

# Virtual Reality and Video Games for Trunk Rehabilitation in Post-stroke Patients: A Scoping Review

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## ABSTRACT

Impaired trunk control after a stroke significantly affects functional activities and balance. Virtual Reality (VR) and game-based rehabilitation methods to facilitate trunk control in stroke patients have become popular. The objective of the present scoping review was to map, gather and evaluate information on VR and video game-based interventions for the restoration of trunk control in stroke survivors. A search of PEDro, Cochrane and PubMed database (2016-2025) identified total eight studies including five randomised controlled trials (including pilot randomised trials), two non-randomised or quasi-experimental designs and one laboratory based experimental study (n=247 participants) on VR/Video game-based trunk training lasting 4-12 weeks using devices like Nintendo Wii, Kinect, Oculus Quest 2, Driving simulations, non-immersive Doctor Kinetic gaming system and immersive Cave Automatic Virtual Environment (CAVE) system. These interventions lead to significant improvement in the various outcome measures of trunk control. Gait, quality of life and motivation also demonstrated improvement. However, some studies did not report exact p-values, and one experimental study assessed postural responses rather than clinical outcomes. VR and video games therapies might be an effective supplementary treatment to standard trunk rehabilitation following a stroke, improving control, balance and function.

**Keywords:** Cave automatic virtual environment, Outcome measures, Quality of life, Stroke

## INTRODUCTION

A stroke is a clinically defined acute illness characterised by abrupt localised neurological impairment brought on by vascular injury to the central nervous system (haemorrhage or infarction). Stroke continues to rank as the world's second leading cause of death and the third leading contributor to the combined burden of mortality and disability, as measured by Disability-Adjusted Life Years (DALYs) [1]. Stroke patients typically experience unequal weight distribution, trunk malalignment, and difficulty in maintaining balance. Compared to healthy people, survivors victims have a significantly reduced ability for trunk control [2]. Reduced mobility and a greater risk of falls are related to reduced trunk and postural control, as well as impaired balance. As a result, they become disabled and dependent on others for everyday tasks [3]. Six months after a stroke, independent ambulation and motor functional results are significantly predicted by trunk performance during the first two weeks (1-2) [4]. Good postural stability is essential for both balance and the use of the extremities during everyday functional activities. Trunk stability has been linked to improved limb function and balance, according to earlier studies [5].

VR offers an interactive, three-dimensional (3D) simulated environment that closely mimics the actual world, allowing users to move, engage, and experience complete immersion through many sensory cues [6]. VR programs are increasingly being used in healthcare settings because they are frequently more entertaining and engaging than traditional therapy, which encourages patient participation [5]. VR and interactive video games are new methods for stroke rehabilitation; the degree of immersion varies depending on the program and devices design [7]. Realistic, repeatable 3D training is made possible by VR, and research utilising gadgets like the Wii Balance Board demonstrates that non-immersive VR significantly enhances postural control and balance in stroke patients who are not yet fully recovered [8].

Various studies are available that examine the effect of VR and videogames on upper limb and lower limb post-stroke rehabilitation,

but there is limited research that examines their effect on post-stroke trunk rehabilitation, as very few studies are available in this area. The purpose of this review is to find the effect of video games and VR on trunk rehabilitation in post-stroke patients by combining the results from randomised controlled trials, comparative experimental, two-centre clinical trials.

## MATERIALS AND METHODS

The scoping review followed the methodological framework by Arksey and O'Malley (2005) [9], refined by Levac et al. (2010) [10], and updated by the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis (2020) [11]. Following these criteria, we defined research questions, identified and selected studies, organised data, and summarised findings. Reporting adhered to Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping (PRISMA-ScR), a 22-item checklist ensuring comprehensiveness, reproducibility, and transparency [12].

