

IMPACT OF VIRTUAL REALITY ON BALANCE AND MOBILITY IN PATIENTS WITH MULTIPLE SCLEROSIS: A SYSTEMATIC REVIEW

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Abstract

Background: Multiple sclerosis is an autoimmune disease of the central nervous system, characterized by motor, cognitive, and balance-related symptoms that limit autonomy. The objective of this review was to compare the effects of virtual reality-based therapy versus traditional treatments on balance and mobility in individuals with multiple sclerosis through a systematic review.

Methods: A systematic review was conducted following PRISMA guidelines across five databases up to February 2025. Five controlled studies were included, comprising a total of 121 participants (64 in the Virtual Reality group and 57 in the control group), who were assessed using objective scales such as the Berg Balance Scale (BBS), Tinetti, and Timed Up and Go (TUG) to evaluate balance and mobility. Cochrane tools were used to assess risk of bias and methodological quality.

Results: Analyses showed that Virtual Reality therapy led to significant improvements in balance (BBS: $Z = 2.53$, $p = 0.01$; heterogeneity $I^2 = 0\%$), with differences favoring the experimental group. However, no significant effects were found regarding functional mobility (TUG: $Z = 0.04$, $p = 0.97$; $I^2 = 47\%$). The types of Virtual Reality interventions included exergaming, robotic training, and immersive reality.

Conclusion: Virtual Reality appears to be a promising strategy for improving balance in patients with multiple sclerosis, potentially more effective than traditional therapies. However, there is insufficient evidence to conclude that it improves overall mobility. Further clinical studies with larger sample sizes and rigorous designs are needed to validate and optimize these personalized interventions.

Keywords: Virtual Reality Exposure Therapy; Multiple Sclerosis; Postural Balance; Active Mobility

Introduction

Multiple sclerosis (MS) is a condition that predominantly affects young adult populations and women [23]. According to estimates, approximately 2.8 million people are affected by MS, with a prevalence of 35.9 cases per 100,000 individuals [36]. Its complex pathophysiology is based on the activation of immune cells [9, 15], which cross the blood-brain barrier [9, 15, 30], triggering an autoimmune response against myelin [9]. The heterogeneity of symptoms largely depends on the location of the lesions and the progression of the disease [17], with early stages presenting alterations such as tingling, muscle weakness, and vision problems [13, 17]; while more advanced stages involve issues such as motor dysfunction and walking difficulties [17, 23]. In this context, comprehensive

management of MS heavily relies on multidisciplinary interventions, including rehabilitation and social support [13, 23], aimed at reducing disability and improving the quality of life for patients [23]. The management of MS focuses on both pharmacological and non-pharmacological treatments, primarily aimed at reducing the risk of permanent disabilities [31, 34]. Medications such as interferon beta (IFN- β) and gabapentin [4, 27], are among the most commonly used, as their mechanisms of action interfere with lesion formation and help control symptoms such as spasticity and neuropathic pain [20, 26]. Another traditional treatment method that receives significant emphasis is personalized physical rehabilitation therapies, which prioritize resistance and strength exercises aimed at restoring balance and motor function [20]. The unilateral or combined integration of both treatment methods has shown benefits in symptom control for patients, improving their autonomy and independence in many cases. However, there are limitations associated with individual responses and treatment adherence in each patient [11, 32, 38], which highlights the need for more personalized and adaptive approaches [38].

The integration of virtual reality into physical rehabilitation programs has gained prominence, emerging as an innovative tool for the treatment of MS [39]. Its applicability includes both immersive and non-immersive designs, which differ depending on the type of technology used to develop functional tasks. Furthermore, previous reviews have shown that this therapy demonstrates higher patient adherence and motivation compared to conventional therapies [35], improving patients' balance and gait [14, 21, 25, 28, 35]. However, this review is not fully up to date and requires an update in light of new technological advancements being incorporated into recently published clinical trials. Therefore, the present research aims to compare the effects of virtual reality-based therapy with traditional therapies on motor function and balance in patients with multiple sclerosis, building on previous research.

