GMR
The Original

ADVANCING PARKINSON'S DISEASE REHABILITATION THROUGH VIRTUAL REALITY: A NARRATIVE REVIEW OF CLINICAL OUTCOMES AND FUNCTIONAL BENEFITS

Clawdia Adikari[1*], David Ratna Paul T[2*], Amlan Banik[3], Sreeraja Kumar R[4]

[1] PhD Scholar, Faculty of Nursing, Chulalongkorn University, Thailand. https://orcid.org/0009-0000-3359-9580
[2] Associate Professor, Sharda school of Nursing Science and Research, Sharda University, https://orcid.org/0000-0003-0319-1175
[3] Senior Tutor, Sharda School of Nursing Science and Research, Sharda University.
[4] Associate Dean, Sharda School of Nursing Science and Research, Sharda University
*Corresponding Author: Clawdia Adikari, cloudadikari@gmail.com

ABSTRACT

Background: Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder characterized by motor impairments such as tremor, rigidity, and postural instability, along with non-motor symptoms that affect quality of life. Conventional physiotherapy remains essential in PD management; however, limitations in patient motivation and adherence have led to the exploration of novel rehabilitation approaches such as virtual reality (VR) and exergaming.
Objective: This narrative review aims to synthesize and critically evaluate current evidence on the effectiveness of VR-based interventions for improving balance, gait, motor performance, and quality of life in individuals with PD compared to conventional or passive rehabilitation programs.
Methods: A comprehensive literature search was conducted across PubMed, Cochrane Library, Scopus, CINAHL, PsycINFO, and Embase for studies published between 2020 and 2025, following PRISMA 2020 guidelines. Randomized and quasi-randomized controlled trials involving adults with PD (Hoehn and Yahr stages 1–4) were included. Methodological quality was appraised using the JBI checklist.
Results: Fourteen trials involving 16–200 participants demonstrated that VR and exergaming significantly improved balance, mobility, and motor outcomes, as indicated by enhancements in Berg Balance Scale (BBS), Timed Up and Go (TUG), and Unified Parkinson's Disease Rating Scale (UPDRS-III) scores. Secondary outcomes revealed benefits in gait performance, cognitive function, balance confidence, and health-related quality of life. Semi-immersive and telerehabilitation VR formats also showed comparable efficacy, enhancing accessibility and adherence.
Conclusion: VR-based rehabilitation represents a promising adjunct to conventional physiotherapy in Parkinson's disease, offering multidimensional improvements in balance, motor function, cognition, and quality of life. Future large-scale, longitudinal studies are needed to validate long-term efficacy and optimize personalized VR protocols for sustainable functional recovery.

KEYWORDS: Parkinson's disease, virtual reality, exergaming, balance, rehabilitation, gait, quality of life.

INTRODUCTION

Description of the condition

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder mainly affecting the dopaminergic neurons in the substantia nigra pars compacta, leading to motor and non-motor disfunctions (Kalia & Lang, 2015). Clinically, PD is considered by inactive tremor, bradykinesia, inflexibility, and postural variability, which pointedly damage motion and regular functioning (Tysnes & Storstein, 2017). Non-motor indications such as cognitive impairment, depression, and sleep disturbances further worsen the quality of life of patients and enact a heavy problem on caregivers and healthcare systems (Pringsheim et al., 2014). Internationally, about six million personalities are identified with PD, and the incidence lasts to upsurge, predominantly in low- and middle-income countries (Ou et al., 2021). The progressive nature of PD and its related gait and balance shortages increase the risk of falls, which disturbs more than 80% of patients at some stage of the disease (Ashburn et al., 2008). Falls not only result in physical injuries but also induce fear of falling, loss of confidence, and social withdrawal, all of which further worsen debility (Mak & Pang, 2009).

Description of the intervention

Conventional physiotherapy remnants an important part of PD management, concentrating on balance reinstruction, strength workouts, and gait improvement (King & Horak, 2008). However, observance to traditional rehabilitation programs is regularly restricted due to boredom, conveyance problems, and reduced inspiration among patients (Teo, Zheng & Bird, 2022). In recent years, virtual reality (VR) and exergaming methods have developed as capable assistants to conventional therapy. These Method of interventions deliver an immersive, collaborative, and inspiring environment where patients can participate in task-specific motor exercise with real-time visual and auditory response (Farič et al., 2021). Systems such as the Nintendo Wii, Xbox Kinect, and other VR-based rehabilitation platforms have been employed to improve balance and postural control in PD by stimulating multisensory response and encouraging neuroplastic variation (Alagumoorthi et al., 2022).

The Wii sports-based approach exercise, for example, enables both fixed-support and change-in-support postural tactics through dynamic body activities such as marching, reaching, and trunk rotation. This method has been revealed to lessen the drop the fall rates while refining overall motor control (Alagumoorthi et al., 2022). Similarly, home-based VR balance training using instruments like the Nintendo Wii or C-Mill treadmill has proved significant progresses in functional outcomes assessed by the Berg Balance Scale (BBS) and Timed Up and Go (TUG) test (Anwar et al., 2021; Gulcan et al., 2022). By offering engaging, feedback-rich environments, exergaming enhances patient motivation, cognitive engagement, and adherence, addressing some of the limitations of conventional therapy (Gu et al., 2025).

Why it is important to do this review

Despite the increasing evidence supporting VR and exergaming in PD rehabilitation, the heterogeneity in study designs, intervention protocols, and outcome measures makes it difficult to draw conclusions about their efficacy and long-term uses. Therefore, leading a narrative review is vital to comprehensively analyze and synthesize the available research evidence. Such a review can provide understanding into the mechanisms, therapeutic value, and feasibility of VR-based rehabilitation, guide clinical decision-making, and identify gaps for future randomized controlled trials. Moreover, considering the comparative advantages of immersive and semi-immersive technologies may help researchers personalize therapeutic methods to optimize practical recovery, safety, and quality of life in individuals living with Parkinson’s disease.

Aim/Purpose of the narrative review:

the aim or objective is to critically evaluate the effectiveness of VR based rehabilitation programmes either implemented alone and along with conventional therapies on balance, mobility, gait, functioning, cognition and quality of life.

