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DEVELOPMENT AND PSYCHOMETRIC VALIDATION OF OPTOMETRIC SCREENING TOOLS FOR EYE MOVEMENT ABNORMALITIES IN PARKINSON'S DISEASE

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Abstract

Background: Parkinson's disease (PD) is increasingly recognized as a multisystem disorder in which eye movement abnormalities provide important diagnostic and prognostic insights.

Objective: This review synthesizes current evidence on oculomotor disturbances in PD, their clinical relevance, and their potential as biomarkers for early detection and disease monitoring.

Methods: A systematic literature review was conducted using PubMed, Scopus, and Web of Science databases up to 2025. Eligible studies included clinical, neurophysiological, and eye-tracking investigations that reported on saccades, vergence, and smooth pursuit in PD patients. Data on study characteristics, patient demographics, methods, and outcomes were extracted and narratively synthesized.

Results: Across studies, PD patients demonstrated prolonged saccadic latency, reduced vergence amplitudes, and impaired smooth pursuit, often correlating with disease severity. Some abnormalities were evident even in early stages, preceding overt motor dysfunction. Interventions such as prisms, vergence exercises, and vision therapy showed potential benefits in alleviating diplopia and improving visual function. Quantitative eye-tracking measures emerged as promising objective biomarkers for disease monitoring.

Discussion: Oculomotor assessment offers significant clinical implications, from supporting early diagnosis and differential recognition of parkinsonian syndromes to guiding rehabilitative strategies that enhance visual quality of life. However, heterogeneity of methodologies and limited longitudinal data constrain generalizability.

Conclusions: Eye movement abnormalities represent a valuable, underutilized tool in PD care. Standardization of assessment protocols, integration with neuroimaging, and validation through large-scale longitudinal studies are essential to establish oculomotor metrics as reliable biomarkers for clinical practice.

Keywords: Parkinson's disease, eye movement abnormalities, saccades, vergence, smooth pursuit, biomarkers, visual rehabilitation

INTRODUCTION

Parkinson's disease (PD) is a progressive, idiopathic neurodegenerative disorder primarily affecting the nigrostriatal dopaminergic pathway, with hallmark pathology including α-synuclein accumulation and Lewy body formation.(1)(2) Although historically characterized by cardinal motor symptoms tremor, rigidity, bradykinesia, and postural instability