### Step 1: Identifying the Research Question

The Population, Concept, and Context (PCC) framework (population, concept, and context) was used to create the research question [13]. The population of interest included patients with stroke. The concept focused on the use and different types of VR and video game-based training and their effects on trunk rehabilitation. The context included stroke rehabilitation settings such as hospitals, clinics, outpatient centers, and supervised therapy environments where these interventions were used either alone or alongside conventional rehabilitation therapy.

### Step 2: Identifying the Relevant Articles

The PCC framework was used to establish study eligibility: the setting featured outpatient therapy, the idea focused on video games and VR for post-stroke trunk rehabilitation, and the population included stroke patients aged  $\geq 18$ . Using appropriate keywords along with Boolean operators [Table/Fig-1], relevant studies were found in PubMed, PEDro and Cochrane [14].

Database	Keywords and operators	Articles hit
PubMed	("stroke" OR "cerebrovascular accident") AND ("virtual reality" OR "VR" OR "video game" OR "game-based therapy" OR "interactive game") AND ("trunk training" OR "trunk control" OR "postural control" OR "postural stability")	45
Cochrane	("stroke" OR "cerebrovascular accident") AND ("virtual reality" OR "VR" OR "video game" OR "game-based therapy" OR "interactive game") AND ("trunk training" OR "trunk control" OR "postural control" OR "postural stability")	50
PEдро	Problem=Stroke OR Cerebrovascular accident; Title/Abstract=Virtual reality, VR, Video game, Game-based therapy, Interactive game; Title/Abstract=Trunk training, Trunk control, Postural control, Postural stability	10
	Sub-total	105

[Table/Fig-1]: Search strategy.

### Step: 3 Selection of Studies

All primary study designs published in peer-reviewed journals were eligible for inclusion, including randomised controlled trials, non-randomised, and experimental studies. Editorials, conference papers, and grey literature were excluded. Review articles were not included as primary evidence; however, their reference lists were screened to identify additional eligible primary studies. Only the original eight research studies meeting the inclusion criteria were included in the final analysis. All records were cross-checked with a title, authorship and year of publication to reduce duplication and overlap. Duplicate studies identified from research databases and/or review articles were excluded, and then studies were included only once. The analysis comprised eight studies in total.

### Step: 4 Charting the Data

In order to construct a descriptive summary, data charting entailed gathering and arranging study data, such as author, year, design, sample, demographics, VR application, intervention specifics, outcomes, major findings, limitations, and funding. Before analysis, the extracted data were checked for accuracy.

### Step: 5 Compiling, Summarising and Presenting the Results

An analytical framework was created during this stage to fully understand the existing literature. The qualitative analysis was organised in a table, and the findings were then combined qualitatively. This combination aims to acknowledge the state of the art in the field of study.

## RESULTS

A total of 105 records were retrieved via database searching. Nine full-text articles were assessed for eligibility, and one study was excluded due to irrelevant content. Eight studies that met the inclusion criteria were ultimately included in this scoping review [Table/Fig-2]. The eight included studies (published from 2016 to 2025) were conducted in South Korea, India, Italy, China, and Spain. The sample sizes ranged from 10 to 48 stroke patients. They included randomised controlled trials (including pilot trials), non-randomised comparative studies, and one laboratory-based experimental study [5-8,15-18] [Table/Fig-3].

### Effects of VR and Video Game-based Interventions

VR and video game-based interventions showed improvement in trunk control, balance, and functional outcomes in post-stroke patients. Most randomised controlled trials found improvements in dynamic sitting balance, postural stability and trunk control as assessed by the Trunk Impairment Scale [16,17]. Measures like the Berg Balance Scale, Tinetti Scale and Functional Reach Test showed improvement in balance [6,7]. The Dynamic Gait Index and Modified Barthel Index demonstrated improvements in gait and activities of daily life [16,17].



[Table/Fig-2]: PRISMA flow diagram illustrating the search framework.

Several studies reported improvements in quality of life, motivation and adherence to rehabilitation programs [7]. However, variability existed in outcome measures, intervention protocols and reporting of statistical values across studies. One experimental study focused on postural responses rather than clinical outcomes [18], and some did not provide detailed statistical data [8,16].