METHODOLOGY

Study design and ethical aspects

The current research carried out with Narrative review by following the PRISMA 2020 Guidelines

Criteria for Considering Studies for this Review

Research Question and Study selection-PICOS

Research Question was “What is the effectiveness of virtual reality (VR) interventions for improving balance and functional rehabilitation outcomes in individuals with Parkinson's disease, compared to conventional or passive control interventions?”

The study selection was prepared based on the PICOS. The following table describes the Type of Participants, Type of Intervention and comparison, type of Outcome measure, and study design.

Type of Participants**:** the present narrative review focused on the Adults clinically diagnosed with Parkinson’s disease (PD) at Hoehn and Yahr stages 1–4, meeting UK Parkinson’s Disease Society Brain Bank or equivalent diagnostic criteria. There were no restrictions on participants’ age, gender, disease duration, or severity.

Type of Intervention: this narrative review includes the Virtual Reality (VR)–based rehabilitation or exergaming interventions, used either alone or in combination with conventional physiotherapy. These included computer-generated, motion-based exercises providing real-time, multisensory feedback for balance, gait, or mobility training. Interventions comprised VR physiotherapy, Wii-based games, exergames, or immersive VR platforms aimed at improving postural control, gait, and mobility.

Type of Comparison: the control group or comparison group should have Conventional physiotherapy or exercise programs without a VR component. These typically included standard balance, gait, strengthening, and mobility exercises of comparable duration and frequency to the intervention groups.

Types of Outcome measures: the out come of this narrative review comprises with primary outcome and secondary outcome.

Primary Outcomes: Measures of balance and gait, including the Berg Balance Scale (BBS), Mini-Balance Evaluation Systems Test (Mini-BESTest), Limit of Stability (LOS), Activities-Specific Balance Confidence Scale (ABCS), Falls Efficacy Scale-International (FES-I), Timed Up and Go (TUG), 6-Minute Walk Test (6MWT), 10-Meter Walk Test (10MWT), Dynamic Gait Index (DGI), and Unified Parkinson’s Disease Rating Scale Part III (UPDRS III).

Secondary Outcomes: Functional, cognitive, and psychosocial domains including Functional Independence Measure (FIM), Five Times Sit-to-Stand Test (FTSST), Barthel Index, Disabilities of Arm, Shoulder and Hand (DASH), Montreal Cognitive Assessment (MoCA), Mini-Mental State Examination (MMSE), Parkinson’s Disease Questionnaire (PDQ-39 or PDQ-8), Short Form Health Surveys (SF-12, SF-36), and related self-efficacy and quality-of-life scales.

Study Desing: All randomized controlled trials (RCTs) and quasi-randomized controlled trials published between January 2020 and April 2025 that examined VR or exergaming interventions in individuals with PD. Only English-language full-text articles were included. Studies were identified through systematic database searches (Cochrane Trials, CENTRAL, MEDLINE and Web of Science) and manual reference screening.

Data Source and Search Strategy:
The present research was caried by with the support of PRISMA 2020 Strategies. To identify the articles, a comprehensive search was conducted across the following data base PubMed/MEDLINE, Cochrane Library and Web of Sciences from the year 2020 to 2025 to confirm complete exposure of the available research articles on virtual reality rehabilitation in Parkinson's disease. Search strategies combined relevant keywords and Medical Subject Headings (MeSH) terms such as "virtual reality," "exergaming," "Parkinson's disease," "balance," "gait," and "rehabilitation". Additionally, reference lists of retrieved articles and relevant reviews were hand-searched to identify any studies not captured through database queries. Searches were conducted with no language or journal date limitations to lessen bias. Grey literature sources such as conference abstracts, theses, and clinical trial registries were also explored. The methodological quality assessment of the included study was assessed using JBI check list (Hilton, 2024). Without such critical appraisal, narrative reviews risk overestimating benefits or underestimating harms, compromising their clinical utility. Thus, systematic and transparent quality assessment frameworks like the JBI checklist are indispensable components for trustworthy narrative reviews of RCTs

RESULTS

Result of Search/Study Selection

The PRISMA method was utilized the process of selection of the studies. An initial search across the PubMed, Cochrane and Web of Science acknowledged 723 records (315, 187 and 221 respectively). After removing 180 duplicates 543 title and abstracts were screened. 503 excluded through automated filtering and manual relevance assessment. Full text of 40 research papers was recovered, but, 9 reports were not available, leaving 31 to assess the eligibility. Out of these, 16 were removed after the concluding that control group not receiving conventional physiotherapy and experimental group receiving the intervention in the absence of physiotherapy and Full text articles were not available. The remaining 14records were included in this review.

Included studies:

All studies were published between 2020 to 2025

Table 1 Demographic Characteristic of the study Participants

Study (Year)	Sample Size (EG/CG)	Age Range or Mean (years)	Hoehn & Yahr Stage	Gender Distribution	Other Demographics/ Notes	Primary Outcome	Secondary Outcomes	Follow-Up Duration and Details
Alagumoorthi et al (2023)	192 (96/96)	Mean 68.7 ± 8.2	2.5 to 4	Not specified	History of at least 3 falls in last 3 months	Number of fallers, Fall rate, Berg Balance Scale (BBS), Timed Up and Go (TUG)	Parkinson's Disease Questionnaire-39 (PDQ-39)	36 weeks post-intervention follow-up
Anwar et al (2021)	24 (12/12)	Mean 59.3 ± 7.7	II to III	18 males, 6 females	MMSE > 24	Berg Balance Scale (BBS), Timed Up and Go (TUG)	None reported	No explicit follow-up beyond 4 weeks
Cetin et al (2024)	23 (12/11)	Mean 62.8 ± 8.1	1.5 to 3	13 males, 10 females	MMSE ≥ 24	9-Hole Peg Test (9HPT), Minnesota Manual Dexterity Test (MMDT), Trunk Impairment Scale (TIS), Montreal Cognitive	Movement Disorder Society-UPDRS (MDS-UPDRS) parts II and III	No follow-up beyond 8 weeks intervention

