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REVIEW ARTICLE **OPEN ACCESS**

VIRTUAL REALITY-BASED REHABILITATION'S IMPACT ON MOVEMENT AND QUALITY OF LIFE IN PARKINSON'S: AN UPDATED SYSTEMATIC REVIEW OF RANDOMIZED CONTROLLED TRIALS

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ABSTRACT

Background: Parkinson's disease is a neurodegenerative disorder that can significantly impact an individual's mobility, balance, and overall quality of life. Movement disorders, including tremors, rigidity, bradykinesia, and gait disorder characterize it. In addition to pharmacological therapy, rehabilitation approaches play an essential role in the management of occurring movement disorders. One of the potential rehabilitation methods is virtual reality (VR).
Objective: This systematic review aims to determine the impact of VR-based rehabilitation on balance, mobility, motor function, and the quality of life of Parkinson's patients. **Methods:** Systematic research was conducted in February 2024 using PubMed, Scopus, and ScienceDirect. A combination of MeSH terms "virtual reality," "Parkinson," "exergame," "effectivity," and "rehabilitation" was employed. The articles selected for review were randomized controlled trials designed and published in the last ten years in English. The quality of individual articles was assessed using the Cochrane risk-of-bias tool. All analyses were stratified by the outcome: balance, mobility, motor function, and quality of life. **Results:** Fourteen randomized controlled trials with 637 patients were included in the analysis. Most clinical trials show that VR-based rehabilitation has a statistically significant impact on balance compared to conventional rehabilitation. Mobility and motor function show promising improvements in the VR group, but there is still controversy about its superiority over traditional rehabilitation. Improved quality of life is also seen in VR groups, but no clinical trials in this review show statistical significance compared to conventional rehabilitation.
Conclusion: This systematic review shows that VR-based rehabilitation has the potential to improve balance, mobility, motor function, and quality of life in Parkinson's patients

Keywords: motoric assessment, Parkinson's disease, quality of life, rehabilitation, virtual reality

Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disease after Alzheimer's, affecting 3% of the 65-year-old population and 5% of the population over the age of 85. The degeneration that occurs in the substantia nigra causes the primary motor symptoms of PD, namely tremors, rigidity, bradykinesia, and gait disorders. Such motor symptoms will lead to movement constraints that ultimately affect the patient's quality of life.[1,2]

Exercise has become a significant aspect of rehabilitation in PD.[3] Previous research has demonstrated that physical rehabilitation can improve motor function in Parkinson's patients; however, the challenges of exhaustion and boredom from repetitive therapeutic activities can contribute to decreased patient compliance and worsened motor symptoms.4 To address these challenges, virtual reality (VR) provides more interactive, varied, and flexible therapeutic designs, which can encourage patients to participate in rehabilitation more consistently.

Several randomized controlled clinical trials using VR have been conducted to test its effectiveness as a therapy intervention in Parkinson's patients. Current research focuses mainly on Parkinson's motor symptoms like balance, mobility, and function. However, there is no agreement on the impact of VR on Parkinson's motor symptoms across trials.[5–7] Therefore, this systematic review aims to determine the effects of VR-based rehabilitation on the motor evaluation and quality of life of Parkinson's patients.

Methods

Design Study

This systematic review was structured using qualitative methods. The reporting method was based on the principles of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).8 This review was registered in the PROSPERO (International Prospective Register for Systematic Reviews) on June 6, 2024 (CRD42024551040).

Search Strategy

Searches for specific keywords on PubMed, ScienceDirect, and Scopus were conducted in February 2024 and limited to 2014–2024 to demonstrate the extent of technological progress in artificial intelligence research and development as a rehabilitation approach. Keyword combinations using general terms and Medical Subject Headings (MeSH) in a variety of combinations with Boolean operators such as "OR" and "AND." Data search strategies are described in Table 1.

