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Assessment of vestibulo-ocular reflex function in people with Parkinson's disease: a cross-sectional study in a rehabilitation setting using the video head impulse test

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ABSTRACT

Background Parkinson's disease (PD) is a neurodegenerative, progressive disorder known for motor and non-motor symptoms. The vestibular system, via the vestibulo-ocular reflex (VOR), is crucial for maintaining dynamic gaze stability, and its role in PD is raising interest among researchers. Indeed, vestibular dysfunction in PD may exacerbate postural instability and gait disturbances; however, the prevalence of vestibular dysfunctions remains unclear. This study aims to objectively investigate the VOR function in people with PD using the video head impulse test.

Methods This is a cross-sectional study conducted in a neurorehabilitation hospital. People with PD were included if they had no cognitive impairment and the ability to walk without physical assistance. The video head impulse test was used to assess the VOR function across all six semicircular canals, using both the Head Impulse Paradigm (HIMP) and the Suppression Head Impulse Paradigm (SHIMP) paradigms.

Results 35 people with PD (mean age: 69.9±8.4; 11 females) with moderate motor symptoms (MDS-UPDRS-part III: 27.7±6.8) were included. Using normative cut-offs, 69% of the participants had at least one dysfunctional canal (60% hypo-gain, 9% hyper-gain). The prevalence reached 83% when both the HIMP and SHIMP paradigms were considered.

Conclusion There is a high prevalence of vestibular dysfunction in people with PD. The instrumental assessment of VOR gains could reveal undiagnosed vestibular dysfunctions and, in the future, lead to more specific rehabilitation management of people with PD.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study employed both the Head Impulse Paradigm and the Suppression Head Impulse Paradigm paradigms, allowing a comprehensive evaluation of all semicircular canals.
⇒ Normative cut-offs specific to each canal and paradigm were applied to define dysfunction.
⇒ The cross-sectional design precludes inference of causal relationships.
⇒ Use of video Head Impulse Test focused on peripheral vestibular components, excluding central pathways.
⇒ Results may not be generalisable to broader Parkinson's disease populations due to selective inclusion criteria.

INTRODUCTION

Parkinson's disease (PD) is a progressive neurodegenerative disorder primarily characterised by motor symptoms, including bradykinesia, rigidity, resting tremor and postural instability.[1] While these features dominate the clinical presentation, a growing body of evidence highlights the significance of vestibular dysfunctions as contributors to functional impairments.[2–7] Vestibular dysfunction in PD may exacerbate postural instability and gait disturbances, increasing the risk of falls and reducing quality of life.[5]

The vestibular system, through the vestibulo-ocular reflex (VOR), plays a critical role in maintaining dynamic gaze stability and activities of daily living.[8] Impairments in VOR have been well-documented in neurological conditions; however, the extent and clinical implications of VOR abnormalities in PD remain less explored. Previous research suggests that patients with PD exhibit vestibular dysfunctions, potentially due to dopaminergic deficits within the basal ganglia and vestibular nuclei.[7 9] However, evidence regarding the prevalence and impact of VOR abnormalities in PD have been inconsistent, with limited understanding of their relationship with functional outcomes, such as balance and gait.[7]

The video Head Impulse Test (vHIT) provides an objective and quantitative evaluation of VOR function across all six semicircular

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canals.[10] This tool measures angular VOR gains during rapid head movements, identifying both overt and covert saccades. Previous studies often report mean VOR gains across groups, potentially overlooking the clinical relevance of isolated canal dysfunctions that can be detected at the individual level.[7 9 11] This individual-level analysis allows for the identification of subtle vestibular impairments, such as isolated vertical canal dysfunctions, which are commonly missed when relying on mean values alone.[12 13] Furthermore, previous studies have shown contrasting findings: while some report no significant changes in VOR gain in people with PD compared with healthy controls,[11] others describe increased VOR gains, particularly in the early stages of the disease, which may reflect compensatory mechanisms or early vestibular dysfunction.[9] These discrepancies could arise from methodological differences, as many studies focus exclusively on hypofunctions, potentially overlooking hyperfunctions or compensatory increases in VOR gain.[9] The ability to detect subtle VOR dysfunctions using vHIT offers potential for managing the disease progression and new rehabilitation strategies.[12 13]

