employed the same balance control strategy as PD patients in difficult balance tasks, thereby reducing the difference between the two groups. According to the results, the quantitative variables were similar in both groups under all conditions. Therefore, these variables are not sensitive to PD, and changes in visual conditions or BOS did not result in significant changes in them. The results regarding COP movement complexity showed that complexity was higher in the PD group than in the control group. According to complexity theory, fluctuations in variability relate to an individual's adaptability and flexibility [22, 41]. Increased

complexity doesn't necessarily signify "poor" control solutions; past studies have demonstrated that individuals may require variability to adapt to environmental constraints and execute movements successfully. Lipsitz et al. (1999) and Stergiou et al. (2011 and 2013) have suggested that irregularity and complexity values follow a U-shaped pattern, indicating that with a significant decrease in these values, movements become entirely predictable, and individuals have minimal adaptability to environmental changes. Conversely, as complexity increases, individuals become more sensitive to minor environmental changes. Therefore, if entropy values are moderate and proportional to the individual, their adaptability to environmental disturbances will be greater [20, 22, 26]. The findings of this study indicated that individuals with PD demonstrated greater complexity in postural control, alongside increased postural sway, indicating balance impairment and differences in postural control strategies compared to the control group. Based on the results, the complexity variable assessed in this study exhibited greater sensitivity to PD compared to other balance variables. Changing the level of support surface had a more pronounced effect on balance variables than eliminating visual information. Due to the elderly composition of the control group, alterations in visual conditions and BoS resulted in similar changes in both groups.

In the STS balance test, there was no significant difference between the groups in the spatial CoP variables. However, the quantitative variables (speed and acceleration of COP movements) were lower in the PD group compared to the control group. Mean COP velocity is one of the quantitative variables used to assess balance and reflects various aspects of balance control strategy and the magnitude of oscillations. A higher COP velocity indicates that the balance control system is actively and rapidly correcting postural oscillations, while a lower velocity suggests a slower and less active control strategy [42]. Therefore, based on these results, the control group is employing automatic balance control mode to maintain posture in the STS test. On the other hand, the PD group reduces degrees of freedom, leading to decreased irregularity and speed of CoP movements, and likely employs vigilant control strategies to maintain balance during the STS test. In this test, quantitative variables were more sensitive to PD compared to other variables evaluated in this study.

Conclusion

In conclusion, the higher complexity and irregularity of postural control in individuals with PD indicate a reduced ability to adapt to environmental changes, which increases their risk of falls. Spatial variables and complexity measures in balance tests are particularly sensitive to changes in the base of support, highlighting the importance of these metrics in assessing and addressing balance issues in PD. Additionally, the differences in speed and acceleration of CoP movements during the Sit-to-Stand (STS) test suggest that individuals with PD rely less on automatic posture control strategies compared to healthy individuals. These findings underscore the need for targeted interventions to enhance balance and reduce fall risk in the PD population.

Ethical Considerations:

Compliance with ethical guidelines

All ethical principles were fully observed in the conduct of this study. Written informed consent was obtained from all participants, and all procedures were performed in accordance with the ethical standards

of the Declaration of Helsinki (1983). The study protocol was reviewed and approved by the Ethical Committee Board of the Islamic Azad University, Hamedan Branch (IR.IAU.H.REC.1401.001). Participants were assured of confidentiality, voluntary participation, and the right to withdraw at any time without any consequences. No personal identifying information was recorded or disclosed, and the data were used solely for research purposes.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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تحلیل مقایسه‌ای راهبردهای کنترل تعادل و پیچیدگی مرکز فشار در بیماری پارکینسون و افراد سالم

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چکیده

هدف: اختلال تعادل یکی از ویژگی‌های برجسته و ناتوان‌کننده در بیماری پارکینسون (PD) است که به کاهش تحرک و افزایش خطر سقوط منجر می‌شود. درک دقیق‌تر راهبردهای کنترل قامتی و شناسایی متغیرهای تعادلی حساس به این بیماری می‌تواند به طراحی مداخلات هدفمند کمک کند. هدف این مطالعه، مقایسه شاخص‌های مرتبط با تعادل و راهبردهای تنظیم پاسچر بین افراد مبتلا به پارکینسون و بزرگسالان سالم از نظر عصبی بود.

روش شناسی: با استفاده از نرم‌افزار G^*Power حجم نمونه مورد نیاز برآورد شد و شرکت‌کنندگان به صورت هدفمند و در دسترس انتخاب شدند. در مجموع پانزده فرد مبتلا به پارکینسون و هفده فرد سالم پروتکل را تکمیل کردند. کنترل قامتی با استفاده از نیروسنج Kistler در چهار وضعیت ایستادن با تغییر پایداری سطح و شرایط بینایی ارزیابی شد. داده‌های مرکز فشار (CoP) به مدت ۲۰ ثانیه با فرکانس ۱۰۰۰ Hz ثبت گردید. متغیرهای جهات قدامی-خلفی (AP) و داخلی-خارجی (ML) شامل شاخص‌های فضایی (جابجایی CoP، نوسان، RMS)، کمی (شتاب، سرعت) و پیچیدگی (آنترופی نمونه) مورد تحلیل قرار گرفتند. علاوه بر این، آزمون نشستن-ایستادن (STS) نیز ارزیابی شد.

نتایج: دستکاری سطح اتکا (BoS) موجب تغییر معنی‌دار در متغیرهای فضایی CoP و پیچیدگی در هر دو گروه شد ($p < 0.05$). در آزمون STS، متغیرهای کمی در گروه کنترل بیشتر از گروه پارکینسون بود ($p < 0.05$); همچنین مقادیر پیچیدگی در تمام شرایط در افراد مبتلا به پارکینسون به طور معنی‌داری بالاتر بود ($p < 0.05$).

نتیجه گیری: افزایش دامنه نوسان و بی‌نظمی بیشتر در گروه پارکینسون نشان‌دهنده اتکای بیشتر به راهبردهای آگاهانه و کمتر خودکار در کنترل پاسچر است؛ امری که سازگاری با تغییرات محیطی را کاهش داده و احتمال سقوط را در شرایط ناپایدار افزایش می‌دهد. علاوه بر این، شاخص‌های پیچیدگی و متغیرهای کمی STS نسبت به پارکینسون حساس‌اند، در حالی که متغیرهای فضایی پاسخ‌پذیری بالایی به تغییرات سطح اتکا و شرایط بینایی در آزمون‌های تعادل نشان می‌دهند.

واژه‌های کلیدی: بیماری پارکینسون، تعادل، مرکز فشار، پیچیدگی

