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Original Article

Effect of Virtual Reality-Based Therapy Combined with Conventional Physiotherapy versus Conventional Physiotherapy Alone on Balance, Gait Speed, Postural Stability, and Functional Mobility in Patients with Stroke: A Randomized Controlled Trial

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ABSTRACT

Background: Stroke commonly causes persistent impairments in balance, postural control, walking, and functional mobility. Virtual reality (VR)-based rehabilitation may supplement conventional physiotherapy through repetitive, task-oriented practice and augmented feedback. Objective: To compare VR-based therapy combined with conventional physiotherapy with conventional physiotherapy alone for improving balance, postural stability, gait speed, and functional mobility in patients with stroke. Methods: This prospective parallel-group randomized controlled trial included 40 patients aged 40–70 years with first-ever stroke, randomly allocated to experimental (n=20) and control (n=20) groups. The experimental group received 15 minutes of VR-based therapy plus 15 minutes of conventional physiotherapy, whereas the control group received 30 minutes of conventional physiotherapy, three sessions weekly for six weeks. Outcomes were measured using the Berg Balance Scale (BBS), Postural Assessment Scale for Stroke Patients (PASS), 10-Meter Walk Test (10MWT), and Timed Up and Go (TUG) test. Results: Both groups improved significantly across all outcomes ($p<0.001$). Post-intervention differences favoured the experimental group for BBS (6.25 points; 95% CI 3.57–8.93), PASS (4.55 points; 95% CI 2.65–6.45), 10MWT (0.17 m/s; 95% CI 0.09–0.25), and TUG (−2.96 s; 95% CI −4.28 to −1.64), all $p<0.001$. Conclusion: Incorporating VR-based therapy into time-matched conventional physiotherapy produced greater short-term improvements in balance, postural stability, gait speed, and functional mobility than conventional physiotherapy alone. Keywords: Stroke; Virtual reality-based therapy; Conventional physiotherapy; Balance; Gait speed; Postural stability; Functional mobility; Randomized controlled trial.

INTRODUCTION

Stroke remains a major cause of mortality, disability, and long-term functional dependence worldwide. Survivors frequently require prolonged rehabilitation because residual motor, sensory, balance, and mobility impairments can substantially restrict activities of daily living and community participation. The global cardiovascular and stroke burden remains closely linked to ageing populations and

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modifiable vascular risk factors, emphasizing the continuing importance of both stroke prevention and effective rehabilitation after an established event (1,2).

Motor impairment after stroke may include hemiparesis, reduced lower-limb strength, altered muscle tone, impaired selective motor control, sensory dysfunction, poor coordination, reduced ankle mobility, postural instability, and gait asymmetry. Conventional physiotherapy consequently incorporates stretching, joint mobility exercises, strengthening, weight-shifting, balance practice, sit-to-stand training, gait re-education, and repetitive functional activities. Previous stroke rehabilitation studies have demonstrated that targeted ankle interventions, supported locomotor training, and lower-limb motor training can influence gait-related function and mobility (3–5). Functional mobility is commonly assessed using clinically practical measures such as the Timed Up and Go test, which integrates standing, walking, turning, and sitting performance (6).

Virtual reality has emerged as a technology-assisted rehabilitation approach that allows patients to interact with computer-generated or augmented environments while performing goal-directed motor tasks. Evidence across stroke rehabilitation suggests potential benefits for motor recovery, although effect estimates vary according to the body region trained, stroke phase, VR modality, comparator, and treatment dose. Systematic reviews have reported favourable effects of VR-assisted rehabilitation on post-stroke motor function, including evidence from chronic and subacute populations, while emphasizing heterogeneity in protocols and study quality (7,8). Reviews focusing on early-stage stroke and broader neurorehabilitation have similarly found VR feasible and potentially useful, although superiority over well-matched conventional rehabilitation is not consistently demonstrated across all outcomes (9,10). A recent Cochrane review likewise indicates that VR may improve selected outcomes such as balance and activity limitation while evidence for gait speed remains less certain (11).