Materials and Methods

The systematic review was conducted following the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) across five electronic databases: Medline, Scopus, Web of Science, Lilacs, and Cochrane, from their inception until early July 2025. The search strategy included terms and keywords integrated into MeSH (Medical Subject Headings), with language restrictions applied only to studies published in English, Spanish, and Portuguese. The inclusion criteria were as follows: 1) Population: Adults ≥ 18 years old diagnosed with multiple sclerosis of any phenotype and stage; 2) Intervention: Therapy based on immersive and non-immersive virtual reality; 3) Comparator: Patients receiving conventional therapies; 4) Objective measurement: Objective measures of balance and mobility; 5) Study type: Randomized controlled trials (RCTs). Additionally, studies were excluded if they did not have at least one objective outcome related to balance/mobility, as well as non-original publications such as letters, editorials, protocols, and conference proceedings. No protocol for this review was registered in any database.

Data Extraction

Two independent reviewers (Y.A.S.D and R.C.V.R) extracted the data using a template that included study characteristics (author, year, country, design), participant characteristics (sample size, age, sex), intervention details (VR modality, devices, frequency, duration, intensity), comparators (BBS, TUG, Tinetti, 10MWT). Discrepancies were resolved by consensus or with a third reviewer (C.E.O.R). When necessary, authors were contacted for missing data.

Assessment of Methodological Quality

Two reviewers (C.E.O.R. and H.A.V.Z.) independently assessed the risk of bias. For randomized controlled trials, we used the Cochrane RoB 2 tool, rating each pre-specified outcome across the five domains (randomization process; deviations from intended interventions; missing outcome data; outcome measurement; selection of reported outcomes) as low risk, some concerns, or high risk [18].

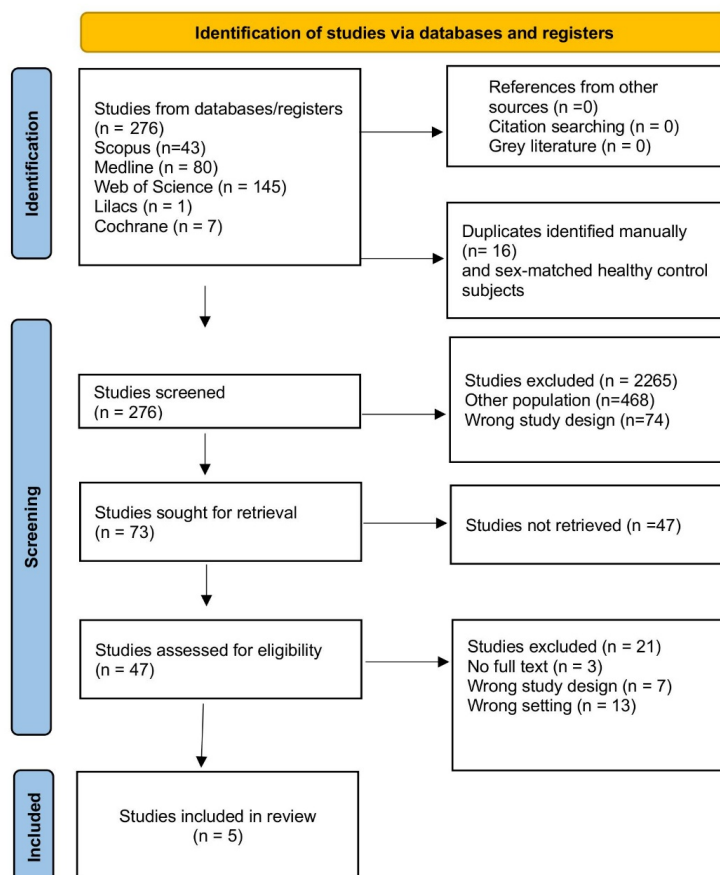
For non-randomized and quasi-experimental studies, we applied ROBINS-I across its seven domains, with overall judgments ranging from low risk to critical risk of bias [33]. Disagreements were resolved through discussion; a third reviewer (Y.A.S.D.) adjudicated when necessary.