## DISCUSSION

From the eight included studies, the findings suggest that video game-based and VR interventions designed to optimise trunk training might have an impact in rehabilitation following post-stroke. While several studies indicated improvements in trunk control, balance, and functional outcomes, the level of evidence is mixed, and statistical details were not always provided. While some studies reported comprehensive trunk-specific outcome measures, others more broadly focused on balance and functional performance. These interventions may prove effective as adjunct interventions to conventional rehabilitation, addressing trunk control deficits after stroke, and treatment should be further supported by high-quality research demonstrating their effectiveness.

### Technology-Specific Approaches to Trunk Training

Significant improvements in trunk control were shown in studies employing Nintendo Wii for seated trunk training. According to Lee MM et al., the experimental group's Trunk Impairment Scale (TIS) improvements were greater ( $2.8 \pm 1.3$ ) than the controls' ( $1.0 \pm 0.7$ ). The benefits of lateral posture training were further supported by the Modified Functional Reach Test, which revealed greater lateral reach gains (33-41%) than forward reach gains (19%) [5]. Similarly, another study showed gains in trunk control in the experimental group, forward reach increased by 5.14 cm and lateral reach increased by 6.73 cm, along with significant reductions in postural sway [15].

### Custom Gaming Applications

Lee D and Bae Y identified significant gains in trunk coordination ( $1.73 \pm 1.10$  to  $3.09 \pm 1.57$ ) and total TIS ( $11.73 \pm 1.56$  to  $15.91 \pm 3.59$ ) using a simple driving simulator without back support and these improvements were observed in trunk training. The same benefits

Study	Country	Study design	Aim/Objective	Population	VR & video games	Outcome measures	Results	Conclusion
1. Lee MM et al., 2016 [5]	South Korea	Pilot randomised controlled trial	To assess the applicability of canoe game-based VR training on upper limb motor function, balance, and trunk postural control.	10 subacute stroke patients	Nintendo Wii Sports Resort	Trunk Impairment scale (TIS), Functional reach test (FRT), Berg Balance Scale (BBS), Timed Up and Go Test (TUG), Fugl-Meyer Assessment (Upper Limb)	Both postural balance and upper limb function were significantly improved in the experimental group with a higher usability score compared with control ( $p<0.05$ ).	VR training based on canoe games is a suitable and successful strategy for enhancing upper limb motor function, balance, and trunk postural stability.
2. Peláez-Vélez FJ et al., 2023 [6]	Spain	Pilot Randomised Controlled Trial	To Assessing the impact of integrating VR-based program with a conventional neurological physiotherapy technique in stroke patients	24 stroke patients	Head-Mounted Display (HMD)	Daniels and Worthingham Scale, Modified Ashworth Scale, Motricity Index, Trunk Control Test, Tinetti Scale, Berg Balance Scale	VR group improvement compared to control was significant for motor function ( $p=0.005$ ), trunk control ( $p=0.008$ ), balance (Tinetti: $p=0.004$ ; Berg Balance Scale: $p=0.007$ ), and functional ambulation ( $p=0.038$ ).	In stroke treatment, using Virtual Reality (VR) in conjunction with conventional physiotherapy is a helpful and successful approach that significantly improves trunk control, balance, gait, and functional level of gait.
3. Cano-Mañas MJ et al., 2020 [7]	Spain	Randomised controlled trial	To determine the effect of commercial video games on balance, motivation, postural control, function and quality of life in subacute stroke patients	48 patients with subacute stroke	The Xbox 360 <sup>®</sup> and the Kinect <sup>®</sup>	Modified Rankin Scale, Barthel Index, Functional Reach Test, Tinetti Scale, Timed Up and Go Test, Baropodometry, EuroQoL5D (EQ-5D)	Significant improvements in functional disability (Modified Rankin Scale; $p<0.01$ ), activities of daily living (Barthel Index; $p=0.05$ ), balance (Tinetti gait; $p=0.02$ ), functional mobility (Functional Reach Test; $p<0.01$ ; Timed Up and Go Test; $p=0.05$ ), and quality of life domains (EQ-5D; $p<0.01$ for pain/discomfort and anxiety/depression, where as other domains showed no significant changes ( $p=0.21$ )). Motivation, self-esteem, and adherence also improved significantly ( $p<0.01$ ).	Patients with subacute stroke may benefit from a semi-immersive video-game-based rehabilitation protocol in addition to traditional therapy to improve their motivation, balance, postural control, functionality, and quality of life.
4. D'Antonio E et al., 2020 [8]	Italy	Comparative, experimental cross-sectional design	To investigate postural control in dynamic virtual settings and to evaluate the effect of VR signals on the balance of young, healthy volunteers, age-matched adults, and stroke patients.	45 post-stroke patients	Free Steps, Sensor Medica software	Sway Path Length, Anteroposterior (AP) and Mediolateral (ML) Sway, Berg Balance Scale, Functional Ambulation Category (FAC) Tinetti Scales	VR exposure increased sway path length in healthy subjects and reduced changes in postural response; clinical outcomes did not change significantly for stroke patients.	Dynamic virtual environment causes postural oscillations, especially in young healthy subjects, although adaptation is reduced in older adults and post-stroke patients who are less susceptible to VR stimulation
5. Lee MM et al., 2018 [15]	South Korea	Randomised controlled trial	To examine the impact of game-based Virtual Reality (VR) canoe paddling training, in conjunction with traditional physical rehabilitation regimens, on postural stability and upper extremity functionality	30 patients with subacute stroke	Nintendo Wii Sports Resort, Pedalo <sup>®</sup> Springboard	Modified functional reach test, postural sway test	Postural balance and upper limb functions were significantly improved in the experimental group as compared to the control group ( $p<0.05$ ), including functional reach and manual function.	Adding game-based VR canoe paddling training to traditional post-stroke rehabilitation programs is more effective than conventional rehabilitation alone.