The clinical relevance of VR may be particularly important when it is incorporated into rather than substituted for conventional rehabilitation. VR-based telerehabilitation has been evaluated among stroke patients in Pakistan, supporting the feasibility of incorporating technology into rehabilitation delivery within local clinical contexts (12). Randomized and controlled studies of VR-based treadmill and gait-adaptation training have also demonstrated improvements in selected balance, walking, and functional-mobility outcomes after stroke (13,14). Augmented-reality treadmill training and walking-adaptability programmes further illustrate how environmental challenges, obstacle negotiation, variable stepping demands, and repetitive locomotor adaptation may be incorporated into post-stroke gait rehabilitation (15,16).

Several features of technology-assisted rehabilitation could plausibly contribute to motor improvement. Visual biofeedback during weight-shifting and balance practice provides immediate information about performance and may facilitate active correction of movement errors (17,18). Post-stroke locomotor rehabilitation studies using feedback-based, self-paced, auditory-cued, and higher-speed training paradigms further support the importance of intensive, repeated and performance-oriented gait practice for addressing asymmetry and locomotor limitations (19–21). These mechanisms are compatible with contemporary motor-learning principles in which task specificity, repetition, meaningful sensory feedback, progressive difficulty, and active participation influence acquisition and refinement of motor skills.

Technology-assisted gait training has also been investigated outside stroke populations. VR-based gait training has been evaluated for balance and gait among older adults, while C-Gait and C-Mill systems have been investigated for gait adaptability and freezing-related mobility impairments in Parkinson's disease (22–24). These studies do not constitute direct evidence of effectiveness in stroke; however, they demonstrate the broader application of interactive, feedback-based and adaptability-oriented gait technologies across populations with mobility limitations and provide contextual support for continued evaluation of similar rehabilitation principles after stroke.

Despite growing interest in VR-assisted stroke rehabilitation, uncertainty remains regarding whether incorporating a relatively brief VR component into a time-matched conventional physiotherapy session can produce additional improvements simultaneously across balance, postural control, gait speed, and functional mobility. Previous studies have employed heterogeneous VR systems, treatment schedules, rehabilitation stages, and outcomes, making direct clinical translation difficult (8–16). The present randomized controlled trial therefore aimed to compare VR-based therapy combined with conventional physiotherapy with conventional physiotherapy alone for improving balance, postural stability, gait speed, and functional mobility in patients with stroke. It was hypothesized that the combined intervention would produce greater post-intervention improvements than conventional physiotherapy alone.

MATERIALS AND METHODS

This prospective parallel-group randomized controlled trial evaluated VR-based therapy combined with conventional physiotherapy compared with conventional physiotherapy alone in patients with stroke. A total of 40 participants were recruited using convenience sampling and subsequently allocated in a 1:1 ratio to an experimental group (n=20) or control group (n=20). Random allocation was performed using a computer-generated randomization list, with allocation concealment implemented using opaque sealed envelopes.

Eligible participants were adults aged 40–70 years who had experienced a first-ever ischemic or hemorrhagic stroke 1–6 months previously. Participants were required to have mild-to-moderate motor impairment, be able to ambulate independently or with minimal assistance, and have a Mini-Mental State Examination score of at least 24. Participants were excluded if they had recurrent stroke, severe cognitive impairment, uncontrolled cardiovascular disease, severe visual or vestibular dysfunction, other neurological or musculoskeletal conditions likely to interfere with mobility training, or a contraindication to physical activity.

Both groups received three treatment sessions per week for six consecutive weeks, providing 18 scheduled sessions. Each session lasted 30 minutes. Participants in the experimental group received 15 minutes of VR-based therapy followed by 15 minutes of conventional physiotherapy. VR training incorporated interactive balance activities, weight shifting, stepping, reaching, obstacle negotiation, and gait-related tasks. These components were consistent with commonly investigated technology-assisted approaches emphasizing visual feedback, gait adaptability, repeated stepping, and functional locomotor challenges after stroke (13–20).

The conventional physiotherapy component consisted of lower-limb stretching, strengthening exercises, sit-to-stand practice, static and dynamic balance activities, overground gait training, stair climbing, and functional mobility training. These treatment components are consistent with established lower-limb and gait-rehabilitation approaches applied in stroke populations (3–5,21). Participants in the control group received 30 minutes of conventional physiotherapy using the same categories of conventional exercises but without VR-based training. Total scheduled treatment duration and weekly frequency were therefore equivalent between groups.