there is growing consensus that non-motor features constitute a substantial component of the disease burden.(3) Among these, visual and oculomotor disturbances are gaining increased attention due to their high prevalence, early onset, and measurable impact on functional autonomy. (4)Visual dysfunction in PD extends beyond reduced visual acuity and includes complex deficits in ocular motor control, which are often underrecognized in routine clinical assessments(5). These include abnormalities in saccadic execution, smooth pursuit tracking, vergence mechanisms, fixation stability, and blink dynamics.(6) Such disturbances often manifest before or independently of overt motor signs, indicating their potential utility as prodromal biomarkers. Moreover, these oculomotor impairments compromise patients' ability to perform essential visual tasks, such as reading, scanning the environment, and maintaining visual fixation, directly impacting quality of life and increasing the risk of falls and accidents. Saccadic eye movements rapid, conjugate shifts in gaze that direct the fovea to targets of interest are frequently impaired in PD.(7) These saccadic anomalies typically present as hypometric responses, prolonged latency periods, and diminished peak velocities.(8) These patterns are believed to arise from basal ganglia dysfunction and disrupted connectivity between the superior colliculus, frontal eye fields (FEF), and supplementary eye fields (SEF). In PD, voluntary saccades during cognitive tasks such as reading or visual search may become effortful, imprecise, or delayed. Importantly, saccadic performance is often more compromised during anti-saccade or memory-guided tasks, reflecting deficits in executive control. (9)Smooth pursuit eye movements, which enable continuous tracking of moving objects, are likewise significantly affected in PD. Reduced pursuit gain defined as the ratio of eye velocity to target velocity is a consistent finding, often accompanied by compensatory catch-up saccades that interrupt smooth gaze.(10) Pursuit deficits are attributed to impaired cortico-basal ganglia circuitry, involving the dorsolateral prefrontal cortex, parietal lobe, and cerebellum.(11) Unlike reflexive eye movements, smooth pursuit relies on integrative cortical functions, which are disrupted in early PD, sometimes even in the absence of motor symptoms.(12) These changes suggest early cortical involvement and highlight smooth pursuit analysis as a valuable tool in early-stage diagnostics. Convergence insufficiency is another prominent oculomotor anomaly in PD, reported in up to 30 to 40% of cases. Patients may report symptoms such as intermittent diplopia, asthenopia, blurred near vision, or difficulty concentrating during reading.(13) The pathophysiology is likely multifactorial, involving dopaminergic depletion in midbrain structures such as the supraoculomotor area, which controls vergence, as well as impaired coordination between the medial rectus subnuclei.(14) Notably, convergence insufficiency in PD may partially respond to dopaminergic medications but often remains sub optimally corrected, necessitating additional rehabilitative measures.(15) Fixation instability is also well-documented, manifesting as increased occurrence of square-wave jerks, micro saccades, and fixational drift. These involuntary movements are particularly prominent during attempted steady gaze and are associated with reduced frontal lobe inhibition and cerebellar modulation. Such instability can interfere with reading, targeting, and sustained attention, and often correlates with neurocognitive decline, especially executive dysfunction.(16) Eye-tracking technologies have revealed increased variability in fixation duration and precision among PD cohorts, particularly in later stages or in individuals with coexisting cognitive impairment.(17) An additional layer of complexity arises from non-motor ocular manifestations, including reduced blink rate, blepharospasm, impaired pupillary response, and dry eye symptoms.(18) These factors contribute to visual discomfort, photophobia, and compromised visual endurance. The reduced blink frequency in PD, resulting from impaired basal ganglia output, contributes to tear film instability, exacerbating symptoms of dry eye disease and further impairing visual clarity.(18) Despite the significant burden of visual and oculomotor disturbances in PD, their recognition remains limited in standard neurological practice. The underdiagnosis may stem from the prioritization of motor symptom management and the lack of systematic visual assessments during routine care.(19) However, structured optometric evaluations offer an accessible, non-invasive avenue to detect and monitor these visual abnormalities. Clinical tools such as dynamic retinoscopy, prism cover testing, Maddox rod evaluation, vergence amplitude assessment, and computerized oculography allow for precise quantification of these deficits.(20) Importantly, many of these visual disturbances are amenable to rehabilitative intervention. For example, convergence insufficiency can be addressed using base-in prism lenses, vision therapy exercises to enhance fusional reserves, and reading aids. Saccadic training programs, including software-based protocols or guided visual scanning exercises, have shown efficacy in improving ocular control and compensatory strategies.(21) Visual cueing methods and contrast enhancement techniques may help mitigate some visual deficits by leveraging preserved pathways. Furthermore, collaborative care models involving neurologists, optometrists, and rehabilitation specialists can ensure that visual complaints are neither minimized nor misattributed to cognitive or psychological factors.(22) From a pathophysiological perspective, these visual anomalies underscore the broader systems-level disruption in PD that extends well beyond the nigrostriatal axis.(23) Involvement of cortical, cerebellar, and brainstem structures, as well as cholinergic and serotonergic systems, is evident in the genesis of oculomotor symptoms. Hence, visual abnormalities in PD serve as both a functional impairment and a reflection of widespread neurodegeneration. Their temporal evolution may also mirror the disease's trajectory, offering potential

markers for disease staging and prognosis(24). In conclusion, eye movement abnormalities in PD are pervasive, clinically significant, and highly informative. Their presence offers valuable insights into the underlying neural networks affected in the disease and provides a unique opportunity for early detection, objective monitoring, and personalized intervention. As PD is increasingly recognized as a multisystem disorder, incorporating optometric screening and rehabilitative protocols into comprehensive care pathways is not only justified but essential for optimizing patient outcomes.(25)

Despite substantial research on oculomotor abnormalities in Parkinson's disease, current literature often treats these deficits in isolation, lacking integration of their progression, functional relevance, and therapeutic implications within a unified clinical context. Furthermore, the role of optometric assessments in early diagnosis and phenotypic staging across PD subtypes remains underexplored. This review consolidates current evidence on ocular motor dysfunctions in PD(26), emphasizing their diagnostic and rehabilitative significance. It further proposes an interdisciplinary, protocol-driven approach to incorporate eye movement analysis into routine PD care. By positioning oculomotor deficits as both clinical features and potential biomarkers of multisystem neurodegeneration, this work underscores the need for standardized visual screening in PD management a perspective not yet reflected in prevailing neurological guidelines.