Despite these advancements, the clinical relevance of VOR dysfunction in PD is not fully understood. In this study, we aimed to investigate semicircular canal function in a cohort of patients with PD using vHIT and both the Head Impulse Paradigm (HIMP) and Suppression Head Impulse Paradigm (SHIMP). Unlike previous studies, we employed an individualised analysis of VOR gains, focusing on the prevalence of dysfunctions at the patient level rather than reporting summary statistics alone. This novel approach highlights the potential to detect isolated canal dysfunctions, which could inform patient-specific rehabilitation strategies.[12 13] By adopting this method, we aim to contribute to a deeper understanding of vestibular dysfunctions in PD and their implications for personalised therapeutic interventions.

METHODS

This cross-sectional study was carried out at Santa Lucia Foundation Institute for Research and Healthcare, and it was approved by the Local Independent Ethics Committee with protocol number Prot. CE/2022_011. All procedures contributing to this work comply with the ethical standards of the relevant national and institutional human experimentation guidelines and the World Medical Association Declaration of Helsinki and adhere to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[14] All participants gave written consent to publish the results obtained from their clinical examinations and instrumental tests.

Participants

People with PD were recruited among outpatients attending the neurorehabilitation services of the Hospital Santa Lucia Foundation from March 2024 to November 2024. Two experienced movement disorder neurologists assessed patients using the Movement Disorder Society-sponsored revision of the Unified Parkinson Disease Rating Scale,[15 16] and the Hoehn and Yahr Scale (H&Y).[17] Patients were included if they had no cognitive impairment (Mini-Mental State Examination[18] score >25), H&Y: 2–3; ability to walk without any device, or need for continuous physical assistance (Functional Ambulation Category [19]>3). Exclusion criteria were severe vision damage with inability to focus on visual targets or impaired eye movements, history of ear surgery, chronic otitis media, deafness and vertigo, limited neck movement because of neck injury and the presence of neurological, orthopaedic or cardiac comorbidities. Exclusion criteria were assessed during a standardised screening performed by an experienced neurologist, based on clinical history, neurological examination and relevant medical records. When necessary, participants were referred for ophthalmological screening prior to inclusion.

Instrumental assessment of the VOR

A trained researcher used the vHIT (ICS Impulse, Otometrics/Natus, Denmark) to assess the gain of the VOR for all the semicircular canals. Two evaluation paradigms, the Head Impulse Paradigm (HIMP) and the Suppression Head Impulse Paradigm (SHIMP), were used to identify vestibular canal function. In the HIMP paradigm, the individual focuses on an earth-fixed target during small, abrupt, passive and unpredictable impulsive turns aligned with the tested canal's plane.[10] In the SHIMP paradigm, the person focuses on a head-fixed target during small, abrupt, passive and unpredictable impulsive turns in the horizontal plane.[20]

In cases of vestibulopathy, the HIMP reveals the emergence of a covert or overt saccade during the test. Conversely, during the SHIMP, individuals with both unilateral and bilateral vestibulopathy do not exhibit a corrective saccade, referred to as a 'SHIMP's saccade'.

As reported in the literature,[20 21] a functional VOR gain was considered between 0.8 and 1.29 for the HIMP paradigm and between 0.66 and 1.29 for the SHIMP paradigm. If the VOR gain fell outside these ranges, it was classified as dysfunctional, with hypo-gain or hyper-gain defined according to the direction of stimulation.[20–22]

Statistical analysis

All the data were analysed using STATA 18.5 software (StataCorp. 2023, College Station, TX, USA). All continuous data are presented as mean and SD, and categorical data are reported with frequencies (count and percentage). A bootstrap analysis with 2000 replications was used to calculate CIs for values with asymmetric distribution.