Outcome assessments were performed at baseline and after completion of the six-week intervention by an assessor blinded to group allocation. Balance was evaluated using the Berg Balance Scale (BBS), postural stability using the Postural Assessment Scale for Stroke Patients (PASS), gait speed using the 10-Meter Walk Test (10MWT), and functional mobility using the Timed Up and Go (TUG) test. The TUG assesses a composite mobility task involving rising from a chair, walking, turning, returning, and sitting and is widely used for functional-mobility assessment (6). Higher BBS and PASS scores and greater 10MWT gait speed represented better performance, whereas shorter TUG completion time represented better functional mobility.

Baseline demographic and clinical variables included age, sex, time since stroke, and stroke type. The principal clinical outcomes were BBS score, PASS score, 10MWT gait speed in metres per second, and TUG completion time in seconds, evaluated before and after the six-week intervention.

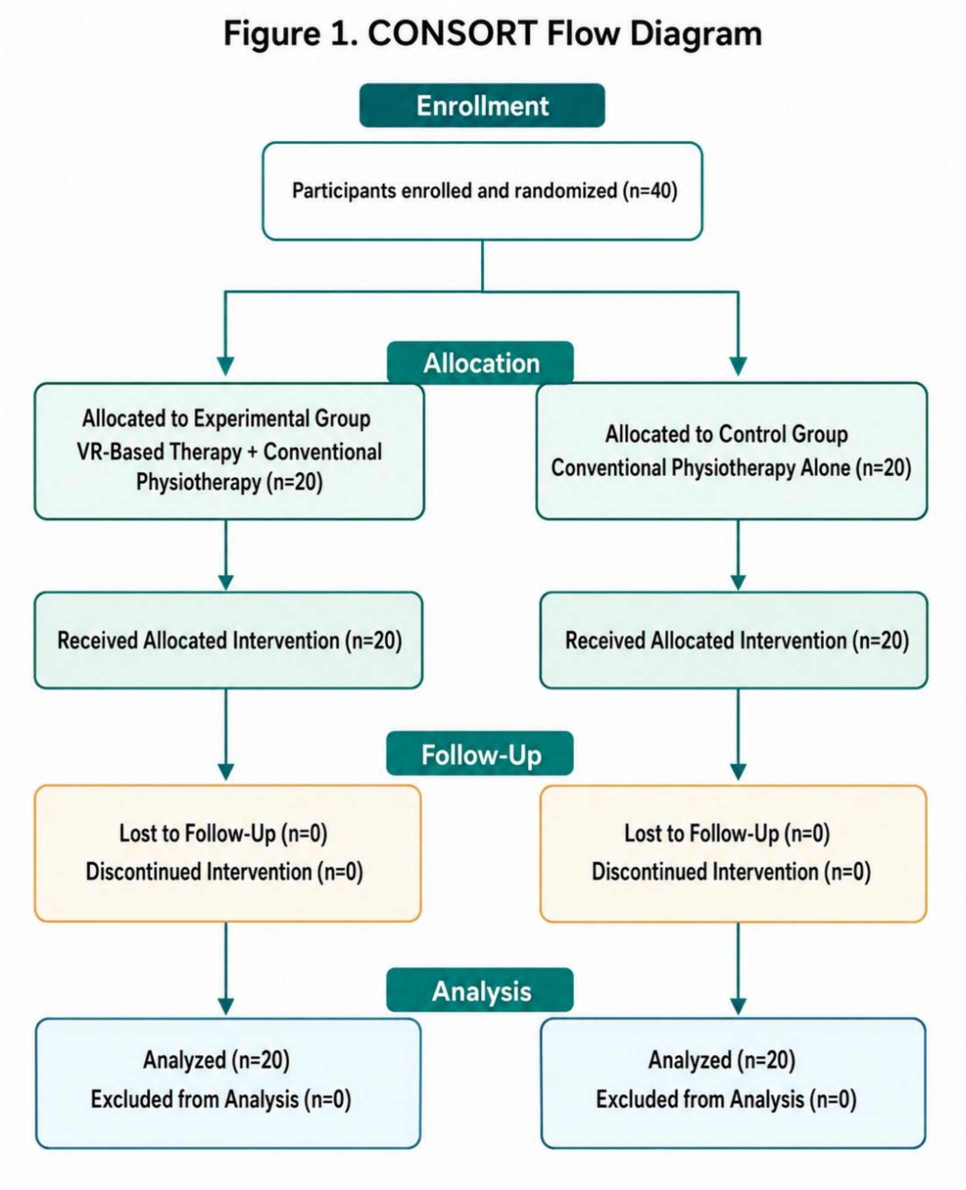

Figure 1 CONSORT Flowchart

Data were analysed using IBM SPSS Statistics version 26.0. Continuous variables were summarized as mean ± standard deviation (SD), whereas categorical variables were summarized as frequency and percentage. Baseline continuous variables were compared using independent-samples t-tests, and categorical variables were compared using chi-square tests. Within-group pre-post comparisons were performed using paired-samples t-tests, while post-intervention between-group comparisons were performed using independent-samples t-tests. Statistical significance was defined as a two-sided $p<0.05$.

For enhanced presentation of the reported outcomes, descriptive mean change was calculated as the post-intervention mean minus the baseline mean. Post-intervention experimental-minus-control mean differences and 95% confidence intervals (CIs) were derived from the reported group data, and standardized between-group effects were expressed using Hedges' g with small-sample correction. Positive estimates favoured the experimental group for BBS, PASS, and 10MWT, while negative estimates favoured the experimental group for TUG because shorter completion time indicates better functional mobility.