SCREENING AND REHABILITATION APPROACHES

Early identification and management of oculomotor dysfunction in Parkinson's disease (PD) are essential to reduce visual disability and improve functional independence. A structured optometric screening protocol should include- Dynamic retinoscopy, prism cover test, and Maddox rod for detecting binocular misalignment and convergence insufficiency. Vergence range measurement and computerized eye tracking for analysing saccades, pursuits, and fixation control. Blink rate observation and tear film tests to evaluate dry eye symptoms associated with reduced blink frequency.

Many of these visual disturbances are amenable to rehabilitation: Prism lenses and vision therapy (e.g., Brock string, pencil push-ups) help address convergence issues. Saccadic and pursuit training software improves gaze control and reading efficiency. Fixation stability exercises and visual attention tasks enhance executive eye movement control. Blink training and lubrication therapy support ocular surface health and comfort. A collaborative care model involving neurologists, optometrists, and rehabilitation specialists ensures comprehensive management. Incorporating these assessments into routine PD care offers a practical, non-invasive way to improve both diagnostic accuracy and quality of life an area still underrepresented in current guidelines.

FUNCTIONAL IMPACT OF EYE MOVEMENT ABNORMALITIES IN PARKINSON'S DISEASE

Eye movement abnormality	Functional impact in PD
Saccadic dysfunction	Delayed reading & impaired target shifting
Smooth pursuit deficit	Poor tracking of moving stimuli
Convergence insufficiency	Blurred near vision, diplopia
Fixation instability	Difficulty in visual fixation & attention
Reduced blink rate	Visual discomfort & dry eye symptoms

LITERATURE REVIEW

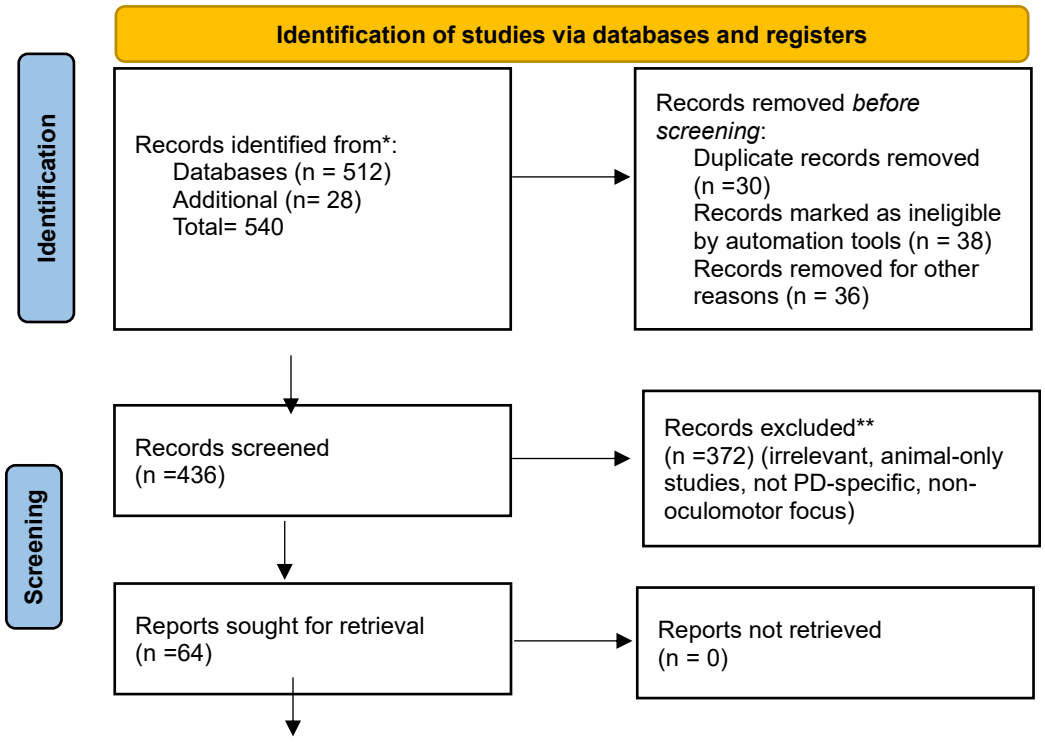
No.	Authors & Year	Review Design	Methodology	Identified Gaps	Key Results & Conclusion
1	Stefanescu et al., 2024(27)	Retrospective	Eye-tracking of visually guided saccades in 62 PD patients correlated with cognition and demographics	No longitudinal follow-up limited scope of oculomotor analysis	Saccadic metrics linked with cognitive status and demographics, highlighting eye-tracking as a promising, non-invasive PD monitoring tool.