						Assessment (MoCA)		
GoffrEdo et al (2023)	97 (49/48)	Mean 70.1 ± 8.9	≤ 3	51 males, 46 females	Drug treatment stable for 1 month	Mini-Balance Evaluation Systems Test (Mini-BESTest)	Timed Up and Go (TUG), 6-Minute Walk Test (6MWT), MDS-UPDRS part III	No long-term follow-up; post 6–10 week intervention
Gulcan et al (2022)	30 (15/15)	Mean 59.5 ± 7.5	≤ 3	Not reported	MMSE > 24	Berg Balance Scale (BBS), Posturography (Huber 360 system)	UPDRS-III, Activities-specific Balance Confidence (ABC), TUG	No follow-up mentioned beyond 6-week intervention
Kashif et al (2022)	28 (14/14)	Mean 57.2 ± 6.1	I to III	20 males, 8 females	MMSE ≥ 24	UPDRS parts II & III, Berg Balance Scale (BBS)	Activities-specific Balance Confidence (ABC) scale	Follow-up at 16th week showed sustained improvements
Kashif et al (2024)	60 (20/20/20)	Mean 57.5 ± 6.2	I to III	Not specified	MMSE > 24	UPDRS part III, Berg Balance Scale (BBS), Activities of Daily Living (ADLs)	--	Follow-up at 16th week post-intervention
Maranesi et al (2023)	32 (16/16)	Mean 72.6 ± 6.1	1 to 3	18 males, 14 females	FAC ≥ 2, GDS negative	Tinetti Performance Oriented Mobility Assessment (POMA)	Fall Efficacy Scale-International (FES-I), SF-12 (mental & physical components)	No long-term follow-up; after 5-week intervention
Pazzaglia (2020)	51 (26/25)	Mean 71.1 ± 7.2	Not specified	35 males, 16 females	MMSE > 25	Berg Balance Scale (BBS)	Dynamic Gait Index (DGI), Disabilities of Arm, Shoulder and Hand (DASH), SF-36	No explicit follow-up beyond 6 weeks
Pullia et al (2023)	20 (10/10)	50 to 70	H&Y 2 to 4	12 males, 8 females	FAC > 2	6-Minute Walk Test (6MWT), 10-Meter Walk Test (10MWT), Timed Up and Go (TUG), Berg Balance Scale (BBS), Tinetti Scale (TS)	Falls Efficacy Scale-International (FES-I), UPDRS Part III, Functional Independence Measure (FIM)	No follow-up beyond 5-week intervention
Qayyum et al (2022)	16 (8/8)	40 to 65	Stages 1 to 3	8 males, 8	—	Unified Parkinson's Disease Rating Scale	--	No long-term follow-up specified

				femal es		(UPDRS), Dynamic Gait Index (DGI)		
Schuch et al (2023)	23 (11/12)	Mean 63.5 ± 7.4	Not report ed	Not report ed	Montr eal Cognit ive Assess ment > 24	Mobility smoothness (Spectral Arc Length, SPARC) via inertial measurement unit during Timed Up and Go (TUG) and 10MWT	Anxiety (STAI), Memory (RBMT-3)	No long-term follow-up reported
Silva et al (2023)	45 (24/21)	Mean 63.8 ± 8.7	I to III	30 males, 15 femal es	MMS E > 24	Mini-Balance Evaluation Systems Test (Mini-BESTest), Center of Pressure (COP) metrics	Timed Up and Go (TUG), Activities-specific Balance Confidence (ABC), Parkinson's Disease Questionnair e (PDQ-39), UPDRS-III, Five Times Sit to Stand Test (FTSST)	No follow-up beyond 7-week intervention
Yuan et al (2020)	24 (12/12)	Mean 69.4 ± 4.7	I to III	Not report ed	MMS E > 23	Berg Balance Scale (BBS)	Modified Falls Efficacy Scale (MFES), Multi-Directional Reach Test (MDRT), Maximum Step Length (MSL), Short Form 36 (SF-36)	No follow-up beyond 12 weeks in crossover design

Table 2 Methodological characteristics of the included studies

Author	**Desing**	**Randomization**	**Blinding**	**Intervention Group Details**	**Control Group Details**	**Key Study Findings**
Alagumoorthi (2023)	Single-blind RCT	Computer-generated sealed envelopes	Assessor blinded	Wii sports-based strategy training, 30-40 min + 30 min conventional PT, 3x/week, 12 weeks	Traditional balance training + same conventional PT as intervention, 3x/week, 12 weeks	Wii sports training reduced fallers and fall rate, improved Berg Balance Scale and Timed Up and Go performance; PDQ-39 QoL improved
Anwar et al (2021)	Quasi-experimental RCT	Simple random assignment	Assessor blinded	Wii VR balance training with Nintendo Wii, 45	Conventional balance physiotherapy,	Wii VR training showed significant

				min sessions, 3x/week, 4 weeks	45 min sessions, 3x/week, 4 weeks	improvement in Berg Balance Scale and Timed Up and Go compared to conventional therapy
Cetin (2024)	Prospective RCT	Computer-generated randomization	Assessor blinded	USE-IT Smart Physiotherapy exergames targeting upper limb, trunk, cognition; 1 hr sessions, 3x/week, 8 weeks	Conventional physiotherapy including warm-up, balance, strength, 1 hr sessions, 3x/week, 8 weeks	Exergame group improved dexterity, trunk control, and cognition more than conventional physiotherapy; significant gains in primary outcomes
GoffrEdo et al (2023)	Multicenter RCT	Envelope-based concealed allocation	Assessor blinded	Non-immersive VRRS tablet-based telerehabilitation, adaptive virtual task games, 30 sessions over 6-10 weeks	Home-based self-administered conventional balance and strength exercises, 30 sessions, matched duration	Telerehabilitation group showed significant improvements in Mini-BESTest, TUG, 6MWT, and motor scores compared to control
Gulcan et al (2022)	RCT	Random assignment (method unspecified)	Assessor blinded	AR/VR gait training with C-Mill VR+ device + conventional electrotherapy, 1.5 hr sessions, 3x/week, 6 weeks	Conventional balance and gait training physiotherapy, 1 hr sessions, 3x/week, 6 weeks	VR gait training group improved UPDRS-III, posturography parameters, BBS, and balance confidence more than control
Kashif et al (2022)	Single-center RCT	Lottery method	Assessor blinded	Routine physical therapy + 10-15 min VR and 5-10 min motor imagery, 3x/week, 12 weeks	Routine physical therapy only, 3x/week, 12 weeks	VR + motor imagery group improved UPDRS, BBS, and ADLs significantly more than routine PT alone
Kashif et al (2024)	Single-center RCT	Lottery/random allocation	Assessor blinded	Group 1: VR+Physical therapy; Group 2: Motor imagery + PT; Group 3: PT only, all 3x/week, 12 weeks	As per group allocation, PT structured similarly except added VR/MI	VR + PT group showed significant improvements in balance, motor function, and ADLs over MI + PT and PT alone groups
Maranesi et al (2023)	Single-blind RCT	Computer-generated randomization	Assessor blinded	Conventional rehab (30 min) + 20 min Tymo® semi-immersive VR exergame, 2x/week, 5 weeks	Conventional physiotherapy only, 50 min sessions, 2x/week, 5 weeks	VR exergaming group showed greater improvement in Tinetti scores, gait, and mental health scores vs control