RESULTS

All 40 randomized participants completed the six-week intervention and were included in the statistical analysis, with 20 participants in the experimental group and 20 in the control group. There were no withdrawals during the intervention. Baseline demographic and clinical characteristics were comparable between groups. Mean age was 58.20 ± 8.14 years in the experimental group and 57.75 ± 7.86 years in the control group (p=0.86). Men represented 60.0% and 55.0% of the respective groups. Mean time since stroke was 3.48 ± 1.24 months in the experimental group and 3.61 ± 1.31 months in the control group (p=0.74). Ischemic stroke accounted for 75.0% of participants in the experimental group and 70.0% in the control group.

Table 1. Baseline Demographic and Clinical Characteristics

Characteristic	Experimental Group (n=20)	Control Group (n=20)	p-value
Age, years, mean ± SD	58.20 ± 8.14	57.75 ± 7.86	0.86
Sex, n (%)			0.75
Male	12 (60.0)	11 (55.0)	
Female	8 (40.0)	9 (45.0)	
Time since stroke, months, mean ± SD	3.48 ± 1.24	3.61 ± 1.31	0.74
Stroke type, n (%)			0.72
Ischemic	15 (75.0)	14 (70.0)	
Hemorrhagic	5 (25.0)	6 (30.0)	

Data are presented as mean ± SD or n (%). Independent-samples t-tests were used for continuous variables and chi-square tests for categorical variables. SD, standard deviation.

Baseline clinical outcome scores were also similar between groups. Mean BBS scores were 34.20 ± 5.12 and 34.55 ± 5.08 in the experimental and control groups, respectively (p=0.82). Corresponding baseline values were 22.80 ± 3.18 versus 22.95 ± 3.42 for PASS (p=0.89), 0.56 ± 0.12 versus 0.57 ± 0.11 m/s for 10MWT (p=0.84), and 19.52 ± 2.46 versus 19.34 ± 2.28 seconds for TUG (p=0.81).

Table 2. Baseline Comparability of Clinical Outcomes

Outcome	Experimental Group, Mean ± SD	Control Group, Mean ± SD	p-value
BBS, points	34.20 ± 5.12	34.55 ± 5.08	0.82
PASS, points	22.80 ± 3.18	22.95 ± 3.42	0.89
10MWT, m/s	0.56 ± 0.12	0.57 ± 0.11	0.84
TUG, s	19.52 ± 2.46	19.34 ± 2.28	0.81

BBS, Berg Balance Scale; PASS, Postural Assessment Scale for Stroke Patients; 10MWT, 10-Meter Walk Test; TUG, Timed Up and Go; SD, standard deviation.