Eligibility Criteria

A literature search was conducted to determine the impact of VR-based rehabilitation on Parkinson's patients compared to conventional rehabilitation. PD is defined as an abnormality of brain function characterized by degeneration of basal ganglia, loss of pigmentation of substantia nigra, presence of cytoplasmic inclusion (Lewy body), as well as a decrease in dopamine in substantia nigra pars compacta and corpus striatum.[9] VR is a technology that enables real-time interaction between devices and users by stimulating a range of senses (visual, aural, and tactile). The simulated environment is designed to make users feel as though they actually in the environment.[10]

Table 1. Data search strategy

Date	Database	Keywords	Results
February 5, 2024	PubMed	“virtual reality,” “exergame,” and “Parkinson's”	1,828 articles
February 5, 2024	Science Direct	"Parkinson," "virtual reality," and "effectivity"	942 articles
February 6, 2024	Scopus	"Parkinson's," "virtual reality," and "rehabilitation"	336 articles
Total			**3,106 articles**

This review covered randomized controlled trials (RCTs) with at least one intervention relevant to VR-based rehabilitation. The articles included in the systematic review had the following criteria: (i) published in 2014–2024; (ii) written in English; (iii) the subject matter of the study was Parkinson's patients; (iv) the primary intervention was VR-based rehabilitation; and (v) assessed the impact of the intervention on the balance, mobility, motor function, and quality of life of the patient. Conventional therapies, which are used as a control group to compare with VR, include various standard physical therapies or any other type of exercise intervention without VR. Exclusion criteria include (i) articles with paid full text, (ii) articles published without peer review (conference proceedings, editorial opinions), and (iii) articles duplicated.

Screening

Filtering of relevant articles was carried out by removal of duplication, screening of titles and abstracts, and screening of full-text manuscripts. Duplication removed with review manager Rayyan. Studies that did not meet the inclusion criteria were excluded. Two reviewers (M and YRB) independently screened the title and abstract according to the inclusion and exclusion criteria. All the remaining articles from this process were then screened through the entire text by two reviewers (M and HM). Unresolved disagreements between reviewers will be discussed with HA. Data extraction, grouping, and labeling were conducted by M and validated by HM.

Risk of Bias Assessment

Two authors (M and HM) evaluated the risk of bias in the included articles separately. We assessed the included RCTs using version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2). Five domains of bias were evaluated: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result. Based on responses to the signaling questions, an algorithm generates a suggested assessment of the probability of bias resulting from each domain. All domains were categorized as having a high, low, or some concern about the risk of bias based on the Cochrane Handbook's established criteria. Disagreements between the reviewers were resolved by discussion.

Data Extraction and Synthesis

Three authors (M, HM, and YRB) extracted the following data using a pre-planned data extraction approach from the included studies. The information that was extracted included the following: general study information (title, first author, year of publication, country), study characteristics (study design, target population, inclusion criteria, exclusion criteria), intervention measures (type of VR, length of treatment, and comparison information), outcome indicators, and main results. The results of the data synthesis were presented in a descriptive narrative, focusing on the effectiveness of VR rehabilitation interventions in improving balance, mobility, motor function, and quality of life in patients with Parkinson's Disease (PD). The findings provide insights into how VR therapies contribute to these key patient health and well-being aspects.

Results

Summary of Selected Studies

Figure 1 presents the PRISMA flowchart, which illustrates the article selection process. Initially, after the removal of duplicates, a total of 3,044 articles remained. These articles were then screened based on their titles and abstracts to assess their relevance and validity for inclusion in the review. During this process, a significant portion of the articles were excluded for various reasons.

Of the 3,044 articles, 1,595 (51.35%) were deemed irrelevant based on their content and excluded from further consideration. Additionally, 1,435 (46.20%) articles were removed because they did not meet the predefined inclusion criteria for the study. As a result, only 14 full-text articles remained, which were subsequently included in the quality assessment phase of the review.