Pazzaglia (2020)	Single-blind RCT	Block randomization	Assessor blinded	NIRVANA system non-immersive VR with IR cameras, wall projections, balance and coordination games, 3x/week, 6 weeks	Conventional rehab: Warm-up, coordination, balance, gait training, 3x/week, 6 weeks	VR rehabilitation improved balance, gait, upper limb function, and mental health compared to conventional therapy
Pullia et al (2023)	Pilot RCT	Block randomization	Assessor blinded	Treadmill training with semi-immersive VR (C-Mill), gait exercises + VR games, 4x/week, 5 weeks	Conventional rehab including gait training with obstacles and cueing, 4x/week, 5 weeks	Semi-immersive VR treadmill training group improved gait, balance, UPDRS, and functional independence more than control
Qayyum et al (2022)	RCT	Coin flip randomization	Not reported	Wii based exer-gaming (Wii perfection, skiing, cycling), 50 min sessions, 3x/week, 8 weeks	Conventional therapy including balance, gait, strengthening, 50 min sessions, 3x/week, 8 weeks	Exer-gaming group showed superior improvement in UPDRS and dynamic gait index compared to conventional therapy
Schuch et al (2023)	Double-blinded RCT	Computer-generated randomization	Assessor blinded	Smartphone-based VR balance training (headset), virtual tightrope walker, 10 sessions over 5 weeks	Psychoeducation sessions without exercise, matched frequency	VR balance training feasible and safe but did not significantly improve gait smoothness or cognitive outcomes over control
Silva et al (2023)	Single-blind RCT	Block randomization, sealed envelopes	Assessor blinded	Xbox Kinect Adventures task-oriented exergaming, 60 min sessions, 2x/week, 7 weeks	Conventional physiotherapy with flexibility, strength, balance, motor control, 60 min sessions, 2x/week, 7 weeks	Kinect exergame improved postural control, motor function, and QoL similarly to conventional physiotherapy
Yuan et al (2020)	12-week crossover RCT	Computer-generated randomization	Assessor blinded	Interactive video game-based stepping exercises (IVGB), 30 min sessions, 3x/week, 6 weeks	No exercise during control phase (cross-over design)	IVGB exercise improved balance measures, stepping ability, and fall confidence; no change in quality of life

Sample characteristics

The demographic characteristics across the included studies predominantly featured middle-aged to older adults diagnosed with idiopathic Parkinson's disease, typically within Hoehn and Yahr stages I to III, reflecting mild to moderate disease severity. Sample sizes varied, ranging from small pilot samples of about 16 to larger trials with nearly 200 participants. The mean ages reported generally ranged from the late 50s to early 70s. Most studies reported a higher proportion of males versus females, consistent with Parkinson’s epidemiology. Sample sizes varied widely from smaller pilot studies of approximately 16 participants to larger randomized controlled trials including nearly 200 subjects (Alagumoorthi et al., 2025; Çetin et al., 2024; Yuan et al., 2020). Mean ages typically ranged from late 50s to early 70s, with a predominant representation of males over females, consistent with PD epidemiology (Gulcan et al., 2022; Kashif et al., 2024; Silvia et al., 2023). Cognitively intact individuals, screened using measures like the Mini-Mental State Examination with cut-offs above 24, were included to ensure suitability for VR interventions (Schuch et al., 2020; Yuan et al., 2020). Participants were ambulatory and community-dwelling, with many studies also requiring stable anti-parkinsonian medication during the trial period to limit confounding effects (Pazzaglia et al., 2020; Pullia et al., 2023). These consistent inclusion criteria across studies support the generalizability of findings to mild-to-moderate PD populations amenable to exercise interventions incorporating virtual reality (Qayyum et al., 2022; Kashif et al., 2022). The detailed interpretation of the demographic characteristics of the participants represented in Table 1

Methodological characteristics of the included studies

A randomized controlled trials (RCTs) has explored the effectiveness of virtual reality (VR) and exergaming-based interventions on motor and functional outcomes in Parkinson's disease (PD). Most studies employed single-blind, assessor-blinded RCT designs with computer-generated or concealed randomization to minimize bias (Alagumoorthi, 2023; Cetin, 2024; Maranesi et al., 2023; Silva et al., 2023; Yuan et al., 2020). Interventions typically combined immersive or semi-immersive VR-based balance and gait training with conventional physiotherapy, administered two to three times weekly over 5–12 weeks. Findings consistently demonstrated superior improvements in balance, gait, and motor performance compared to conventional rehabilitation alone (Anwar et al., 2021; Gulcan et al., 2022; Kashif et al., 2022; Pullia et al., 2023). The detailed methodological interpretation was presented in table 2

Intervention

The experimental groups across the studies mainly involved virtual reality or exergaming-based rehabilitation programs combined with conventional physiotherapy for patients with Parkinson's disease (Alagumoorthi et al., 2025; Çetin et al., 2024; Goffredo et al., 2023). These programs were typically involved balance and gait exercises using advanced VR systems such as Nintendo Wii, USE-IT Smart Physiotherapy, VRRS Tablet, and semi-immersive platforms like C-Mill, which given the collaborative, task-specific exercise and real-time feedback to improve motor and cognitive areas (Gulcan et al., 2022; Pullia et al., 2023; Silvia et al., 2023). Session durations ranged from 30 to 60 minutes, mostly conducted 2–3 times per week for 4 to 12 weeks (Anwar et al., 2021; Kashif et al., 2024).