Both groups demonstrated statistically significant within-group improvement across all four clinical outcomes after six weeks (p<0.001 for all comparisons). In the experimental group, BBS increased from 34.20 ± 5.12 to 47.90 ± 3.84, corresponding to a descriptive improvement of 13.70 points, whereas the control group increased from 34.55 ± 5.08 to 41.65 ± 4.36, representing a 7.10-point improvement. PASS increased by 9.80 points in the experimental group compared with 5.10 points in the control group. Mean gait speed increased by 0.35 m/s and 0.17 m/s, respectively, while TUG completion time decreased by 6.40 seconds in the experimental group and 3.26 seconds in the control group.

Table 3. Baseline, Post-Intervention, and Descriptive Within-Group Changes

Outcome	Group	Baseline, Mean ± SD	Post-Intervention, Mean ± SD	Mean Change	Within-Group p-value
BBS, points	Experimental	34.20 ± 5.12	47.90 ± 3.84	+13.70	<0.001
	Control	34.55 ± 5.08	41.65 ± 4.36	+7.10	<0.001
PASS, points	Experimental	22.80 ± 3.18	32.60 ± 2.81	+9.80	<0.001
	Control	22.95 ± 3.42	28.05 ± 3.26	+5.10	<0.001
10MWT, m/s	Experimental	0.56 ± 0.12	0.91 ± 0.13	+0.35	<0.001
	Control	0.57 ± 0.11	0.74 ± 0.12	+0.17	<0.001
TUG, s	Experimental	19.52 ± 2.46	13.12 ± 1.91	−6.40	<0.001
	Control	19.34 ± 2.28	16.08 ± 2.14	−3.26	<0.001

Mean change was calculated as post-intervention minus baseline. Positive values indicate improvement for BBS, PASS, and 10MWT; negative values indicate improvement for TUG. SD, standard deviation.

Post-intervention between-group comparisons favoured the experimental group for every outcome. BBS was 6.25 points higher in the experimental group (95% CI 3.57–8.93; t=4.72; p<0.001), corresponding to Hedges' g=1.46. PASS was 4.55 points higher (95% CI 2.65–6.45; t=4.84; p<0.001; Hedges' g=1.50). Gait speed was 0.17 m/s higher (95% CI 0.09–0.25; t=4.19; p<0.001; Hedges' g=1.30), whereas TUG completion time was 2.96 seconds lower (95% CI −4.28 to −1.64; t=−4.55; p<0.001; Hedges' g=−1.41).

Table 4. Post-Intervention Between-Group Effects

Outcome	Experimental, Mean ± SD	Control, Mean ± SD	Mean Difference	95% CI	t-value	p-value	Hedges' g
BBS, points	47.90 ± 3.84	41.65 ± 4.36	6.25	3.57–8.93	4.72	<0.001	1.46
PASS, points	32.60 ± 2.81	28.05 ± 3.26	4.55	2.65–6.45	4.84	<0.001	1.50
10MWT, m/s	0.91 ± 0.13	0.74 ± 0.12	0.17	0.09–0.25	4.19	<0.001	1.30
TUG, s	13.12 ± 1.91	16.08 ± 2.14	−2.96	−4.28 to −1.64	−4.55	<0.001	−1.41

Mean difference represents experimental minus control. Positive estimates favour the experimental group for BBS, PASS, and 10MWT; negative estimates favour the experimental group for TUG. CI, confidence interval; SD, standard deviation.

Overall, both rehabilitation strategies were associated with improvement during the six-week period, but descriptive pre-post changes and post-intervention comparisons consistently favoured VR-based therapy combined with conventional physiotherapy.

DISCUSSION

The present randomized controlled trial demonstrated improvement in balance, postural stability, gait speed, and functional mobility following both treatment approaches, with consistently greater post-intervention performance in participants receiving VR-based therapy combined with conventional physiotherapy. The findings therefore indicate that replacing half of a time-matched conventional physiotherapy session with interactive VR-based training may provide additional short-term benefit across several clinically relevant domains of post-stroke mobility.

The improvement in BBS observed in the experimental group is consistent with the broader evidence base supporting VR-assisted rehabilitation. Systematic reviews of VR interventions have identified potential improvements in post-stroke motor function and balance, although effect magnitude varies according to stroke chronicity, intervention characteristics, comparator treatment, and methodological quality (7–11). The present findings are particularly compatible with evidence that VR may provide additional benefit when incorporated alongside conventional rehabilitation rather than considered as an isolated replacement for established therapy (8,11).