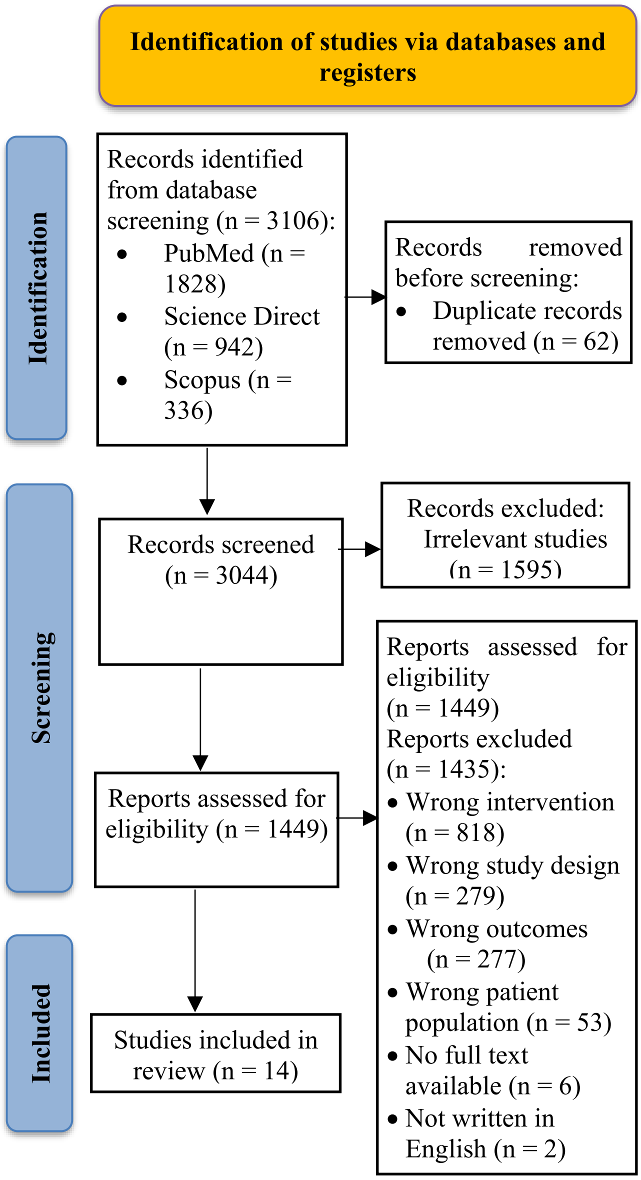

Figure 1. PRISMA flowchart outlining the order of study selection

Table 2 presents the data for the included studies. The fourteen studies were carried out across several nations: Italy (4), China (4), Brazil (3), Pakistan (1), Turkey (1), and Dutch (1). A sample of 637 were collected from the 14 RCTs that met the inclusion criteria.

The enrollment criteria for the fourteen included trials were similar; these included Parkinson's patients with Hoehn and Yahr scores 1-3, the absence of cognitive impairment, and the absence of any other medical problems that would interfere with mobility and balance (such as knee arthritis). All patients receive routine treatment for PD, and intervention was carried out within 2 hours after taking the drug ("on" period). Multiple types of VR-based rehabilitation were studied; 8 out of 14 (57%) of the devices utilized in the research were VR devices that were commercially accessible, whereas the remaining six devices (43%) were specifically designed for therapy.

