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UTILIZATION OF VIRTUAL REALITY (VR) IN PATIENTS AS POST-STROKE REHABILITATION TOOL

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ABSTRACT

Background. Virtual reality (VR) has emerged as a promising adjunct to conventional rehabilitation in post-stroke patients, offering interactive and engaging environments that may enhance motor recovery and functional outcomes. However, the rapidly growing and heterogeneous body of evidence requires up-to-date synthesis.
Aim. To narratively review recent randomized controlled trials (RCTs) published in 2025 that investigated the use of immersive and non-immersive VR as part of post-stroke rehabilitation.
Material and methods. A narrative review was conducted using PubMed and Google Scholar. Searches combined terms related to stroke and virtual reality ("stroke", "cerebrovascular incident", "virtual reality", "immersive virtual reality", "augmented reality", "rehabilitation", "treatment", "therapy") and were limited to peer-reviewed RCTs published in English between 1 January and October 2025. Studies involving only healthy participants, meta-analyses, and trials without clear methodology were excluded. Data on patient characteristics, VR systems, intervention protocols, and clinical outcomes were extracted and qualitatively synthesized.
Results. Nine RCTs involving a total of 391 post-stroke patients (pooled mean age 58.56 years) were included. VR interventions ranged from fully immersive head-mounted display systems (e.g. Oculus Rift, Oculus Quest, NJIT RAVR) to non-immersive or semi-immersive platforms (e.g. Kinect-based systems, BioRescue, smartphone VR). Most studies delivered VR as an adjunct to conventional physiotherapy or occupational therapy. Improvements in motor recovery assessed by the Fugl–Meyer Assessment were consistently greater in VR groups compared with controls. Several trials also reported significant gains in balance (Berg Balance Scale), mobility (Timed Up and Go, 6-Minute Walk Test), trunk control (Trunk Impairment Scale), and functional independence (Barthel Index/Modified Barthel Index), although results for balance and gait were more variable, with at least one trial showing no additional benefit of home-based non-immersive VR on BBS or TUG. Heterogeneity in stroke chronicity, sample sizes, VR equipment, training intensity, and outcome measures limited direct comparability across studies.
Conclusions. Recent RCTs suggest that VR can be a useful adjunct to conventional post-stroke rehabilitation, particularly for improving limb motor function and, in selected populations, balance, mobility, and activities of daily living. Nonetheless, the evidence remains heterogeneous, and small sample sizes and variable protocols restrict generalizability. Larger, methodologically robust trials with standardized VR interventions, direct comparisons of immersive versus non-immersive systems, and long-term follow-up are needed to better define which patients benefit most from VR-based rehabilitation.

KEYWORDS

Stroke, Virtual Reality, Rehabilitation, Cerebrovascular Incident, Immersive Virtual Reality, Treatment, Therapy, Augmented Reality

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Introduction

Stroke continues to be one of the most prevalent conditions worldwide, with approximately 11.9 million stroke incidence occurrences and 93.8 million individuals affected in 2021[1]. The term stroke is generally understood to mean an interruption of blood supply to the brain. It may occur because of arterial occlusion by a thrombotic or embolic event, or due to the rupture of a cerebral blood vessel, ultimately resulting in neurological disorder. According to World Stroke Organization: Global Stroke Fact Sheet 2025, stroke ranks as the third-leading reason for disability globally[2].

Common types of post-stroke disability (PSD) include motor dysfunction and spasticity, cognitive impairment, dysphagia, depression, epilepsy, aphasia, pain, and fatigue[3]. Stroke-affected patients recurrently experience persistent deficits in muscle strength, coordination and postural stability, manifesting clinically as gait and balance abnormalities which substantially limit functional independence and adversely affect quality of life[4]. Initiating rehabilitation early and delivering it at sufficient intensity during subacute phase (approximately 7 days to 6 months following stroke onset) is regarded as essential for optimizing functional outcomes and facilitating activity-dependent neuroplasticity[5].

Conventional rehabilitation approaches are predominantly based on therapist-supervised interventions conducted in hospital. However, as identified in a recent scoping review, resource-related barriers, such as high costs, insufficient infrastructure, lack of skilled professionals, and inadequate policies significantly limit access and utilization of post-stroke rehabilitation services in low- and middle-income countries[6]. Furthermore, repetitiveness and monotony of the exercises influence patients motivation and commitment to therapy[7].