6. He T et al., 2025 [16]	China	Randomised controlled trial	To compare the effect of VR-based training and traditional balance training on trunk control, sitting balance and activities of daily living (Modified Barthel Index) in stroke patients.	36 patients with subacute stroke	Non-immersive VR (Doctor Kinetic iMove 3.0)	Trunk impairment scale, center of Pressure Parameter (Sway velocity, Sway area, Medio-lateral displacement, Anterior-posterior displacement), Modified Barthel Index	Significant improvements were observed in trunk control (TIS total; $p < 0.001$ ), dynamic trunk control ( $p = 0.013$ ), medio-lateral displacement ( $p = 0.016$ ), anterior-posterior displacement ( $p = 0.039$ ), and activities of daily living (MBI; $p < 0.001$ ). The effect size for the total score on the Trunk Impairment Scale (TIS) was large (Cohen's $d = 1.11$ ), while the between-group effect size was moderate ( $d = 0.54$ , 95% CI [0.07, 1.01]).	VR-based training performed better in enhancing lateral trunk control in dynamic activities suggesting its potential value for enabling dynamic postural modification in stroke therapy even though both therapies improved trunk control, sitting balance and ADL respectively. Perspective of customized rehabilitation plans for stroke patients with balance dysfunction is also offered
7. Lee D and Bae Y 2020 [17]	Korea	Two-centre clinical trial	To evaluate the effect of driving-based interactive video games on trunk control and gait in patients with chronic stroke	24 chronic stroke patients	Driving Video Game Grid 2	Trunk Impairment scale, Dynamic Gait Index, Timed Walking Test, Timed Up and Go Test	Significant increases for trunk control (TIS subscales) and gait ability (Dynamic Gait Index and Timed Up and Go Test), in the experimental group showing larger increases; Effect sizes were $\eta^2 = 0.285$ for the total Trunk Impairment Scale (TISall) score and $\eta^2 = 0.243$ for the Trunk Coordination (TISco) subscale.	Patients with chronic stroke may benefit from a rehabilitation program that combines traditional therapy with interactive driving video games to improve their trunk control and gait.
8. Victor BA et al., 2024 [18]	India	Single-Blinded, Comparative Experimental Study	To compare the effects of Immersive VR training combined with gait training and VR training alone.	30 stroke patients	Immersive Virtual Reality (VR) training	Functional Gait Assessment (FGA), Falls Efficacy Scale (FES)	Both groups improved, but group with combined training was more effective, as evidenced by lower FES scores ( $36.66 \pm 11.12$ vs. $46.66 \pm 9.75$ ) and higher FGA scores ( $28.00 \pm 0.93$ vs. $26.06 \pm 1.66$ ), with statistically significant differences ( $p < 0.05$ ).	In stroke patients, immersive Combined training enhances dynamic balance and postural stability more than immersive VR training alone