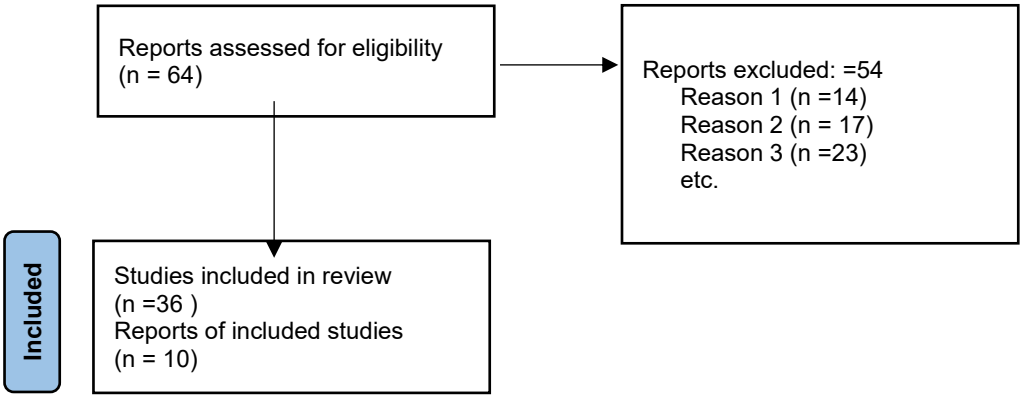
2	Shaikh AG, Sun YR, Ghasia FF (2023)(28)	Narrative Review	Clinical and research studies on eye movement changes in Parkinson's patients were analysed.	Parkinson's patients show abnormal saccades, fixation instability, and vergence issues. Eye movement issues relate to brain areas like basal ganglia and brainstem.	Lack of real-world tracking data, no standardized clinical protocols, and limited use of portable eye-tracking tools
3	Fooken J., Patel P., Jones CB, McKeown MJ, Spering M. (2022).(29)	Experimental Study	Eye-tracking tasks comparing Parkinson's patients and controls using visual targets (moving vs stationary)	Parkinson's patients showed poor eye movement to static targets but normal tracking of moving ones. Suggests alternate motor pathways are preserved.	Small sample, lab-based tasks, lacks real-world application and long-term follow-up.
4	Sekar AT-N, Kaski D. (2025)(30)	Narrative Review	Reviewed studies on eye movement abnormalities in neurodegenerative diseases	Eye movement changes (like saccadic and pursuit deficits) can help differentiate conditions like PD and Alzheimer's.	No standard clinical protocols, limited normative data, and lack of real-world studies.
5	Li H., Zhang X., Yang Y., Xie A. (2023)(31)	Narrative review	Summarized clinical and research studies on eye movements in Parkinson's disease	PD patients show abnormal saccades, fixation issues, and impaired pursuit. Eye tracking may help in diagnosis and monitoring.	No standard protocols, limited real-world validation, and small sample sizes in most studies.
6	Sonawane et al., 2023(32)	Narrative Review	Synthesized data on ocular and retinal changes in PD	Need for reliable biomarkers limited long-term data.	PD is associated with diverse ocular and visual deficits that may act as early indicators and guide targeted interventions.
7	Antoniades & Spering, 2023(33)	Narrative Review	Cross-species synthesis of neurophysiological and behavioural evidence related to oculomotor control in Parkinson's disease	Lack of standardized, disease-specific eye-movement markers; limited clinical integration of oculomotor tools	Eye movement abnormalities in PD reflect underlying neural deficits and treatment status. While not diagnostic in isolation, they hold value as part of a multimodal biomarker approach for disease staging and monitoring.

8.	Bronstein et al., 2022(34)	Book Chapter Review	Descriptive analysis of oculomotor and vestibular impairments in PD based on clinical and experimental evidence	Lack of real-world data, limited ecological validity of lab-based findings	Eye movement abnormalities are well-characterized in lab settings, but their relevance to daily function is underexplored. Field-based studies are essential for clinical translation.
9.	Nieto-Escamez et al., 2023(35)	Narrative Review	Synthesized literature on ocular and visual-perceptual impairments in PD	Incomplete mechanistic understanding; limited longitudinal data	Visual dysfunction in PD spans motor and perceptual domains. Though linked to structural and neurochemical changes, real-world impact remains under-investigated
10.	Gupta et al. 2023(36)	Observational Study	Video-oculography in PD patients vs. controls to assess alignment & disparity-driven vergence	Small sample, no longitudinal data	PD patients showed frequent binocular misalignment and impaired vergence (slower initiation, lower gain), independent of motor stage, highlighting early binocular screening need.