Control groups usually administered conventional therapy concentrating on balance, strength, mobility, and functional training without VR components, carried over matched session periods and frequencies. Few control groups received combined home-based exercises or structured physiotherapy protocols without technological expansion (Pazzaglia et al., 2020; Qayyum et al., 2022). The comparators were intended to isolate the additional profit of VR skills by continuing other rehabilitation essentials reliable across groups (Maranesi et al., 2022; Yuan et al., 2020). Together, these proposals allowed evaluation of VR's possible to improve conventional rehabilitation outcomes in balance, gait, and motor performance in Parkinson's disease (Schuch et al., 2020; Kashif et al., 2022).

Outcomes measures

Balance and gait were the primary outcomes across most reviewed studies, reflecting the central therapeutic goal of virtual reality (VR) and exergaming interventions in Parkinson's disease (PD). The Berg Balance Scale (BBS) was the maximum utilized tools to measure static and dynamic balance through 14 functional tasks, allowing estimation of fall risk and postural control (Alagumoorthi et al., 2022; Gülcan et al., 2022; Kashif et al., 2022, 2024; Pazzaglia et al., 2020; Yuan et al., 2020). Corresponding balance screening tools added the Mini-Balance Evaluation Systems Test (Mini-BESTest), Tinetti Scale (TS), and Limit of Stability (LOS), which provided measurable understandings into balance confidence, stability limits, and postural sway (da Silva et al., 2023; Goffredo et al., 2023; Pullia et al., 2023). The Timed Up and Go (TUG) test and 6-Minute Walk Test (6MWT) were also used as secondary balance-related indicator to assess dynamic postural changes and functional mobility, mainly gait initiation and turning (Anwar et al., 2021; Maranesi et al., 2022; Pullia et al., 2023). Overall, the reliable development in BBS, Mini-BESTest, and TUG scores across multiple trials indicates that VR- and exergaming-based interventions successfully improve balance and reduce fall risk among individuals with PD.

Secondary outcome measures mainly targeted motor function, cognitive performance, and quality of life. The Unified Parkinson's Disease Rating Scale (UPDRS), particularly parts II and III—was widely used to measure motor control, rigidity, tremor, bradykinesia, and activities of daily living (ADL), with most studies reporting significant post-intervention improvement (Anwar et al., 2021; Goffredo et al., 2023; Kashif et al., 2022, 2024; Pullia et al., 2023). Other motor and functional tools, including the Functional Independence Measure (FIM), Dynamic Gait Index (DGI), and Five Times Sit-to-Stand Test (FTSST), measured strength, endurance, and daily task performance (Pazzaglia et al., 2020; da Silva et al., 2023). Cognitive and neuropsychological effects were discovered using the Montreal Cognitive Assessment (MoCA), Trunk Impairment Scale (TIS), and Nine-Hole Peg Test, highlighting the effect of exergaming on cognition, coordination, and fine motor skills (Çetin et al., 2024). Similarly, Schuch et al. (2020) combined sensor-based parameters like Spectral Arc Length (SPARC) and psychological procedures with the Rivermead Behavioral Memory Test (RBMT-3) and State-Trait Anxiety Inventory (STAI) to inspect cognitive and emotional outcomes of VR training.

Quality of life and self-efficacy were commonly assessed using the Parkinson's Disease Questionnaire (PDQ-39 or PDQ-8), 36-Item Short Form Health Survey (SF-36), and various confidence scales such as the Activities-Specific Balance Confidence Scale (ABCS), Falls Efficacy Scale-International (FES-I), and Modified Falls Efficacy Scale (MFES) (Alagumoorthi et al., 2022; Goffredo et al., 2023; Pullia et al., 2023; Yuan et al., 2020). Together, these results specify that VR and exergaming not only improve balance, the primary rehabilitation target but also deliver expressive enhancements in motor performance, cognitive engagement, emotional stability, and health-related quality of life in people with Parkinson's disease.

Quality Assessment

The methodological evaluation of the involved studies verified generally strong design characteristics, with most using proper randomization and valid outcome measures. All studies used random allocation approaches such as computer-generated or block randomization, gaining internal validity. Allocation concealment was sufficiently continued in several studies (e.g., Alagumoorthi, 2025; Çetin, 2024; Goffredo, 2023; Maranesi, 2022; Pazzaglia, 2020; Silvia, 2023; Yuan, 2020), regularly through sealed envelopes or web-based systems, while a few (e.g., Anwar, 2021; Kashif, 2022, 2024; Qayyum, 2022) needed clear reporting, dropping transparency. Baseline group comparison was constantly attained across studies, representing sound randomization effectiveness. Although member blinding was generally absent due to the nature of interventions, evaluator blinding was usually employed, minimizing measurement bias. Follow-up time varied notably, with some trials upholding complete data up to 16–36 weeks (Alagumoorthi, 2025; Kashif, 2022; Kashif, 2024), while others lacked longer-term valuation, limiting understandings into continuous outcomes. All studies used validated and reliable outcome measures with appropriate statistical analyses, ensuring robustness of results. Overall, the methodological quality ranged from moderate to high, with most studies rated as good quality due to rigorous randomization, assessor blinding, and sound analytical procedures, though the absence of participant blinding and limited follow-up in some trials slightly constrained the overall strength of evidence.