Quantitative Analysis and Meta-Analysis

Only trials that met the predefined methodological criteria were included in the meta-analysis. The quantitative analysis was performed using Review Manager (RevMan 5.3, Cochrane) [40], utilizing post-intervention means and standard deviations for the experimental and control groups. Based on the homogeneity of the scales, mean differences (MD) or standardized mean differences (SMD, Hedges g) were estimated, both with 95% confidence intervals, under a random-effects model. Heterogeneity was assessed using Cochran's Q statistics and I^2 [40], and statistical significance was determined using two-tailed tests ($p < 0.05$). Two reviewers independently verified the data extraction and calculations. The results were presented in forest plots. Publication bias was not formally assessed due to the low number of studies per outcome ($k < 10$) [10].

Results

A search was conducted across multiple databases, yielding a total of 2,898 articles. The screening process consisted of two phases. In the first phase, duplicates and articles were excluded based on title and abstract. The second phase involved a detailed evaluation of the full text and the application of inclusion and exclusion criteria. After both phases, only five studies were deemed eligible for inclusion in the review (Figure 1).



Study Characteristics

Of the five studies included, two were conducted in Italy, one in Iran, one in Jordan, and one in Spain. All were controlled trials with both experimental (virtual reality intervention) and control groups. The total sample included 64 participants in the experimental group and 57 in the control group. The average ages ranged from 36.8 ± 8.4 to 51.7 ± 10.24 years in the experimental group, and from 34.87 ± 8.98 to 58 ± 5.83 years in the control group. Balance was assessed using the BBS and Tinetti tests, while mobility was evaluated with the TUG test. The control group received traditional therapies, whereas the experimental group underwent virtual reality-based therapies. Interventions in the experimental group included exergaming, LCD monitors for virtual scenes, robot-assisted training, and combined systems (WorldViz with C-Mill treadmill) (Table 1).

Table 1: Study Characteristics

Study	Desing	Country	VR Group				Control Group			Assessments		
			Age	N°	Female	System	Age	N°	Female	Frequency	Test	Main results
(Molhemiet al., 2021) [19]	CT	Iran	36.8 ± 8.4	19	12	Microsoft Kinect Used for Exergaming: Light Race, Stack'em Up, and 20,000 Leaks.	41.6 ± 8.4	20	12	18 sessions distributed over 6 weeks, three times a week.	BBS, TUG	Both groups showed improvements in the BBS scores; however, the increase was more notable in the VR group
Khali l, et al 2013 [14]	CT	Jordan	39.8 ± 12.75	16	12	Kinect to detect movements, Wii Balance Board to measure balance, and an LCD monitor to display virtual scenes.	34.87 ± 8.98	16	10	12 sessions distributed over 6 weeks, twice a week.	BBS, TUG	The group that received virtual reality (VR) training showed significant improvement compared to the control group that performed traditional balance