METHODOLOGY

This review was planned and written to conform with the reporting expectations of major neurology journals and with the PRISMA 2020 reporting recommendations for systematic reviews. The final manuscript will follow the Journal of the Neurological Sciences' author guidance for review articles and the PRISMA checklist and flow-diagram will be included as supplementary material.





Primary objective To synthesize evidence on oculomotor (saccades, smooth pursuit, vergence, fixation and blink) abnormalities in idiopathic Parkinson's disease (PD), their functional impact, and the effectiveness/feasibility of optometric screening and rehabilitation strategies.
Secondary objectives To describe variability by disease stage and cognitive status, assess which oculomotor metrics are most promising as biomarkers, and identify gaps and recommendations for clinical screening protocols.
Timeframe and language of Publications from 1 January 2020 to 31 July 2025 (to match the user's search window), English language full-text articles.

Eligibility criteria
Inclusion
- Original clinical research (observational cohort, case–control, cross-sectional).
- Interventional trials (randomized or non-randomized) evaluating rehabilitative/optometric interventions. Diagnostic/accuracy studies assessing eye-movement metrics in PD.
- Systematic reviews and meta-analyses (used for background and cross-checking references). Experimental human studies with primary oculomotor outcomes.
- (Quantitative studies only; qualitative studies may be summarized narratively if directly relevant.)
- Adults (≥18 years) with clinically diagnosed idiopathic Parkinson's disease (any stage).
- Studies that report separate data for idiopathic PD if mixed parkinsonian cohorts are used.

Exclusion
- Secondary parkinsonism or atypical parkinsonian syndromes unless idiopathic PD data are separably reported.
- Case reports with <3 subjects, conference abstracts without full text, editorials, commentaries, and animal-only studies.
- Studies lacking primary oculomotor data (e.g., those reporting only retinal imaging without ocular motor measures).
- Non-English full texts (unless translation is available).

DISCUSSION

Eye movement control is a sensitive indicator of neural integrity, and accumulating evidence demonstrates that Parkinson's disease (PD) is associated with a wide spectrum of oculomotor abnormalities. Across the studies reviewed, consistent deficits were observed in saccadic performance, smooth pursuit, fixation stability, and vergence control, supporting the notion that eye movements represent a reliable window into basal ganglia and brainstem dysfunction.
Saccadic abnormalities were the most consistently reported finding.(37),(28) documented prolonged saccadic latency, increased variability, and reduced accuracy, with several parameters correlating with cognitive decline and disease severity. These findings suggest that saccades may reflect both motor and non-motor aspects of PD. However, methodological heterogeneity including variations in recording techniques and patient selection limits direct comparison across studies.
Smooth pursuit impairments were also evident, although their manifestation was task-dependent. (29)It demonstrated that PD patients showed poor tracking of static stimuli but relatively preserved pursuit of moving targets, suggesting

that compensatory neural circuits may remain functional in the early stages. This highlights the importance of differentiating between pursuit subtypes when interpreting clinical findings.

Fixation instability and micro-saccadic intrusions were described in both observational and review-based studies, with potential implications for reading, visual exploration, and daily functioning. While these abnormalities are not specific to PD, their presence in conjunction with other oculomotor deficits may enhance diagnostic accuracy.

Vergence dysfunction particularly convergence insufficiency emerged as another robust feature of PD. (36) It identified early binocular misalignment and reduced vergence gain, while (32) emphasized its clinical relevance, given that patients frequently complain of diplopia, reading difficulty, and ocular fatigue. Unlike saccadic or pursuit deficits, vergence abnormalities often appear independent of motor stage, suggesting that they may serve as early diagnostic markers.

The collective evidence underscores the potential of eye-tracking technologies as objective, non-invasive biomarkers. Automated video-oculography, as employed by (36), enables quantitative characterization of eye movement patterns, providing a feasible tool for both clinical and research settings. Moreover, comparative reviews (30), (33) have suggested that oculomotor profiling may help distinguish PD from other neurodegenerative disorders such as Alzheimer's disease or progressive supranuclear palsy. This diagnostic differentiation is of particular relevance in early disease stages, when motor features may overlap.