Balance improvement may plausibly be related to the repetitive, task-specific and feedback-rich nature of the intervention. Interactive weight shifting, stepping, reaching, obstacle negotiation, and gait activities require continuous modification of the centre of mass relative to the base of support. Similar principles have been applied through visual biofeedback balance training, postural weight-shift training, and other feedback-based rehabilitation strategies after stroke (17,18). Enhanced sensory information may help participants recognize movement errors and modify subsequent performance, although the present study did not directly measure motor learning or neural plasticity.

PASS scores also improved more in the experimental group, indicating better post-intervention postural control. Efficient postural control contributes to standing, reaching, transfers, gait initiation, turning, and other functional activities. Technology-supported balance and gait interventions have been used to create repeated and progressively challenging postural demands in stroke rehabilitation, including VR treadmill training, gait-adaptation training, and augmented-reality approaches (13–16). The direction of the present PASS findings is therefore consistent with the broader rationale for incorporating interactive postural challenges into rehabilitation.

Gait speed increased by 0.35 m/s in the experimental group compared with 0.17 m/s in the control group, with a post-intervention between-group difference of 0.17 m/s. This pattern is compatible with studies demonstrating that VR-assisted or adaptability-oriented gait training can improve selected walking outcomes after stroke (13–16). Feedback-based locomotor strategies, including self-paced walking, visual feedback, rhythmic auditory cueing, and higher-speed locomotor training, have also been investigated as methods for addressing gait asymmetry, walking speed, and locomotor performance after stroke (19–21).

The gait-speed finding should nevertheless be interpreted cautiously. Systematic reviews have not shown uniform superiority of VR over conventional therapy for walking outcomes. Some analyses report favourable effects, particularly in selected subacute or combined-treatment settings, whereas others indicate comparable performance between VR and conventional rehabilitation or considerable uncertainty for gait speed specifically (8–11). Differences among studies in VR technology, stroke phase, session duration, locomotor content, comparator intensity, baseline walking ability, and sample size may contribute to these inconsistent effects.

Functional mobility assessed using TUG improved in both groups, with a greater reduction in completion time in the combined-treatment group. TUG performance integrates several abilities affected by stroke, including transitional movement, standing balance, gait initiation, walking, turning, and controlled sitting. Its use as a practical functional-mobility measure is well established in rehabilitation and geriatric assessment (6). The simultaneous improvements in BBS, PASS, 10MWT, and TUG observed in the experimental group therefore suggest a coherent pattern of improvement across interacting mobility domains rather than an isolated change in one clinical measure.

The current findings are also broadly compatible with evidence from VR-based telerehabilitation in Pakistani stroke populations and randomized VR-based treadmill programmes, indicating that technology-assisted rehabilitation can be implemented through different delivery models and clinical environments (12,13). However, the technologies and protocols used across these studies differ substantially; therefore, their findings should not be treated as evidence that all VR systems are interchangeable or that identical treatment effects can be expected across settings.

The possible contribution of augmented sensory feedback is supported by research using visual biofeedback during balance and gait rehabilitation (17–20). Repeated feedback may allow patients to identify weight-distribution errors, modify stepping behaviour, and practice task-specific movement strategies. In the present intervention, immediate interaction with VR tasks could have increased opportunities for performance correction and repeated movement practice. These explanations remain mechanistic interpretations because feedback processing, cortical activity, number of repetitions, and neuroplasticity were not directly measured.

The broader rehabilitation literature also demonstrates that interactive and adaptability-oriented technologies are not restricted to stroke. VR gait training has been investigated for balance and gait in older adults, while C-Gait and C-Mill systems have been evaluated in Parkinson's disease for mobility and walking adaptability (22–24). These studies support the general feasibility of integrating visually enriched environments and adaptive locomotor tasks into rehabilitation, but their disease-specific findings cannot be directly extrapolated to stroke. Their relevance to the present study lies primarily in the shared rehabilitation principles of task adaptation, feedback, repetition, and progressively challenging walking environments.