To address the limitations mentioned above virtual reality (VR) technologies offer an alternative solution. In a broad sense, virtual reality allude directly to created by computer, interactive, three-dimensional environment that user can interact with in real time. VR systems can be divided into two main groups: immersive and non-immersive. Non-immersive VR usually consists of standard computer screen, and external input devices such as keyboards, joysticks and motion sensors. On the other hand, immersive VR is composed of head-mounted displays, motion capture, and spatial audio[8]. In this context, the aim of this study is to analyse current tendencies and capabilities of VR technology usage in rehabilitation of post-stroke patients.

Methodology

In our narrative review we aimed at summarizing recent evidence on the use of virtual reality in post-stroke rehabilitation. We explored two electronic databases: Google Scholar and PubMed. Search terms included the following keywords and their combinations: “augmented reality”, “cerebrovascular incident”, “immersive virtual reality”, “rehabilitation”, “stroke”, “treatment”, “therapy”, “virtual reality”. We selected studies published between 1 January 2025 and October 2025, and limited to English-written, peer-reviewed articles. This review intentionally focused on the most recent trials published in 2025 to capture emerging trends in VR-based stroke rehabilitation. Chosen studies included randomized control trials. Excluding criteria were: studies published in other than English languages, meta-analyses, studies without clear methodology, studies concerning only healthy subjects. The search was conducted by two people independently.

We are aware that our research may have limitations. First one is, that the analysis is based on limited number of selected studies, which increases the risk of selection bias. Another disadvantage regarding our methodology is fact that the reviewed studies varied in sample sizes, intervention protocols and outcome measures, which inevitably reduces comparability between them. These limitations should be considered when interpreting the findings presented in the Result and Discussion sections.

Results

A total of 391 patients were involved in all analysed studies. Since individual participant age data were not available, a pooled mean age (58.56 years) was calculated using weighted averages, where each study's mean age was weighted by its sample size. Summary of the included studies is presented in Table 1.

Table 1. Main characteristics of included studies.

Author	Patient	Tools	Inclusion Criteria	Training	Intervention	Assessment	Outcome
Kim S, Lee Y, Kim K 2025 [11]	N = 15 (EG = 8, CG = 7)	Oculus Rift, smart insoles, treadmill	1. >6 months post-stroke 2.FAC ≤ 3 3.MMSE ≥ 21 4.No FES allergy. 5.No ankle joint contracture	30 min/day, 5 days/week (treadmill only)	30 min/day, 5 days/week (15 sessions)	Pre/post; FMA, BBS, TUG, OptoGait gait analysis	VR-augmented treadmill training improved motor function, balance, and gait more than treadmill alone.
Wahid E, Ahmad S, Khalil S, et al 2025 [12]	N = 74 (EG = 37, CG = 37)	Smartphone-compatible VR headset	1. ≥3 months post-stroke 2.mild to moderate motor impairments 3.medically stable 4.able to follow commands	30–45 min, 3×/week, 8 weeks	30–45 min, 3×/week, 8 weeks	Pre/post; FMA-UE, BBS, Barthel Index	Home-based VR telerehabilitation produced better functional recovery than clinic-based therapy
Shin S, Han G, Kim Y, et al. 2025 [9]	N = 44 (EG = 30, CG = 14)	Oculus Rift, HTC Vive tracker, LeapMotion	1. ≤18 years 2.<1 month post-stroke 3.MMSE≥10 4.LOS < 40 days	1 h twice daily + 1 session Saturday	30 min/day, 5 days/week, 1 month	Pre/post via medical records; FMA, MMSE, MBI, MVPT, FIM	Immersive VR enhanced upper-limb recovery beyond conventional rehabilitation
Zahoor A., 2025 [13]	N = 32 (EG = 16 CG =16)	Oculus Quest + VR Rehab software	1.3-12 months post-stroke 2.ability to follow verbal commands 3.mild to moderate hemiparesis	60 min/day, 5 days/week, 4 weeks	45 min/day, 5 days/week, 4 weeks	Pre/post; FMA, BBS, MBI	VR-assisted physiotherapy showed greater gains in motor recovery and balance
Sheehy L. et al., 2025 [14]	N = 20 EG = 11, CG = 9)	Jintronix NVIRT, Kinect, iPad	1.ischemic or haemorrhagic stroke resulting in physical impairment 2.standing ≥ 2 min and exercise-capable 3.English comprehension 4.home space for NVIRT	30 min/day, 5 days/week, 6 weeks (iPad-based home exercises)	30 min/day, 5 days/week, 6 weeks (unsupervised home-based VR)	Pre/post by blinded assessor; BBS, TUG, FTSTS, CB&M, SIS, CIQ	Non-immersive VR telerehabilitation was feasible and improved lower-limb function, balance, and gait
Rizwan S. et al., 2025 [10]	N = 60 (EG = 30, CG = 30)	Game Face Mark IV	1.≥6 months post-stroke 2.lower limbs FMA 20-50 3.MMSE>24	45 min, 3×/week, 6 weeks	45 min, 3×/week, 6 weeks	Pre/post; FMA-LL, TUG, 6MWT	VR group demonstrated superior improvements in walking endurance
Ting H. et al., 2025 [15]	N = 36 (EG = 18, CG = 18)	Doctor Kinetic, Kinect, 48-inch monitor	1. ≤6 months post-stroke 2.able to sit independently 3.MMSE>24	PT 60 min + OT 30 min + TCM 30 min/day, 5 days/week	30 min/day, 5 days/week, 4 weeks (VR sitting-balance training)	Pre/post; TIS, COP, MBI	VR showed superior improvements in dynamic sitting balance vs. traditional training
Lee S, Yim J.2025 [16]	N = 30 EG = 15, CG = 15)	BioRescue system	1. <4 months post-stroke 2.MMSE≥21 3.K-TIS ≤ 20 4.able to sit independently	20 min, 3×/week, 3 weeks (VR training)	30 min (10 min trunk training + 20 min VR), 3×/week, 3 weeks	Pre/post; K-TIS, COP, PASS	Pre-VR trunk stabilization improved balance and sway more effectively than VR alone.
Patel J. et al. 2025 [5]	N = 80 (EG = 40, CG = 40)	NJIT RAVR, Track Glove, HoVRS	1.<30 days post-stroke 2.age 30-95 3.had severe to moderate arm weakness ((≥10/66 and ≤49/66 UEFMA) 4.intact cutaneous sensation	10 × 1-h sessions	20 × 1-h sessions (10 standard + 10 additional)	Pre, post, 1M, 4M, 6M; ARAT, BBT, UEFMA, EQ-5D	Recovery patterns were determined by initial hand use rather than VR timing or dose