**[Table/Fig-3]:** Summary of the included studies [5-8,15-18].

were seen with a non-immersive Kinect-based VR system with unique games through the driving simulator for dynamic trunk control which also observed better relative TIS dynamic gains  $\Delta 3.61 \pm 1.75$  compared to  $2.05 \pm 1.80$  as well as medio-lateral movement. Although for both dynamic trunk control was much better for the task-specific interactive gaming in rehabilitation [16,17].

### Adaptations for Commercial Gaming

After eight weeks, whole-body gaming exercises comprising trunk flexion, extension, and rotation using an Xbox 360 with Kinect greatly improved functional reach and postural control. Similarly, immersive trunk training was provided using Oculus Quest 2 VR with Blender software through "Chop the Wood," "Row the Boat," and "Climb the Tree," resulting in higher Trunk Control Test gains ( $+4.2$  vs.  $+2.1$ ) than controls [6,7].

### Results of Gaming-Specific Trunk Training

Clinical effects of gaming therapy upon trunk control were clinically significant on the validated evaluation measures. According to Lee

D and Bae Y (2020) driving game-based intervention study, the Trunk Impairment Scale showed significant improvements with moderate to large effect sizes ( $\eta^2 = 0.243-0.285$ ). Motor learning was supported by a progressive and task-specific reinforcement of trunk control, supported by game platforms [5,7,17].

Overall, in the studies included, it is suggested that gaming-based approaches are used to supplement rather than replace conventional therapy. Among them, intervention protocols were typically sessions of 15-30 minutes and administered three to five times per week for four to eight weeks. The majority of studies reported these interventions to be safe; seated configurations used in some studies provide stability while also enabling trunk control training [5-7,15,16].

### Limitation(s)

Small sample sizes ranging from 10 to 48 participants limited the statistical power and generalisability of the included studies. Training durability could not be evaluated due to the lack of long-term follow-up. Cross-study comparison and isolated assessment of

trunk-specific effects were hampered by wide variance in outcome measures and the inclusion of co-interventions. Different platforms (Nintendo Wii, specialised simulators, VR, non-immersive Kinect-based) made it challenging to identify the best intervention tactics, while differences in stroke severity, chronicity, and cognition made it challenging to identify which patients would benefit the most.

## CONCLUSION(S)

Video games and VR therapies may enhance trunk control following a stroke, according to this scoping review of eight studies. Non-immersive kinect VR system, immersion VR and kinect-based training enhanced static trunk control, reach, and balance were used as an intervention, whereas task-specific games such as driving simulations and seated Nintendo Wii canoe paddling demonstrated the significant improvements. Even with limited sample sizes and brief follow-ups, game-based trunk training consistently shows promise as a useful supplement to traditional therapy. To provide precise clinical guidelines, larger, systematic, long-term investigations are required.