Improvement in the control group reinforces the continuing importance of conventional physiotherapy. Lower-limb stretching, strengthening, ankle and joint mobility interventions, balance exercises, overground walking, weight shifting, sit-to-stand training, and task-oriented gait rehabilitation have established roles in post-stroke motor recovery (3–5). Consequently, the current findings do not support replacing conventional physiotherapy. Instead, they suggest that VR may function as an adjunctive strategy capable of adding interactive task practice within the same overall treatment duration.

A clinically important feature of this trial was that both groups received the same 30-minute session duration, three times weekly for six weeks. The experimental group did not receive additional total session time; rather, 15 minutes of conventional treatment were replaced with VR-based tasks. This design reduces the likelihood that the between-group difference was solely attributable to greater scheduled treatment time and supports interpretation of the findings in relation to the content of rehabilitation.

The study also had several methodological strengths. Participants were randomly allocated to equal-sized groups using a computer-generated sequence with allocation concealment through opaque sealed envelopes. Outcome assessment was performed by a blinded assessor, and no participants withdrew during the six-week intervention. Baseline demographic and clinical measures were comparable between groups. Four complementary clinical outcomes were used to evaluate balance, postural stability, gait speed, and functional mobility, providing a broader assessment than reliance on a single functional endpoint.

Several limitations should be considered. The sample size was small, with only 20 participants per group, which limits precision and generalizability. Participants were recruited using convenience sampling from a single rehabilitation facility before random allocation, which may restrict external validity. The intervention period was limited to six weeks, and no long-term follow-up assessment was performed; therefore, persistence of the observed treatment effects cannot be determined. Additional clinically relevant outcomes such as instrumented gait characteristics, walking endurance, lower-limb muscle strength, quality of life, adherence, satisfaction, and participation were not evaluated.

The analytical strategy represents an additional limitation. The study used paired t-tests for within-group comparisons and independent t-tests for post-intervention between-group comparisons. Although these analyses demonstrated significant improvement in both groups and significant post-intervention differences, a prespecified group-by-time interaction analysis or baseline-adjusted ANCOVA would have provided a more direct estimate of the differential longitudinal treatment effect. The available aggregate data do not permit retrospective reconstruction of the within-participant covariance required for valid inferential comparison of change scores.

Overall, the results support the potential clinical value of integrating VR-based therapy with conventional physiotherapy for appropriately selected patients after stroke. This interpretation is consistent with several systematic reviews and clinical studies supporting VR-assisted motor, balance, gait, and mobility rehabilitation, while also recognizing substantial heterogeneity and uncertainty across protocols and outcomes (7–16). Larger multicentre randomized trials with standardized VR interventions, prespecified primary outcomes, objective treatment-dose measures, longer-term follow-up, and longitudinally adjusted analyses are needed to determine the durability and generalizability of these effects.

CONCLUSION

Both VR-based therapy combined with conventional physiotherapy and conventional physiotherapy alone were associated with significant six-week improvements in balance, postural stability, gait speed, and functional mobility in patients with stroke; however, participants receiving the combined intervention demonstrated greater post-intervention improvement across all four outcomes. Within the limitations of this small single-centre randomized trial, VR-based therapy appears to be a potentially useful adjunct to conventional physiotherapy for improving short-term mobility-related outcomes after stroke.