Nevertheless, significant limitations temper the current evidence base. Most included studies were cross-sectional with relatively small sample sizes, limiting generalizability. There is also considerable variability in methodology, including differences in stimulus paradigms, outcome measures, and analytic frameworks. Furthermore, few studies have integrated oculomotor findings with other biomarkers (e.g., imaging, genetics, electrophysiology), which could enhance mechanistic understanding and clinical applicability. Longitudinal data tracking the progression of eye movement abnormalities alongside motor and cognitive decline remain scarce.

From a clinical perspective, the recognition of oculomotor abnormalities carries both diagnostic and rehabilitative implications. Early identification of convergence insufficiency and vergence deficits may guide targeted interventions such as prism correction, convergence exercises, or vergence therapy, potentially improving quality of life. Similarly, characterizing saccadic and pursuit dysfunction could inform adaptive strategies for reading and navigation. Integration of oculomotor assessments into standard neurological evaluation may therefore add value beyond traditional motor scales.

In conclusion, the evidence reviewed highlights that oculomotor abnormalities are prevalent, multifaceted, and clinically meaningful in PD. While saccadic, pursuit, fixation, and vergence deficits have been reliably demonstrated, further work is needed to standardize protocols, validate biomarkers across diverse populations, and establish longitudinal trajectories. Future research should focus on combining oculomotor measures with neuroimaging, cognitive profiling, and therapeutic interventions to fully exploit their potential as diagnostic and monitoring tools in PD.

Clinical Implications Eye movement abnormalities in Parkinson's disease hold significant clinical value. Early signs such as vergence insufficiency and saccadic latency may support earlier diagnosis and aid in differentiating PD from other neurodegenerative disorders. Targeted interventions like prisms, vergence exercises, and visual training can help manage diplopia, fixation instability, and reading difficulties. Quantitative eye-tracking offers objective biomarkers for monitoring disease progression and treatment response. Incorporating oculomotor assessment into multidisciplinary care, alongside neurologists and ophthalmologists, can improve both functional outcomes and quality of life for patients with PD.

Limitations and Future Directions Current evidence on eye movement abnormalities in Parkinson's disease is limited by small sample sizes, heterogeneous methodologies, and lack of standardized assessment tools. Many studies are cross-sectional, restricting insights into long-term progression. Future research should focus on large, longitudinal studies using uniform eye-tracking protocols, integration with neuroimaging, and exploration of digital, portable eye-tracking tools for routine clinical use. Establishing robust oculomotor biomarkers could improve early detection, track disease progression, and guide individualized rehabilitation strategies.

CONCLUSION

Eye movement abnormalities in Parkinson's disease are not merely ancillary findings but represent sensitive, functionally relevant biomarkers of the disease's multisystem involvement. Evidence from clinical, neurophysiological, and neuroimaging studies underscores their potential role in early detection, phenotypic differentiation, and monitoring of disease progression. The heterogeneity in presentation ranging from saccadic hypometria and pursuit deficits to convergence insufficiency and fixation instability reflects both dopaminergic and

non-dopaminergic pathway dysfunction, explaining the variable responsiveness to current pharmacological and surgical interventions. Importantly, these visual motor disturbances frequently compound sensory deficits, amplifying the burden on daily activities such as reading, navigation, and object tracking. Despite the depth of laboratory characterisation, translation into routine care remains limited by the absence of standardized protocols, normative reference values, and widely accessible assessment tools. The integration of structured optometric screening, supported by portable eye-tracking technologies and telemedicine-ready platforms, offers a feasible and cost-effective pathway to bridge this gap. Coupled with targeted rehabilitation strategies including vision therapy, prism correction, and environmental adaptation such integration can enable earlier intervention, guide personalized management, and improve functional outcomes. Future multicentre longitudinal studies are essential to establish the prognostic value of these measures and to validate their role in comprehensive, multidisciplinary PD care.

Declaration of Interest Statement

The authors declare that there are no conflicts of interest related to the content of this manuscript. This research was conducted independently, and no financial or non-financial support from commercial or institutional entities influenced the study design, data collection, analysis, interpretation, or the writing of this paper.