The effectiveness of virtual reality interventions on primary outcome called balance and Gait, has been supported across studies, demonstrating significant progresses compared to conventional physiotherapy or control conditions. For example, Alagumoorthi et al. (2025) reported notable decreases in fallers and falls rate, alongside significant improvements in the Berg Balance Scale (BBS) scores after Wii sports-based VR training. Anwar et al. (2021) also noted substantial BBS improvements and better Timed Up and Go (TUG) times with Nintendo Wii VR training compared to conventional therapy. Similarly, Çetin et al. (2024) found exergaming with specialized systems enhanced trunk control and balance scales more effectively than traditional methods. Goffredo et al. (2023) showed substantial gains in Mini-BESTest scores through non-immersive telerehabilitation VR programs, highlighting VR's capacity to enhance dynamic balance and mobility. Pazzaglia et al. (2020) established superior enhancements in BBS and related dynamic gait indices with VR compared to standard rehabilitation. Pullia et al. (2023) reported heightened postural stability and gait measures using semi-immersive VR treadmill training. These consistent findings across heterogeneous VR platforms endorse VR as a viable strategy for balance rehabilitation in Parkinson's disease, promising enhanced functional mobility and reduced fall risk (Gulcan et al., 2022; Kashif et al., 2022; Silvia et al., 2023; Yuan et al., 2020). Many studies documented enhanced gait performance, including faster Timed Up and Go times and longer walking distances on the 6-Minute Walk Test (Goffredo et al., 2023; Pullia et al., 2023). Upper limb dexterity and coordination were improved, as measured by tests such as the Nine-Hole Peg Test and Minnesota Manual Dexterity Test (Çetin et al., 2024).

In addition to significant improvements in balance, the primary outcome, the reviewed virtual reality rehabilitation studies reported benefits across several important secondary outcomes. Cognitive benefits were also noted, with interventions showing positive changes in Montreal Cognitive Assessment scores, reflecting improved executive functions and attention (Çetin et al., 2024; Schuch et al., 2020). Several studies reported better fall-related confidence and reduced fear, assessed via scales like the Activities-specific Balance Confidence Scale and Falls Efficacy Scale (Gulcan et al., 2022; Yuan et al., 2020). Quality of life improvements were observed through patient-reported measures such as the Parkinson's Disease Questionnaire-39 and SF-36 (Maranesi et al., 2022; Pazzaglia et al., 2020). Motor symptom severity, frequently assessed with the Unified Parkinson's Disease Rating Scale (UPDRS), was reduced indicating broader motor function enhancement (Kashif et al., 2022; Qayyum et al., 2022). Collectively, these secondary outcomes highlight the multifaceted impact of VR interventions addressing motor, cognitive, and psychosocial aspects in Parkinson's disease rehabilitation (Silvia et al., 2023; Kashif et al., 2024).

Thematic Relevance

Across studies, virtual reality (VR) and exergaming emerge as innovative rehabilitation tools targeting balance deficits and motor dysfunction in Parkinson's disease. Interactive, task-specific, and multisensory VR systems provide real-time feedback, enhancing balance, motivation, and adherence (Alagumoorthi et al., 2025; Goffredo et al., 2023). Research also addresses secondary outcomes such as gait, dexterity, cognition, fall confidence, and quality of life, reflecting a holistic rehabilitation approach (Çetin et al., 2024; Silvia et al., 2023). The use of immersive, non-immersive, and telerehabilitation systems illustrates efforts to optimize delivery for varied disease stages and access needs (Pullia et al., 2023; Goffredo et al., 2023; Yuan et al., 2020). Collectively, evidence supports VR's potential to enhance mobility, reduce fall risk, and improve overall well-being in Parkinson's disease (Kashif et al., 2024; Pazzaglia et al., 2020).

The integrative interpretation across all studies
Reviewed studies consistently show that virtual reality (VR) and exergaming serve as effective adjuncts or alternatives to conventional rehabilitation in Parkinson's disease. VR interventions significantly enhance balance, postural control, and reduce fall risk (Alagumoorthi et al., 2025; Goffredo et al., 2023). They also improve gait, mobility, dexterity, cognition, and quality of life, reflecting a multidimensional impact on motor and non-motor symptoms (Çetin et al., 2024; Kashif et al., 2024; Yuan et al., 2020). Both immersive and non-immersive platforms demonstrate adaptability across disease stages (Pullia et al., 2023; Silvia et al., 2023), while telerehabilitation models expand accessibility and continuity of care (Goffredo et al., 2023). Most studies employ rigorous designs with validated measures, though follow-up and blinding vary. Collectively, evidence supports VR as a flexible, patient-centered approach that enhances traditional therapy and promotes holistic functional recovery in Parkinson's disease (Pazzaglia et al., 2020; Kashif et al., 2022; Schuch et al., 2020).

DISCUSSION

Overview or summary of the findings:
Across 14 controlled trials, virtual reality (VR) and exergaming consistently improved balance, motor function, gait, cognition, and quality of life in individuals with Parkinson's disease. Most studies reported moderate gains in dynamic balance (Berg Balance Scale, Timed Up and Go) and reduced motor symptom severity (UPDRS-III) (Alagumoorthi et al., 2022; Kashif et al., 2022; Pazzaglia et al., 2020). VR interventions enhanced gait velocity and endurance compared to controls (Pullia et al., 2023; Yuan et al., 2020). When combined with cognitive or motor imagery tasks, VR further promoted executive and emotional benefits (Çetin et al., 2024; Schuch et al., 2020). Improvements in balance confidence and reduced fear of falling (ABCS, FES) were frequent psychological outcomes (Kashif et al., 2024; Yuan et al., 2020). Despite variability in quality of life measures, user engagement and adherence were consistently higher in VR-based programs (Da Silva et al., 2023).
These findings confirm and extend prior meta-analyses, supporting VR and exergaming as potent, patient-centered tools that supplement and sometimes surpass traditional physiotherapy by integrating multisensory feedback, cognitive engagement, and enjoyable task-oriented training for sustained functional recovery in PD.
Comparison with Existing Literature
These findings align with earlier reviews showing that virtual reality (VR) and exergaming enhance balance, gait, and motor function in Parkinson's disease (Dockx et al., 2016; Lei et al., 2019). Consistent with prior evidence, VR produced greater improvements in dynamic balance and motor symptoms than conventional physiotherapy (Lheureux et al., 2025). This review extends earlier work by including recent telerehabilitation studies (Goffredo et al., 2023) and multimodal VR with motor imagery (Kashif et al., 2022, 2024), highlighting emerging cognitive-motor integration. Overall, VR appears to be a safe, engaging, and effective adjunct to physiotherapy, enhanced by advances in home-based delivery. Future studies should standardize protocols, identify suitable patient subgroups, and evaluate long-term outcomes to refine clinical application.