Table 2. Study characteristics and findings for final articles included

Author (Year)	Country	Type of Study	Sample Size	Rehabilitation Outcome Target	Intervention	Comparator	Duration	Main Results	Conclusion
Feng H et al. (2019)	China	RCT	28	Balance, mobility, gait, and motor function	VR training	traditional rehabilitation training according to the 2014 edition of the Chinese Guide to Treatment of PD	12 weeks	• Improvement in BBS, TUGT, and FGA scores in both groups • Improvement in UPDRS3 in the VR group • No significant difference in the UPDRS3 between the pre- and post rehabilitation data of the control group	Statistically significant improvement in the VR group in balance, mobility, gait, and motor function compared to the control group
Pazzaglia C et al. (2020)	Italy	RCT	51	Balance, gait, quality of life	VR rehabilitation scenario using NIRVANA (BTS Spa, Garbagnate Milanese, Milan, Italy).	conventional rehabilitation program according to the KNGF guidelines	6 weeks	Statistically significant balance and gait improvement in the VR group	Statistically significant improvement in the VR group in balance and gait compared to the control group
Kashif M et al. (2022)	Pakistan	RCT	44	Motor function, balance, activity of daily living	Wii Fit training and motor imagery	Routine physical therapy	12 weeks	Statistically significant motor function, balance, and activity of daily living improvement in both groups	Statistically significant improvement in the VR group in motor function, balance, and activity of daily living compared to the control group
Yang WC et al. (2016)	China	RCT	23	Balance, gait, mobility, motor function, quality of life	VR balance training system	Conventional balance training	6 weeks	• Statistically significant balance, mobility, gait, and quality of life improvement in both groups • No statistically significant difference in the UPDRS3 between the pre- and post rehabilitation data of both groups	No statistically significant differences were found between groups
Gandolfi M et al. (2017)	Italy	RCT	76	Balance, mobility, gait, and quality of life	TeleWii	Sensory Integration Balance Training (SIBT)	7 weeks	• Statistically significant balance improvement in both groups • Both groups showed an overall significant improvement as measured on the ABCS, 10-MWT, DGI, and PDQ-8	Significant between-group differences were found for balance, but not for quality of life
Gulcan K et al. (2022)	Turki	RCT	30	Motor function, balance, activity of daily living, mobility	C-Mill VR + (Motek Medical, Amsterdam, The Netherlands)	Conventional training	6 weeks	• Statistically significant motor function, balance, and mobility improvement in VR group • No statistically significant difference in mobility between the pre- and post rehabilitation data of control group	• Statistically significant improvement in the VR group in mobility compared to the control group • No statistically significant differences were found in balance and motor function between groups
Ribas CG et al. (2017)	Brazil	RCT	20	Balance, mobility, quality of life	Nintendo® video game console with a Wii Balance Board®	conventional exercise program	12 weeks	• Statistically significant balance improvement in both groups • No statistically significant difference in quality of life between the pre- and post rehabilitation data of both groups	Significant between-group differences were found for balance, but not for quality of life
Santos P et al. (2019)	Brazil	RCT	45	Balance, gait, mobility, quality of life	Nintendo Wii	Conventional exercise group	8 weeks	Statistically significant balance, mobility, and quality of life improvement in both groups	No statistically significant differences were found between groups
Shih MC et al. (2016)	China	RCT	20	Balance and mobility	Kinect sensor (Microsoft Corporation, Redmond, WA, USA) exergaming	conventional balance training	8 weeks	Statistically significant balance and mobility improvement in both groups	Statistically significant improvement in the VR group in balance and mobility compared to the control group
van den Heuvel MR et al. (2014)	Belanda	RCT	33	Balance, mobility, motor function, quality of life	Visual feedback training	Conventional balance training	5 weeks	• No statistically significant difference in balance between the pre- and post rehabilitation data of both groups • Statistically significant motor function and quality of life improvement in both groups	No statistically significant differences were found between groups
Liao YY et al. (2015)	China	RCT	36	Obstacle crossing performance, mobility, quality of life, fall risk	VR-based Wii Fit exercise	Traditional exercise	6 weeks	Statistically significant mobility and quality of life improvement in both groups	No statistically significant differences were found between groups
Goffredo M et al. (2023)	Italy	RCT	97	Balance, mobility, motor function	Non-immersive VR-based telerehabilitation	at-home conventional rehabilitation	6-10 weeks	Statistically significant mobility and motor function improvement in both groups	Significant between-group differences were found for motor function, but not for mobility
Ferraz DD et al. (2018)	Brazil	RCT	62	Mobility, quality of life	Xbox 360 video game with KinectTM	functional training	8 weeks	Statistically significant quality of life improvement in both groups	No statistically significant differences were found between groups
Goffredo M et al. (2023)	Italy	RCT	72	Balance and mobility	VRRS Tablet home telerehabilitation system	at-home treatments without the use of any technological devices	6-8 weeks	Statistically significant mobility improvement in both groups	No statistically significant differences were found between groups

RCT Randomized Controlled Trial, *VR* Virtual Reality, *BBS* Berg Balance Scale, *TUGT* Timed Up and Go Test, *FGA* Functional Gait Assessment, *UPDRS* Unified Parkinson's Disease Rating Scale, *ABCS* Activities-Specific Balance Confidence Scale, *10-MWT* 10 Meter Walk Test, *DGI* Dynamic Gait Index, *PDQ* Parkinson's Disease Questionnaire

The duration of each VR session varied from 30 to 90 minutes, and the participants performed the VR intervention 2 to 5 times a week. As a result, the total VR intervention in the included studies was at least 9 hours and a maximum of 60 hours.