## REFERENCES

- [1] Feigin VL, Brainin M, Norrving B, Martins SO, Pandian J, Lindsay P, et al. World Stroke Organization: Global stroke fact sheet 2025. *Int J Stroke*. 2025;20(2):132-44.
- [2] Kim HY, Moon HI, Chae YH, Yi TI. Investigating the dose-related effects of video game trunk control training in chronic stroke patients with poor sitting balance. *Ann Rehabil Med*. 2018;42(4):514-20.
- [3] Cabanas-Valdés R, Bagur-Calafat C, Girabent-Farrés M, Caballero-Gómez FM, Hernández-Valiño M, Urrútia Cuchí G. The effect of additional core stability exercises on improving dynamic sitting balance and trunk control for subacute stroke patients: A randomized controlled trial. *Clin Rehabil*. 2016;30(10):1024-33.
- [4] Cabanas-Valdés R, Urrútia G, Bagur-Calafat C, Caballero-Gómez FM, Germán-Romero A, Girabent-Farrés M. Validation of the Spanish version of the Trunk Impairment Scale Version 2.0 (TIS 2.0) to assess dynamic sitting balance and coordination in post-stroke adult patients. *Top Stroke Rehabil*. 2016;23(4):225-32.
- [5] Lee MM, Shin DC, Song CH. Canoe game-based virtual reality training to improve trunk postural stability, balance, and upper limb motor function in subacute stroke patients: A randomized controlled pilot study. *J Phys Ther Sci*. 2016;28(7):2019-24.
- [6] Peláez-Vélez FJ, Eckert M, Gacto-Sánchez M, Martínez-Carrasco Á. Use of virtual reality and videogames in the physiotherapy treatment of stroke patients: A pilot randomized controlled trial. *Int J Environ Res Public Health*. 2023;20(6):4747.
- [7] Cano-Mañas MJ, Collado-Vázquez S, Rodríguez Hernández J, Muñoz Villena AJ, Cano-de-la-Cuerda R. Effects of video-game-based therapy on balance, postural control, functionality, and quality of life of patients with subacute stroke: A randomized controlled trial. *J Healthc Eng*. 2020;2020:5480315.
- [8] D'Antonio E, Tieri G, Patané F, Morone G, Iosa M. Stable or able? Effect of virtual reality stimulation on static balance of post-stroke patients and healthy subjects. *Hum Mov Sci*. 2020;70:102569.
- [9] Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. *Int J Soc Res Methodol*. 2005;8(1):19-32.
- [10] Levac D, Colquhoun H, O'Brien KK. Scoping studies: Advancing the methodology. *Implement Sci*. 2010;5(1):69.
- [11] Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. *JBI Evid Synth*. 2020;18(10):2119-26.
- [12] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Ann Intern Med*. 2018;169(7):467-73.
- [13] Stovold E, Beecher D, Foxlee R, Noel-Storr A. Study flow diagrams in Cochrane systematic review updates: An adapted PRISMA flow diagram. *Syst Rev*. 2014;3(1):54.
- [14] Peters MD, Godfrey C, Mclnerney P, et al. Chapter 11: Scoping reviews. In: *JBI manual for evidence synthesis*. 2020 May 24. p. 467-73.
- [15] Lee MM, Lee KJ, Song CH. Game-based virtual reality canoe paddling training to improve postural balance and upper extremity function: A preliminary randomized controlled study of 30 patients with subacute stroke. *Medical Science Monitor: International Medical Journal of Experimental and Clinical Research*. 2018;24:2590.
- [16] He T, Zhang M, Chen X, Lian Y, Zhang Z, Niu W. Comparing the effects of virtual reality and traditional balance training on trunk control, sitting balance, and activities of daily living in patients with stroke: A randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*. 2025;17(1):294.
- [17] Lee D, Bae Y. The effectiveness of driving game on trunk control and gait ability in stroke. *J Mot Behav*. 2020;52(1):33-40.
- [18] Victor BA, Arunachalam R, Angel IS, Kumar BG. Enhancing dynamic balance and postural stability in stroke patients: The impact of immersive virtual reality training. *Cureus*. 2024;16(8):e66299.

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