Strength of the review study:
This review's key strength lies in its comprehensive synthesis of recent, high-quality randomized controlled trials across diverse virtual reality (VR) modalities and exergaming interventions for Parkinson's disease rehabilitation. It integrates multidimensional outcomes including objective motor and balance measures and cognitive-psychosocial domains, providing a holistic perspective. Unique contributions include inclusion of emerging telerehabilitation studies and multimodal VR combined with motor imagery, highlighting novel cognitive-motor integration. By accounting for participant demographics, disease stages, intervention types, and durations, it enhances contextual interpretation. This structured and thematic approach facilitates identification of research gaps and clinical translation, supporting VR's role as an engaging, patient-centered adjunct to conventional physiotherapy.

Limitations
Across the 14 reviewed studies, common limitations include small sample sizes, heterogeneous VR systems and protocols, and variable participant characteristics, mostly involving mild to moderate Parkinson's disease. Short intervention durations and limited follow-up periods restrict evidence on long-term benefits. The use of diverse outcome measures and nonstandardized assessments reduces comparability, while the absence of neurophysiological correlates limits understanding of underlying mechanisms. Potential selection bias, lack of blinding, and reliance on self-report further constrain validity. Few studies addressed cost-effectiveness or accessibility in resource-limited contexts. Future research should employ larger, multicenter randomized trials with standardized protocols, extended follow-up, mechanistic evaluation, and economic analysis to confirm VR's clinical and practical value in Parkinson's rehabilitation.

Clinical and Practical Implication:
This review highlights the growing clinical value of virtual reality (VR) and exergaming as adjuncts to Parkinson's disease rehabilitation. VR enhances balance, motor control, gait, and cognition while promoting motivation and adherence through engaging, feedback-based training that supports neuroplasticity. Telerehabilitation models further expand access for patients with mobility limitations. Clinicians can integrate VR safely with physiotherapy to address multidimensional symptoms, reduce fall risk, and improve quality of life. Tailoring programs to disease stage, patient preference, and technological comfort remains essential for optimal outcomes.

Funding: NIL

Conflict of Interest: NIL

REFERENCES
1. Alagumoorthi, G., D, B. J., Thirunavukarasu, S., V, R., & A, K. (2022). Effectiveness of Wii sports- based strategy training in reducing risk of falling, falls and improving quality of life in adults with idiopathic Parkinson's disease- a randomized comparative trial. Clinical rehabilitation, 36(8), 1097–1109. https://doi.org/10.1177/02692155221089030
2. Anwar, N., Akram, S., Ilyas, A., Khalid, K., Munir, M., & Hayat, M. K. (2021). Comparison of virtual reality and conventional balance training to improve balance and walking in Parkinson's disease patients. Medical Forum, 32(7), 129-133.
3. Ashburn, A., Stack, E., Pickering, R. M., & Ward, C. D. (2001). A community-dwelling sample of people with Parkinson's disease: characteristics of fallers and non-fallers. Age and ageing, 30(1), 47–52. https://doi.org/10.1093/ageing/30.1.47
4. Çetin, B., Kılınç, M., & Çakmaklı, G. Y. (2024). The effects of exergames on upper extremity performance, trunk mobility, gait, balance, and cognition in Parkinson's disease: a randomized controlled study. Acta neurologica Belgica, 124(3), 853–863. https://doi.org/10.1007/s13760-023-02451-3
5. Da Silva, K. G., Nuvolini, R. A., Bacha, J. M. R., De Freitas, T. B., Doná, F., Torriani-Pasin, C., & Pompeu, J. E. (2023). Comparison of the Effects of an Exergame-Based Program with Conventional Physiotherapy Protocol Based on Core Areas of the European Guideline on Postural Control, Functional Mobility, and Quality of Life in Patients with Parkinson's Disease: Randomized Clinical Trial. Games for health journal, 12(3), 228–241. https://doi.org/10.1089/g4h.2022.0039
6. Dockx, K., Bekkers, E. M., Van den Bergh, V., Ginis, P., Rochester, L., Hausdorff, J. M., Mirelman, A., & Nieuwboer, A. (2016). Virtual reality for rehabilitation in Parkinson's disease. The Cochrane database of systematic reviews, 12(12), CD010760. https://doi.org/10.1002/14651858.CD010760.pub2
7. Farič, N., Smith, L., Hon, A., Potts, H. W. W., Newby, K., Steptoe, A., & Fisher, A. (2021). A Virtual Reality Exergame to Engage Adolescents in Physical Activity: Mixed Methods Study Describing the Formative Intervention Development Process. Journal of medical Internet research, 23(2), e18161. https://doi.org/10.2196/18161
8. GBD 2016 Neurology Collaborators (2019). Global, regional, and national burden of neurological disorders, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet. Neurology, 18(5), 459–480. https://doi.org/10.1016/S1474-4422(18)30499-X
9. Goffredo, M., Baglio, F., DE Icco, R., Proietti, S., Maggioni, G., Turolla, A., Pournajaf, S., Jonsdottir, J., Zeni, F., Federico, S., Cacciante, L., Cioeta, M., Tassorelli, C., Franceschini, M., Calabrò, R. S., & RIN_TR_Group (2023). Efficacy of non-immersive virtual reality-based telerehabilitation on postural stability in Parkinson's disease: a multicenter randomized controlled trial. European journal of physical and rehabilitation medicine, 59(6), 689–696. https://doi.org/10.23736/S1973-9087.23.07954-6
10. Gu, Q., Mao, J., Sun, J., & Teo, W. P. (2025). Exercise intensity of virtual reality exergaming modulates the responses to executive function and affective response in sedentary young adults: A randomized, controlled crossover feasibility study. Physiology & behavior, 288, 114719. https://doi.org/10.1016/j.physbeh.2024.114719
11. Gulcan, K., Guclu-Gunduz, A., Yasar, E., Ar, U., Sucullu Karadag, Y., & Saygili, F. (2023). The effects of augmented and virtual reality gait training on balance and gait in patients with Parkinson's disease. Acta neurologica Belgica, 123(5), 1917–1925. https://doi.org/10.1007/s13760-022-02147-0
12. Hilton M. (2024). JBI Critical appraisal checklist for systematic reviews and research syntheses. The Journal of the Canadian Health Libraries Association, 45(3), 180–183. https://doi.org/10.29173/jchla29801
13. Kalia, L. V., & Lang, A. E. (2015). Parkinson's disease. Lancet (London, England), 386(9996), 896–912. https://doi.org/10.1016/S0140-6736(14)61393-3
14. Kashif, M., Ahmad, A., Bandpei, M. A. M., Gilani, S. A., Hanif, A., & Iram, H. (2022). Combined effects of virtual reality techniques and motor imagery on balance, motor function and activities of daily living in patients with Parkinson's disease: a randomized controlled trial. BMC geriatrics, 22(1), 381. https://doi.org/10.1186/s12877-022-03035-1
15. Kashif, M., Albalwi, A. A., Zulfiqar, A., Bashir, K., Alharbi, A. A., & Zaidi, S. (2024). Effects of virtual reality versus motor imagery versus routine physical therapy in patients with parkinson's disease: a randomized controlled trial. BMC geriatrics, 24(1), 229. https://doi.org/10.1186/s12877-024-04845-1