Risk of Bias in the Included Studies

The risk of bias evaluations for individual studies is summarized in Figure 2.

Study ID	D1	D2	D3	D4	D5	Overall
Feng 2019	!	+	+	+	+	!
Pazzaglia 2020	+	+	+	+	+	+
Kashif 2022	+	+	+	+	+	+
Yang 2016	+	+	+	+	!	!
Gandolfi 2017	+	+	+	+	+	+
Liao 2015	+	+	+	+	+	+
Gulcan 2023	!	+	+	!	+	!
Ribas 2017	+	+	+	+	+	+
Santos 2019	+	+	+	+	+	+
Shih 2016	+	+	+	+	+	+
Van den Haufell 2014	+	+	+	+	+	+
Goffredo 2023a	!	+	+	+	+	!
Ferraz 2017	+	!	+	+	+	!
Goffredo 2023b	+	+	+	+	+	+

+ Low risk ! Some concerns – High risk
D1 Randomization process
D2 Deviations from the intended intervention
D3 Missing outcome data
D4 Measurement of the outcome
D5 Selection of the reported result

Figure 2. Risk of bias assessment summary of bias items for each included study

VR-based Rehabilitation Impact on Parkinson

The analysis was carried out on 14 articles through comprehensive individual reading. Four outcomes related to VR-based rehabilitation and its impact on Parkinson's disease were examined in the synthesized literature.

Four of the ten studies proposing VR-based rehabilitation for balance implemented Nintendo Wii training.[11–14,] While the others used different VR training equipment. The intervention was carried out for at least 5 weeks and a maximum of 12 weeks. Nine studies showed a significant improvement in the VR group after intervention, while one showed no significant within-group difference.[15] Gait VR-based rehabilitation programs aim to improve gait performance, assessed through various measures, including walking speed, stride length, and step length. But, in this study, we found that the stability did not improve significantly between groups. Six studies revealed significant balance differences between the VR and control groups.[7,11–13,16,17] While the other four showed no significant differences. However, these studies show that the VR group did not exhibit improvement beyond the control group, which received conventional rehabilitation. Specifically, commercially accessible VR devices were used, and results indicate that the balance function improves more with VR-based rehabilitation than with traditional rehabilitation.[11–13,17]

Mobility Eight studies assessing the impact of VR-based rehabilitation on mobility were conducted over 6-12 weeks. All studies included in this review used the Timed Up and Go Test (TUGT) for outcome measures related to mobility. Across all eight studies, participants showed significant improvements within their respective groups after completing the training programs.[7,14,17–22] When comparing the outcomes between different groups, three out of the eight studies demonstrated significant differences. In these studies, the VR groups outperformed the control groups regarding mobility.[7,17,19] of the remaining five studies revealed no significant differences.[14,18,20–22]

Motor Function Approximately 43% (6/14) of the studies investigated the influence of different VR-based rehabilitation methods on motor function in PD by the Unified Parkinson's Disease Rating Scale (UPDRS3).[7,11,15,18–20] The participants in the study considered the intervention positively, and 15 and half of the studies suggested the superiority of VR-based rehabilitation over conventional rehabilitation.7,11,20 Within their respective groups, both VR-based and conventional rehabilitation programs demonstrated significant improvements in motor function following the training sessions.

Quality of Life Seven studies implemented VR-based rehabilitation to assess improved quality of life in PD patients. The duration of the intervention ranges from 6 to 12 weeks. Six out of seven studies showed improvement in quality of life within groups after training sessions, both the VR and control groups, but no significant differences were observed between groups. This demonstrates that physical exercise therapy, as a general approach, has more of an effect on the quality of life outcomes of Parkinson's patients when measured by the Parkinson's Disease Questionnaire (PDQ) than the type of rehabilitation programs.