Two studies focused on upper limb motor function[5,10], one on lower limb[5] and six on balance and gait[11-16]. All the 9 included studies were RCTs. All studies involved patients from a hospital, a rehabilitation clinic or a medical centre. Three trials included patients with post-acute stroke [5,9,16] two with chronic stroke [11,15] one between 3-12 months, one <4 months post-stroke, one <6 months post-stroke and in one it was not clearly specified.

Rehabilitation approaches varied widely across studies, differing in the length of individual sessions, weekly training frequency, and total intervention duration (Table 1.). Several studies incorporated head-mounted display. Kim S, Lee Y, Kim K.[11], used an Oculus Rift integrated with smart insoles and a treadmill to provide real-time gait feedback. Shin S, Han G, Kim Y, et al.[9] employed a fully immersive setup combining an Oculus Rift, HTC Vive trackers and LeapMotion for upper-limb motor training. Zahoor A.[13] implemented Oculus Quest with VR Rehab software, while Lee S, Yim J.[16] used the BioRescue platform for postural control rehabilitation. Patel J. et al.[5] applied NJIT RAVR with Track Glove and HoVRS, targeting upper-limb motor impairment in the subacute phase. Other studies adopted non-immersive or semi-immersive VR solutions. Wahid E, Ahmad S, Khalil S, et al.[12], used smartphone-compatible VR headset, Sheehy L., et al.[14] utilized the Jintronix NVIRT telerehabilitation platform consisting of a Kinect camera, tablet and TV screen. Rizwan S. et al.[10] used Game Face Mark IV system, a gamified lower-limb rehabilitation tool. Ting H. et al.[15] used Doctor Kinetic gaming system with a Kinect sensor and large monitor for sitting balance training.

In most trials VR therapy was provided as an adjunct to conventional rehabilitation. Intervention structure also varied considerably. Kim S, Lee Y, Kim K.[11], supplemented treadmill training with VR-based gait feedback. Shin S, Han G, Kim Y, et al.[9] integrated immersive VR with standard inpatient PT and OT. Zahoor A.[13] and Rizwan S.[10] provided VR training in parallel with conventional physiotherapy. In Ting H. et al.[15], VR was used to complement sitting-balance exercises and traditional therapy modalities. Lee S, Yim J.[16] implemented a combined protocol where trunk stabilization education preceded VR-based balance exercises.