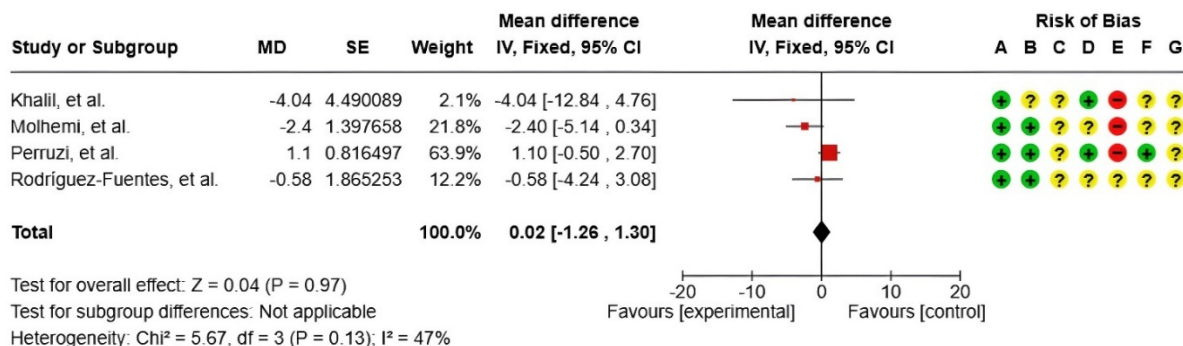
												exercises.
Munari, 2020 [21]	CT	Italy	51,7 ± 10,24	9	5	Robot-assisted training, with a 42-inch monitor to simulate a park, synchronized with the G-EO platforms.	58 ± 5,83	8	5	12 sessions of, over 6 weeks, twice a week.	BBS	Significant improvement in BBS performance for the experimental group compared to the control group.
Perruzzi, 2017 [25]	CT	Italy	43.6 ± 10.2	10	6	System that combines (WorldViz) with a treadmill (C-Mill) to provide visual feedback.	42.0 ± 12.0	15	7	18 sessions distributed over 6 weeks, three times a week.	BBS, TUG	The results indicated that, after the intervention, participants in the VR - TT group showed significant improvements in the BBS.
Rodriguez-Fuentes, 2024 [28]	CT	Spain	48.20 ± 5.40	10	2	Boxing exergame that simulated being in a gym, with movements involving the upper and lower limbs, torso, and head.	41.3 ± 4.88	8	6	16 sessions distributed over 8 weeks, twice a week.	Tinetti, TUG	The experimental group significantly improved their lower limb strength, functional mobility, and reduced the risk of falls.

N°: Number of patients; F: Female; VR group: Experimental group; CT: Controlled trial, BBS: Berg Balance Scale, TUG: timed Up and Go, Tinetti: Gait and Balance Assessment Scale

Effect of Virtual Reality-Based Therapy on the BBS Test

Post-treatment results of the BBS test show a comparison between the Experimental Group and the Control Group, with an average standardized mean difference (SMD) that significantly favored the Experimental Group. In the studies analyzed, the SMD for Khalil et al. was 0.768, for Molhemi et al. was 0.561, for Munari et al. was 0.495, and for Perruzzi et al. was 0.408, indicating a positive trend towards the experimental group. The test for the overall effect presented a Z statistic of 2.53 (p=0.01),

suggesting the efficacy of the treatment administered to the Experimental Group. Heterogeneity between the studies was low, with a χ^2 of 2.06 (df=3; p=0.56) and an I^2 of 0%, supporting the consistency of the findings (Figure 2).

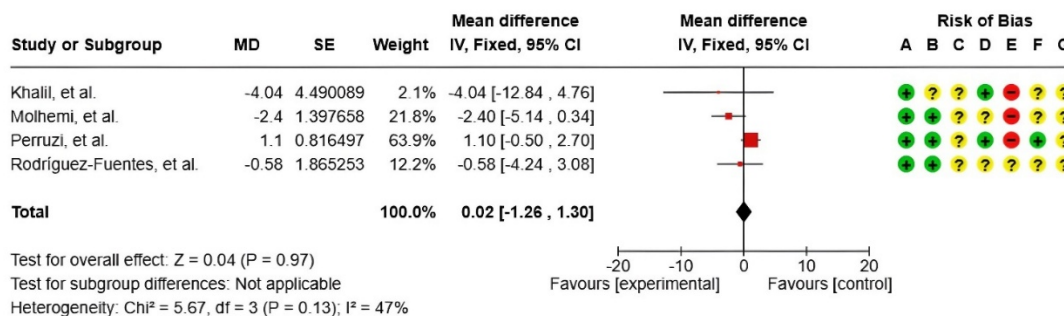


Risk of bias legend

- (A) Random sequence generation (selection bias)
- (B) Allocation concealment (selection bias)
- (C) Blinding of participants and personnel (performance bias)
- (D) Blinding of outcome assessment (detection bias)
- (E) Incomplete outcome data (attrition bias)
- (F) Selective reporting (reporting bias)
- (G) Other bias