Due to the lack of prior data in the literature on the prevalence of vestibular dysfunction in patients with PD and given the exploratory nature of the study, a convenience sample was therefore adopted, including all consecutive patients evaluated during the defined period. However,

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Table 1 Baseline characteristics

Variables	Mean
Age (years)	69.9±8.4
Time from diagnosis (years)	6.5±4.7
Education (years)	14.6±3.6
MDS-UPDRS part III	27.7±6.8
MMSE	27.6±1.8
Hohen & Yahr (range)	2–3

Data are reported as mean±SD.
MDS-UPDRS, Movement Disorder Society-Unified Parkinson's Disease Scale; MMSE, Mini-Mental State Examination.

a post hoc analysis was conducted to determine the CI of the estimated prevalence using the Wilson method.

Patient and Public Involvement Statement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

35 people with PD who met our eligibility criteria were included in this study (mean age: 69.9±8.4; 11 females). Demographic characteristics are reported in table 1.

The HIMP assessment was possible for 34 participants since, in one case, the patient could not avoid blinking during the impulse, even after several attempts. In another case, the anterior canals were not assessed for the same reason. The VOR gain for the SHIMP paradigm was collected for the 35 participants. Data are reported in table 2.

The vHIT assessment showed abnormal VOR gains in each canal and paradigm (prevalence range: 14–38%), with the right posterior canal most affected (figure 1).

On an individual basis, 60% (95% CI: 43.6% to 74.5%) of people with PD had at least one abnormal (ie, hypo-gain) vestibular canal; this prevalence increases to 69% (95% CI: 52.5% to 81.8%) if we include both hypo- and hyper-gain dysfunctions. Considering also the SHIMP paradigm, 83% (95% CI: 67.5% to 92.0%) of participants presented an abnormal VOR gain in at least one canal.

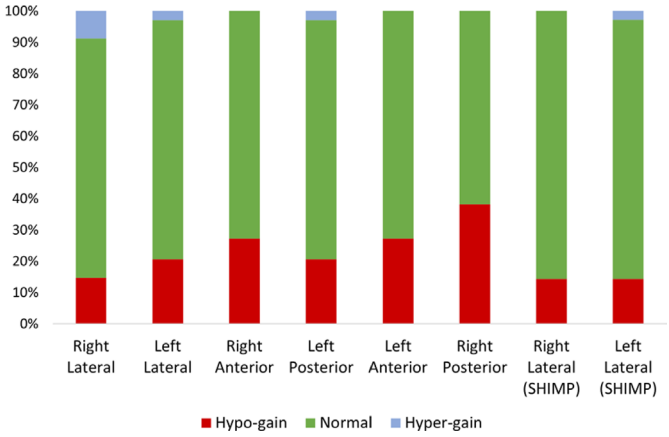

Figure 1 Prevalence of vestibulo-ocular reflex (VOR) gain dysfunction across the six semicircular canals. The vertical axis represents the percentage of participants, while the horizontal axis shows each canal tested. Bar segments are colour-coded to indicate the proportion of VOR gain categorised as hypo-gain (red), normal gain (green) or hyper-gain (light blue). The distribution of VOR dysfunctions highlights the prevalence of hypo-gains, particularly in the posterior canals, while hyper-gain is relatively rare. SHIMP, Suppression Head Impulse Paradigm.

DISCUSSION

This study aimed to investigate the function of semicircular canals in a cohort of people with PD patients using the vHIT through both the HIMP and SHIMP paradigms. Our research highlights the feasibility of an instrumental vestibular assessment in people with Parkinson's diseasePD in a rehabilitation setting. Moreover, we found that 69% of people with PD had at least one abnormal finding including both hypo- and hyper-gain dysfunctions. These results appear to contradict a recent study that found the VOR gain is to be essentially unchanged in people with PD compared with healthy controls.[11]