16. King, L. A., & Horak, F. B. (2009). Delaying mobility disability in people with Parkinson disease using a sensorimotor agility exercise program. Physical therapy, 89(4), 384–393. https://doi.org/10.2522/ptj.20080214
17. Lei, C., Sunzi, K., Dai, F., Liu, X., Wang, Y., Zhang, B., He, L., & Ju, M. (2019). Effects of virtual reality rehabilitation training on gait and balance in patients with Parkinson's disease: A systematic review. PloS one, 14(11), e0224819. https://doi.org/10.1371/journal.pone.0224819
18. Lheureux, A., Lejeune, T., Simons, A., Gillis, A., & Everard, G. (2025). Virtual reality effects on balance and mobility in people with Parkinson's disease: A systematic review with meta-analysis. Annals of physical and rehabilitation medicine, 68(6), 101967. https://doi.org/10.1016/j.rehab.2025.101967
19. Mak, M. K., & Pang, M. Y. (2009). Fear of falling is independently associated with recurrent falls in patients with Parkinson's disease: a 1-year prospective study. Journal of neurology, 256(10), 1689–1695. https://doi.org/10.1007/s00415-009-5184-5
20. Maranesi, E., Casoni, E., Baldoni, R., Barboni, I., Rinaldi, N., Tramontana, B., Amabili, G., Benadduci, M., Barbarossa, F., Luzi, R., Di Donna, V., Scendoni, P., Pelliccioni, G., Lattanzio, F., Riccardi, G. R., & Bevilacqua, R. (2022). The Effect of Non-Immersive Virtual Reality Exergames versus Traditional Physiotherapy in Parkinson's Disease Older Patients: Preliminary Results from a Randomized-Controlled Trial. International journal of environmental research and public health, 19(22), 14818. https://doi.org/10.3390/ijerph192214818
21. Ou, Z., Pan, J., Tang, S., Duan, D., Yu, D., Nong, H., & Wang, Z. (2021). Global Trends in the Incidence, Prevalence, and Years Lived With Disability of Parkinson's Disease in 204 Countries/Territories From 1990 to 2019. Frontiers in public health, 9, 776847. https://doi.org/10.3389/fpubh.2021.776847
22. Pazzaglia, C., Imbimbo, I., Tranchita, E., Minganti, C., Ricciardi, D., Lo Monaco, R., Parisi, A., & Padua, L. (2020). Comparison of virtual reality rehabilitation and conventional rehabilitation in Parkinson's disease: a randomised controlled trial. Physiotherapy, 106, 36–42. https://doi.org/10.1016/j.physio.2019.12.007
23. Pringsheim, T., Jette, N., Frolkis, A., & Steeves, T. D. (2014). The prevalence of Parkinson's disease: a systematic review and meta-analysis. Movement disorders : official journal of the Movement Disorder Society, 29(13), 1583–1590. https://doi.org/10.1002/mds.25945
24. Pullia, M., Ciatto, L., Andronaco, G., Donato, C., Aliotta, R. E., Quartarone, A., De Cola, M. C., Bonanno, M., Calabrò, R. S., & Cellini, R. (2023). Treadmill Training Plus Semi-Immersive Virtual Reality in Parkinson's Disease: Results from a Pilot Study. Brain sciences, 13(9), 1312. https://doi.org/10.3390/brainsci13091312
25. Schuch CP, Balbinot G, Bonilla MN, Guedes Machado A and de Oliveira AA (2020) Feasibility of a Short-Term Virtual Reality Balance Intervention to Improve Mobility Smoothness in Parkinson's Disease. Front. Virtual Real. 1:7. doi: 10.3389/frvir.2020.00007
26. Shahbaz Qayyum, Zeest Hashmi, Shoaib Waqas, Muhammad Tariq, Muhammad Waqas Mughal, Mohsin Tanvir. (2023). Effects of Exer–Gaming on Balance and Gait in Parkinson’s Patients. Pakistan Journal of Medical & Health Sciences, 16(12), 213. https://doi.org/10.53350/pjmhs20221612213
27. Teo, J. L., Zheng, Z., & Bird, S. R. (2022). Identifying the factors affecting 'patient engagement' in exercise rehabilitation. BMC sports science, medicine & rehabilitation, 14(1), 18. https://doi.org/10.1186/s13102-022-00407-3
28. Tysnes, O. B., & Storstein, A. (2017). Epidemiology of Parkinson's disease. Journal of neural transmission (Vienna, Austria : 1996), 124(8), 901–905. https://doi.org/10.1007/s00702-017-1686-y
29. Yang, Y. R., Tsai, M. P., Chuang, T. Y., Sung, W. H., & Wang, R. Y. (2008). Virtual reality-based training improves community ambulation in individuals with stroke: a randomized controlled trial. Gait & posture, 28(2), 201–206. https://doi.org/10.1016/j.gaitpost.2007.11.007
30. Yuan, R. Y., Chen, S. C., Peng, C. W., Lin, Y. N., Chang, Y. T., & Lai, C. H. (2020). Effects of interactive video-game-based exercise on balance in older adults with mild-to-moderate Parkinson's disease. Journal of neuroengineering and rehabilitation, 17(1), 91. https://doi.org/10.1186/s12984-020-00725-y