To evaluate the motor function of the lower and upper limbs the Fugl-Meyer assessment was used. To assess the balance ability of the post-stroke patients the Berg Balance Scale and Timed Up and Go test was conducted. To evaluate the gait ability Kim S, Lee Y, Kim K.[11], used the OptoGait analyzer, which looked at the spatiotemporal characteristics of walking. To judge independence in activities of daily living Wahid E, Ahmad S, Khalil S, et al.[12], used the Barthel Index. In addition Shin S, Han G, Kim Y, et al.[9] used Functional Independence Measure and Mini-Mental Status Examination for assessing autonomy in daily functioning. In their research they also examined visual perceptual abilities with Motor-Free Visual Perception Test. Sheehy L. et al.[14], used Five Times Sit-To-Stand test as additional in assessing lower-extremity strength, Community Balance and Mobility Scale, Community Integration Questionnaire and Stroke Impact Scale to examine individual independence in activities of daily living. 6-Minute Walk Test was conducted by Rizwan S. et al.[10], to assess gait. Trunk Impairment Scale and Centre of Pressure was measured for assessing trunk control and balance results by Ting H. et al[15]. To evaluate balance and trunk control Lee S, Yim J.[16], used Postural Assessment Scale for Stroke. Patel J. et al.[5] applied Action Research Arm test and the Box and Block test in evaluation of manual dexterity and functional ability of upper-limb.

The Fugl-Meyer assessment was statistically significant, favoring the experimental group in Kim S, Lee Y, Kim K ($p < 0.05$)[11], Wahid E, Ahmad S, Khalil S, et al. (mean FMA-UE score rise from 40.8 at baseline to 51.9 post-intervention)[12], Shin S, Han G, Kim Y, et al.[VR: 15.50 (4.00; 30.00) vs. control: 2.00 (0.00; 11.00); $W = 109.5$, $p = 0.01$][9], Zahoor A.[(FMA) scores increased from a pre-test mean of 58.4 ± 7.1 to a post-test mean of 72.0 ± 6.3, reflecting a mean improvement of 13.6 points ($p<0.001$)][13], and Rizwan S. et al.(VR Group showed an increase of 12.4 points in FMA, while the TST Group showed an increase of 8.6 points)[10].

The Berg balance scale had significant differences observed, with a statistically significant difference in the experimental group compared to control group in in Kim S, Lee Y, Kim K.($p < 0.05$)[11], Wahid E, Ahmad S, Khalil S, et al.($p=0.01$)[12], Zahoor A.[increasing from 34.6 ± 4.9 to 43.3 ± 4.2 (mean gain of 8.7 points, $p < 0.001$][13]. However in the Sheehy L. et al. research VR training did not improve BBS scores, as the VR group showed no change (50.1 pre vs. 49.6 post), with no significant time, group, or interaction effects[14].

Barthel Index score improved in the VR's group by over 18 points by follow-up, compared to a 10-point gain in the control group ($p=0.00$) in Wahid E, Ahmad S, Khalil S, et al. research[12]. Also gains were greater in VR group (VR: 24.03 ± 14.04 vs. control: 21.86 ± 12.10; $t = 0.84$, $p = 0.62$) in Shin S, Han G, Kim Y, et al.[9], in Zahoor

A. [MBI scores were significantly better in Group A (82.3 ± 7.4) compared to Group B (75.2 ± 7.3), with a mean difference of 7.1 points (p = 0.002)][13], and in Ting H. et al.(VR d=2.15 vs. control d=1.20)[15].

The Timed Up and Go test demonstrated statistically significant difference, favoring the experimental group in Kim S, Lee Y, Kim K.($p < 0.05$)[11], and in Rizwan S, Rashid H, Umar M. (The VR Group decreased their TUG time by 9 seconds, while the TST Group decreased their time by 5.4 seconds.)[10]. On the contrary, there were no statistically significant improvements in Sheehy L, Taillon-Hobson A, Sveistrup H, et al. research[14].

Trunk Impairment Scale results in Ting H. et al., showed significant improvement with the VR group exhibiting numerically greater gains (d=1.72, 95% CI [1.12, 2.32]) than the control group (d=1.07, 95% CI [0.55, 1.59])[15]. Similarly in Lee S, Yim J. mean change was significantly greater in the experimental group (6.60 ± 3.56) than in the control group (3.86 ± 2.47), as indicated by a significant interaction effect (F = 5.958, $p = 0.021$)[16].