Table 2 Sample angular vestibulo-ocular reflex gains

Vestibular canal	N	VOR gain	95% Confidence Intervals	
Right lateral	34	0.99±0.20	0.92	1.06
Left lateral	34	0.94±0.16	0.88	0.99
Right anterior	33	0.87 (0.25)	0.82	0.92
Left posterior	34	0.87 (0.19)	0.81	0.93
Left anterior	33	0.83 (0.15)	0.78	0.88
Right posterior	34	0.82 (0.13)	0.76	0.87
Right lateral (SHIMP)	35	0.83±0.19	0.77	0.90
Left lateral (SHIMP)	35	0.85±0.20	0.78	0.92

Data are reported as mean±SD, or median (IQR) according to their distribution.
SHIMP, Suppression Head Impulse Paradigm ; VOR, vestibulo-ocular reflex.

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However, we reported the prevalence of VOR alterations based on an individual-level analysis, underlining isolated dysfunctions of the semi-circular canals, as previously studied in other neurological diseases.[12 13] Indeed, these findings on canal dysfunction in people with PD complement and confirm those collected by our research group in people with stroke[12] and multiple sclerosis.[13]

The specific evaluation of the canals and paradigms involved could allow for the integration of patient-specific and tailor-made exercises into current rehabilitation strategies.

Although the mean VOR gain in the sample identifies a 'healthy' population, the prevalence analysis on an individual basis overturns the results, highlighting the individual clinical condition. For this reason, we suggest that researchers should not only stop at the traditional summary reporting of mean values but should also break them down into a prevalence analysis of dysfunction based on related normative cut-offs.

Our results confirm those of Berkiten and colleagues[2] who have investigated the clinical utility of cVEMPs and vHIT in people with early-stage PD, finding significant differences compared with a healthy control group. Moreover, the vestibular system appears to be involved in both motor and non-motor symptoms of PD,[5] and a recent systematic review suggesting a possible role of vestibular rehabilitation in improving postural balance needs to be considered.[23]

PD, therefore, completes the range of neurological conditions most frequently managed in the rehabilitation setting[24]; hence, the need to systematically assess vestibular function in the neurorehabilitation setting, just as assessing balance with functional scales is routine. Recent qualitative studies[25 26] report some barriers perceived by clinicians to the knowledge translation of vestibular rehabilitation, which are, however, easily surmountable since it does not require a particularly sophisticated setting and considering the current increasing commercial low-cost availability of the few instruments needed.

Our findings are consistent with and further extend the literature on vestibular alterations in PD. Notably, Hawkins and colleagues reported preserved VOR gain using the HIMP paradigm in patients with PD, but their subsequent work using the SHIMP paradigm revealed altered saccade characteristics, suggesting a possible impairment in the suppression mechanism of the VOR response despite normal gain values.[27] Moreover, additional studies by the same group highlighted altered vestibulo-visual interaction in virtual reality environments[28] and abnormal otolith reflexes in PD,[11] pointing towards a more widespread vestibular involvement beyond semicircular canal gain values alone. These findings reinforce the importance of adopting multimodal vestibular assessments, such as the combination of HIMP and SHIMP, and including otolith function, to fully characterise the vestibular phenotype in PD.

However, some limitations must be acknowledged. First, it is a cross-sectional study that does not allow us to make causative hypotheses for the results found. Second, we evaluated only one component of the peripheral vestibular system (ie, semicircular canals using vHIT), thus capturing a part of the overall functionality. Lastly, we included physically self-sufficient participants with mild to moderate disability; a broader population should be assessed in the future.

CONCLUSION

A VOR gain impairment is highly prevalent in people with PD. The systematic evaluation of vestibular function during rehabilitation care could complete the routine balance assessment in this population. Further studies are needed to confirm these findings and to explore whether targeted vestibular interventions, tailored to individual VOR profiles, may lead to functional improvements in rehabilitation of people with PD.

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Patient consent for publication Consent obtained directly from patients.

Ethics approval This study involves human participants and was approved by the Local Independent Ethics Committeeof Santa Lucia Foundation (Institute for Research and Healthcare) with protocol number Prot. CE/2022_011. Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request. The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials. More detailed information is available from the corresponding author upon reasonable request.

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