Effect of Virtual Reality-Based Therapy on the TUG Test

In this meta-analysis, mean differences (MD) in post-treatment TUG test results between the experimental and control groups were evaluated. The included studies reported moderate differences in effects, with Khalil et al. showing an MD of -4.04, Molhemi et al. -2.4, and Perruzi et al. reporting an MD of 1.1. In contrast, the study by Rodríguez-Fuentes et al. showed a difference of -0.58. When combining the results of these studies, an overall effect with an MD of 0.02 was obtained, with a 95% confidence interval of [-1.26, 1.30], indicating no significant effect ($Z=0.04$, $P=0.97$). Additionally, the analysis revealed a degree of heterogeneity ($\chi^2=5.67$, $df=3$; $P=0.13$; $I^2=47\%$), suggesting variability in results across studies.



Risk of bias legend

- (A) Random sequence generation (selection bias)
- (B) Allocation concealment (selection bias)
- (C) Blinding of participants and personnel (performance bias)
- (D) Blinding of outcome assessment (detection bias)
- (E) Incomplete outcome data (attrition bias)
- (F) Selective reporting (reporting bias)
- (G) Other bias

Discussion

Virtual reality-based interventions show significant benefits in balance control when compared to conventional approaches in patients with multiple sclerosis. However, with regard to functional mobility, the current data do not support clinically relevant superiority of these interventions over traditional therapies.

The results of this study reflect the positive influence of virtual reality-based interventions on balance control in individuals with multiple sclerosis. These findings are consistent with previous studies, which have emphasized that the sensory and motor stimulation provided by virtual reality therapy [5, 35], allows for visual feedback, helping the brain receive accurate information about the motor system [37], thereby improving patient coordination and stability [8, 22]. Additionally, VR creates simulated and safe environments where patients can practice repetitive movements and specific tasks, making it a highly motivating therapy that enhances patient engagement and treatment adherence [12], thus increasing the likelihood of benefits compared to traditional methods. Together, these findings support the use of VR as a complement to conventional interventions, as its effectiveness is consistently demonstrated in balance control and treatment adherence.

This review emphasizes that VR therapy alone would not improve functional mobility, primarily because previous reviews have highlighted that mobility depends on multiple factors within an integrated rehabilitation approach [1, 24]. However, this does not imply that VR lacks significance, as its utility, when combined with strength training [6], multimodal training [16, 29], and the increase in exercise intensity and specificity [6], could enhance the likelihood of improvement [6]. Additionally, telerehabilitation, which uses VR to deliver exercises and therapies remotely [7, 29], has been shown to be effective in improving capacities such as mobility and balance [7]. In this context, a more standardized approach to protocols, encompassing frequency, intensity, duration, and task type [3], could have a greater clinical impact in managing the mobility deficits seen in MS [2]. It is important to acknowledge the findings of this review, which highlight the potential of virtual reality to improve balance control in individuals with multiple sclerosis. However, methodological limitations still persist in the literature, the most significant being the heterogeneity of intervention protocols, the limited standardization of the platforms used, and the variability in follow-up durations. These factors hinder the generalization of the findings and their direct clinical application. Moreover, many studies feature small sample sizes or lack long-term analyses, which limits the strength of their conclusions. In the future, more rigorous clinical trials are required, with controlled designs and sensitive tools that allow for the evaluation not only of the effectiveness but also of the real-world applicability of these technologies in both clinical and home settings.

Conclusions

Various studies indicate that virtual reality interventions may help improve balance in individuals with multiple sclerosis, potentially even more effectively than traditional methods. However, when it comes to overall mobility, there is still insufficient evidence to demonstrate that these therapies offer clear advantages over conventional treatments. Virtual reality appears to be a promising option for enhancing balance, although further evidence is needed to confirm whether it can truly surpass traditional methods in motor recovery.

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