In the Centre of Pressure examination the VR-based balance training group showed significant reductions in the COP anterior-posterior displacement during static sitting (Z=-2.06, p=0.039) after four weeks of intervention, whereas there was no significant change in the control group (Z=-1.89, p=0.058) in Ting H. et al.[15].

Discussion

Across the nine included randomized controlled trials, VR-based interventions demonstrated promising but heterogeneous effects on motor, balance, gait, and functional outcomes. Overall, the findings suggest that VR can serve as a valuable adjunct to conventional rehabilitation, although its effectiveness appears to depend on the target domain, patient characteristics, and specific training protocol.

Improvements in motor recovery, particularly in upper and lower limb function measured by the Fugl–Meyer Assessment (FMA), were the most consistent findings. Several studies reported significantly greater improvements in the VR groups than in their respective control groups, including work by Kim et al.[11], Wahid et al.[12], Lee S, Yim J.[16], Zahoor et al.[13], and Rizwan et al[10]. These consistent gains may reflect key advantages of VR-based therapy, such as enriched sensory feedback, high training intensity, task-specific practice and the motivational value of interactivity. VR may facilitate activity-driven neuroplasticity by promoting repetitive, purposeful movements modelled after real-life tasks, mechanisms known to support motor relearning in post-stroke individuals.

Outcomes related to balance and gait were more variable. Some studies reported meaningful improvements in BBS scores following VR-based balance training, notably in Kim et al.[11], Wahid et al.[12], and Zahoor et al.[13], these results indicate that VR can have a positive effect on postural control when paired with conventional physiotherapy or stabilization exercises. In contrast, Sheehy et al.[14] found no significant benefit of non-immersive, home-based VR training on BBS outcomes, which might be due to the ceiling effects (participants already had high baseline BBS scores), small sample size, and limited training intensity compared with supervised clinical sessions. These findings indicate that VR may be most effective for individuals with moderate baseline deficits.

Similar variability was observed in Timed Up and Go (TUG) outcomes. Significant improvements were reported by Kim et al.[11] and Rizwan et al.[10], whereas Sheehy et al.[14] found no change in TUG performance, again highlighting the effect of baseline functional status and program intensity. Studies assessing gait endurance (e.g., Rizwan et al.[10]) further support the role of VR in enhancing mobility, particularly when VR tasks emphasize dynamic lower-limb engagement and real-time feedback.

In terms of activities of daily living, several trials showed improvements in Barthel Index or Modified Barthel Index scores, suggesting translation of motor and balance gains into functional independence. Positive effects were also seen in trunk control (TIS), postural stability (COP), and perceptual-motor skills (MVPT), indicating that VR may benefit multiple dimensions of post-stroke impairment beyond isolated limb function.

Despite encouraging results, the evidence base remains heterogeneous. Studies differed markedly in sample size, stroke chronicity, VR equipment, duration and intensity of training, and outcome measures. The included trials ranged from fully immersive systems (Oculus Rift, Oculus Quest) to non-immersive or semi-immersive platforms (Kinect, BioRescue, smartphone VR). These variations limit the ability to directly compare findings and draw firm conclusions about the superiority of one VR modality over another. In addition, sample sizes were generally small, increasing the risk of type II error and restricting generalizability.

Another limitation arises from inconsistent reporting on participant compliance, safety, and long-term adherence. Only one study included longer follow-up, making it difficult to determine the durability of VR-induced improvements. Additionally, heterogeneity of patient inclusion criteria ranging from acute to chronic stroke, wide age differences, and differing levels of baseline disability introduces additional complexity in interpreting outcomes.

Conclusions

Despite these limitations, the presented studies collectively suggest that VR can complement conventional rehabilitation by offering motivating, interactive, and adjustable therapeutic environments to allow repetitive motor training. VR may provide potential advantages in scalability and accessibility, especially for home-based or telerehabilitation models, as demonstrated in the work of Wahid et al.[12] and Sheehy et al.[14] For low-resource settings, affordable smartphone-based VR systems could potentially provide a feasible alternative to more sophisticated immersive technologies.

Future research should prioritize large, well-designed randomized controlled trials with standardized intervention protocols, clear reporting of training intensity, and long-term follow-up assessments. Additionally, studies comparing immersive versus non-immersive VR directly with stratification by baseline severity would help clarify which patient subgroups benefit most. Finally, integrating VR with complementary therapeutic approaches, such as trunk stabilization training or robot-assisted therapy, may further enhance rehabilitation outcomes.

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