ETHICAL STATEMENT

This study is a systematic review and meta-analysis based on previously published literature and does not involve the collection of any primary data from human or animal subjects. Therefore, ethical approval and informed consent were not required. All included studies in this review were assumed to have obtained the appropriate ethical clearances as reported by their respective authors

REFERENCES

1. Quinn PMJ, Moreira PI, Ambrósio AF, Alves CH. PINK1/PARKIN signalling in neurodegeneration and neuroinflammation. Acta Neuropathol Commun. 2020 Dec 9;8(1):189.
2. Bloem BR, Okun MS, Klein C. Parkinson's disease. The Lancet. 2021 Jun;397(10291):2284–303.
3. Ferrazzoli D, Ortelli P, Versace V, Stolz J, Dezi S, Vos P, et al. Post-traumatic parkinsonism: The intricate twist between trauma, inflammation and neurodegeneration. A narrative review. J Neurol Sci. 2024 Nov;466:123242.
4. Miglis MG, Adler CH, Antelmi E, Arnaldi D, Baldelli L, Boeve BF, et al. Biomarkers of conversion to α-synucleinopathy in isolated rapid-eye-movement sleep behaviour disorder. Lancet Neurol. 2021 Aug;20(8):671–84.
5. Tolosa E, Garrido A, Scholz SW, Poewe W. Challenges in the diagnosis of Parkinson's disease. Lancet Neurol. 2021 May;20(5):385–97.
6. Bonnet CT, Delval A, Singh T, Defebvre L. Parkinson's disease-related changes in the behavioural synergy between eye movements and postural movements. European Journal of Neuroscience. 2021 Aug 28;54(3):5161–72.
7. Mildner S, Hotz I, Kübler F, Rausch L, Stampfer-Kountchev M, Panzl J, et al. Effects of activity-oriented physiotherapy with and without eye movement training on dynamic balance, functional mobility, and eye movements in patients with Parkinson's disease: An assessor-blinded randomised controlled pilot trial. PLoS One. 2024 Jun 14;19(6):e0304788.
8. Li H, Zhang X, Yang Y, Xie A. Abnormal eye movements in Parkinson's disease: From experimental study to clinical application. Parkinsonism Relat Disord. 2023 Oct;115:105791.
9. Thacker M, Wong KY, Zhou L, Liu J, Wong MS. Exploring ocular disorders in Parkinson's disease: A comprehensive review and future perspectives. Exp Eye Res. 2025 Feb;251:110225.
10. Bernardinis M, Atashzar SF, Jog MS, Patel R V. Visual velocity perception dysfunction in Parkinson's disease. Behavioural Brain Research. 2023 Aug;452:114490.
11. Li H, Ma W, Li C, He Q, Zhou Y, Xie A. Combined diagnosis for Parkinson's disease via gait and eye movement disorders. Parkinsonism Relat Disord. 2024 Jun;123:106979.
12. Fooken J, Patel P, Jones CB, McKeown MJ, Spering M. Preservation of Eye Movements in Parkinson's Disease Is Stimulus- and Task-Specific. The Journal of Neuroscience. 2022 Jan 19;42(3):487–99.
13. Buonocore J, Facchin A, Crasà M, Sgrò G, Cristofaro A, Quattrone A, et al. Eye movement abnormalities in Parkinson's disease motor subtypes: a video-oculographic study. Neurological Sciences. 2025 Aug 21;46(8):3677–84.
14. Bougea A. Synuclein in neurodegeneration. In 2021. p. 97–134.