Five studies performed follow-up examinations. Most studies (80%) indicate improvements were maintained at the follow-up, although one study shows otherwise. Follow-up was conducted at 8–16 weeks in studies that showed significant results on follow-up.[11,12,18,22]. One study with decreased outcomes conducted follow-ups at 20 weeks.[13]

Discussion

Principal Findings

A total of 14 studies published between 2014 and 2024 investigated the effectiveness of VR-based rehabilitation in improving outcomes in individuals with PD. According to the results, the articles have been grouped into four categories: balance (10 articles), mobility (8), motor function (6), and quality of life (7).

Overall, the results on all categories demonstrated the benefits of using VR-based rehabilitation in terms of postintervention improvements and suggested that these acquisitions were retained at follow-up.[11,12,18,22] It suggests that VR-based rehabilitation can be used interchangeably with conventional rehabilitation, and further research might be necessary to determine whether a combination of the two approaches may achieve a better outcome. No adverse effects were found in the studies.

Numerous studies have demonstrated that patients can learn motor abilities in virtual settings and apply those skills to real-world situations.[23–25] Prior research has indicated that the integration of somatosensory and visual information in both static and active modes by VR technology can assist patients in determining their position and direction of movement in space.[26,27] Several studies demonstrate that VR rehabilitation can improve neuroplasticity and promote motor rehabilitation.[10,27–29] VR uses real-world stimuli to stimulate the central nervous system, promoting neuroplasticity and generating new synapses and neural pathways.[30,31]

VR-based rehabilitation offers customization, adaptability, and safety, allowing patients to modify limb alignment, simulate real-life events, and increase motivation and compliance with rehabilitation programs.[28,32] All VR exercises for rehabilitation require control of body posture against gravity through a virtual environment and immediate feedback, which can reform the body's balance and flexibility.[12]

Including active reinforcement is a potential way that VR-based rehabilitation improves user health outcomes. Immediate feedback during rehabilitation allows users to see their training progress, vital in building confidence. This enhances rehabilitation compliance, allowing for immediate improvements in results.[10,27,2] However, some of these studies show that VR-based rehabilitation did not have significantly different outcomes compared to conventional rehabilitation alone. The outcome results were mixed, with some studies reporting statistically significant improvements in balance, mobility, motor function, and quality of life following VR-based rehabilitation. In contrast, others did not find such significant differences between VR-based and conventional approaches. The reason could be related to the characteristics of the study population and the intervention period. These studies indicate the need for more robust research designs, larger sample sizes, and long-term follow-up to fully evaluate the efficacy of VR-based rehabilitation in Parkinson's Disease.

Implication for Clinical Practice

There are various challenges to implementing VR-based rehabilitation in healthcare. Most VR-based rehabilitation uses exergames as tools initially intended for the gaming industry and are not regulated to the licensing requirements needed for medical equipment. Most commercially accessible VR programs are classified as nonmedical devices, and while some software within them is accurate, it cannot help clinical decision-making without legal oversight. It is challenging to visualize allowing the secure implementation of VR-based rehabilitation into current medical treatment models until these issues are resolved.

Strengths and Limitations

Our review has several strong points. Numerous VR programs and studies covering various topics were obtained with many participants. Only randomized controlled trials were used, with other types of research eliminated. We use studies with low risk and some bias concerns to ensure the quality of the studies we assess.

This review's findings are limited due to the inclusion of only English-language and freely accessible articles from the past decade, and this might have excluded a few highly qualified studies. And the lack of a meta-analysis due to the heterogeneity of VR programs. Due to the heterogeneity of VR programs, we could not perform a meta-analysis. Therefore, the benefits of VR-based rehabilitation have not been statistically confirmed in this review.

Conclusion

This systematic review suggests that VR-based rehabilitation has the potential to improve balance, mobility, motor function, and quality of life in Parkinson's patients in comparison to conventional rehabilitation.

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