15. K Kwan SC, Atiya A, Hussaindeen JR, Praveen S, Ambika S. Ocular features of patients with Parkinson's disease examined at a Neuro-Optometry Clinic in a tertiary eye care center. Indian J Ophthalmol. 2022 Mar;70(3):958–61.
16. Garces P, Antoniades CA, Sobanska A, Kovacs N, Ying SH, Gupta AS, et al. Quantitative Oculomotor Assessment in Hereditary Ataxia: Discriminatory Power, Correlation with Severity Measures, and Recommended Parameters for Specific Genotypes. The Cerebellum. 2023 Jan 14;23(1):121–35.
17. Zhang J, Zhang B, Ren Q, Zhong Q, Li Y, Liu G, et al. Eye movement especially vertical oculomotor impairment as an aid to assess Parkinson's disease. Neurological Sciences. 2021 Jun 12;42(6):2337–45.
18. Ungureanu L, Chaudhuri KR, Diaconu S, Falup-Pecurariu C. Dry eye in Parkinson's disease: a narrative review. Front Neurol. 2023 Aug 1;14.
19. Li H, Li C, Ma W, Qin K, Wang Z, Hou B, et al. Eye movement disorders: A new approach to preliminary screening of Parkinson's disease. Neuroscience. 2024 Dec;563:202–11.
20. Zhou H, Wang X, Ma D, Jiang Y, Li F, Sun Y, et al. The differential diagnostic value of a battery of oculomotor evaluation in Parkinson's Disease and Multiple System Atrophy. Brain Behav. 2021 Jul 30;11(7).
21. Ferri N, Casagrande Conti L, Manzari L, Piatti D, De Angelis D, Nocentini U, et al. 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. BMJ Open. 2025 Aug;15(8):e099765.
22. Culicetto L, Cardile D, Marafioti G, Lo Buono V, Ferraioli F, Massimino S, et al. Recent advances (2022–2024) in eye-tracking for Parkinson's disease: a promising tool for diagnosing and monitoring symptoms. Front Aging Neurosci. 2025 May 21;17.
23. Zhang C, Wu Q qian, Hou Y, Wang Q, Zhang G jian, Zhao W bo, et al. Ophthalmologic problems correlates with cognitive impairment in patients with Parkinson's disease. Front Neurosci. 2022 Oct 6;16.
24. Sohns E, Szmulewicz DJ, Tarnutzer AA. Oculomotor and Vestibular Deficits in Friedreich Ataxia - Systematic Review and Meta-Analysis of Quantitative Measurements. The Cerebellum. 2024 Jul 27;23(6):2269–84.
25. Gupta P, Murray JM, Beylergil SB, Jacobs J, Kilbane CW, Shaikh AG, et al. Objective assessment of eye alignment and disparity-driven vergence in Parkinson's disease. Front Aging Neurosci. 2023 Oct 31;15.
26. Nieto-Escamez F, Obrero-Gaitán E, Cortés-Pérez I. Visual Dysfunction in Parkinson's Disease. Brain Sci. 2023 Aug 7;13(8):1173.
27. ŞtefŞnescu E, Strilciuc ştefan, Chelaru VF, Chira D, Mureşanu D. Eye tracking assessment of Parkinson's disease: a clinical retrospective analysis. J Med Life. 2024 Mar;17(3):360–7.
28. Sun YR, Beylergil SB, Gupta P, Ghasia FF, Shaikh AG. Monitoring Eye Movement in Patients with Parkinson's Disease: What Can It Tell Us? Eye Brain. 2023 Jul;Volume 15:101–12.
29. Fooken J, Patel P, Jones CB, McKeown MJ, Spering M. Preservation of Eye Movements in Parkinson's Disease Is Stimulus- and Task-Specific. The Journal of Neuroscience. 2022 Jan 19;42(3):487–99.
30. Sekar A, Panouillères M, Kaski D. Detecting Abnormal Eye Movements in Patients with Neurodegenerative Diseases – Current Insights. Eye Brain. 2024 Apr;Volume 16:3–16.
31. Li H, Zhang X, Yang Y, Xie A. Abnormal eye movements in Parkinson's disease: From experimental study to clinical application. Parkinsonism Relat Disord. 2023 Oct;115:105791.
32. Doke R, Sonawane S, Thorat V, Bhabad S, Lamkhade G, Jadhav S, et al. Through the eyes of Parkinson\'s: A narrative review of clinical spectrum and ophthalmological challenges in Parkinson's disease. Indian Journal of Clinical and Experimental Ophthalmology. 2023 Dec 28;9(4):489–94.
33. Antoniades CA, Spering M. Eye movements in Parkinson's disease: from neurophysiological mechanisms to diagnostic tools. Trends Neurosci. 2024 Jan;47(1):71–83.
34. Bronstein AM, Anderson T, Kaski D, MacAskill M, Shaikh A. Oculomotor and Visual-Vestibular Disturbances in Parkinson's Disease. In: Non-Motor Parkinson's Disease. Cambridge University Press; 2022. p. 115–29.
35. Nieto-Escamez F, Obrero-Gaitán E, Cortés-Pérez I. Visual Dysfunction in Parkinson's Disease. Brain Sci. 2023 Aug 7;13(8):1173.
36. Gupta P, Murray JM, Beylergil SB, Jacobs J, Kilbane CW, Shaikh AG, et al. Objective assessment of eye alignment and disparity-driven vergence in Parkinson's disease. Front Aging Neurosci. 2023 Oct 31;15.
37. ŞtefŞnescu E, Strilciuc Ş, Chelaru VF, Chira D, Mureşanu D. Eye tracking assessment of Parkinson's disease: a clinical retrospective analysis. J Med Life. 2024 Mar;17(3):360–7.