REFERENCES

1. Virani SS, Alonso A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, et al. Heart disease and stroke statistics-2021 update: a report from the American Heart Association. Circulation. 2021;143(8):e254-e743.
2. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation. 2019;140(11):e596-e646.
3. Cho KH, Park SJ. Effects of joint mobilization and stretching on the range of motion for ankle joint and spatiotemporal gait variables in stroke patients. J Stroke Cerebrovasc Dis. 2020;29(8):104933.
4. Chua K, Lim WS, Lim PH, Lim CJ, Hoo CM, Chua KC, et al. An exploratory clinical study on an automated, speed-sensing treadmill prototype with partial body weight support for hemiparetic gait rehabilitation in subacute and chronic stroke patients. Front Neurol. 2020;11:747.
5. Ferry B, Compagnat M, Yonneau J, Bensoussan L, Moucheboeuf G, Muller F, et al. Awakening the control of the ankle dorsiflexors in the post-stroke hemiplegic subject to improve walking activity and social participation: the WAKE (Walking Ankle isoKinetic Exercise) randomised, controlled trial. Trials. 2022;23(1):661.
6. Choo PL, Tou NX, Jun Pang BW, Lau LK, Jabbar KA, Seah WT, et al. Timed Up and Go (TUG) reference values and predictive cutoffs for fall risk and disability in Singaporean community-dwelling adults: Yishun Cross-Sectional Study and Singapore Longitudinal Aging Study. J Am Med Dir Assoc. 2021;22(8):1640-5.
7. Al-Whaibi R, Jadid S, Elserougy H, Badawy W. Effectiveness of virtual reality-based rehabilitation versus conventional therapy on upper limb motor function of chronic stroke patients: a systematic review and meta-analysis of randomized controlled trials. Physiother Theory Pract. 2021;38:1-15.
8. Peng QC, Yin L, Cao Y. Effectiveness of virtual reality in the rehabilitation of motor function of patients with subacute stroke: a meta-analysis. Front Neurol. 2021;12:639535.
9. Hao J, Yao Z, Harp K, Gwon DY, Chen Z, Siu KC. Effects of virtual reality in the early-stage stroke rehabilitation: a systematic review and meta-analysis of randomized controlled trials. Physiother Theory Pract. 2023;39(12):2569-88.
10. Khan A, Podlasek A, Somaa F. Virtual reality in post-stroke neurorehabilitation: a systematic review and meta-analysis. Top Stroke Rehabil. 2023;30(1):53-72.
11. Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Chapman M, et al. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev. 2025;6(6):CD008349.
12. Wahid E, Ahmad S, Khalil S, Khan MS, Bibi N, Humayoon N. Effectiveness of virtual reality-based telerehabilitation for stroke patients in Pakistan: a randomized controlled trial. Healer J Physiother Rehabil Sci. 2025;5(4):38-46.
13. Han SH, Jang HJ, Lee JW, Cheong JW, Kim YD, Nam HS, et al. The effect of virtual reality-based treadmill gait training on functional mobility and balance in chronic stroke patients: a randomized controlled trial. Front Neurol. 2025;16:1603233.

14. Wang X, Qiu J, Zhou Y, Liu W, Zhang S, Gong Y, et al. Effects of virtual reality-assisted and overground gait adaptation training on balance and walking ability in stroke patients: a randomized controlled trial. Am J Phys Med Rehabil. 2024;103(6):480-7.

15. Yang H, Gao Z, Zhou Y, Liao Z, Song C, Mao Y. Effects of gait adaptation training on augmented reality treadmill for patients with stroke in community ambulation. Int J Qual Health Care. 2024;36(1).

16. Timmermans C, Roerdink M, Meskers CGM, Beek PJ, Janssen TWJ. Walking-adaptability therapy after stroke: results of a randomized controlled trial. Trials. 2021;22(1):923.

17. Jo YJ, Kim DH, Kim S, Kim JH, Choi JH, Park JB, et al. Effect of anterioposterior weight-shift training with visual biofeedback in patients with step length asymmetry after subacute stroke. J Pers Med. 2023;13(12).

18. Zhang M, You H, Zhang H, Zhao W, Han T, Liu J, et al. Effects of visual feedback balance training with the Pro-kin system on walking and self-care abilities in stroke patients. Medicine (Baltimore). 2020;99(39):e22425.

19. Oh K, Park J, Jo SH, Hong SJ, Kim WS, Paik NJ, et al. Improved cortical activity and reduced gait asymmetry during poststroke self-paced walking rehabilitation. J Neuroeng Rehabil. 2021;18(1):60.

20. Shin J, Chung Y. The effects of treadmill training with visual feedback and rhythmic auditory cue on gait and balance in chronic stroke patients: a randomized controlled trial. NeuroRehabilitation. 2022;51(3):443-53.

21. Pressler D, Schwab-Farrell SM, Reisman DS, Billinger SA, Boyne P. Effects of maximal speed locomotor training on spatiotemporal gait changes in individuals with chronic stroke: a secondary analysis of a randomized controlled trial. Gait Posture. 2025;122:232-9.

22. Lee K. Virtual reality gait training to promote balance and gait among older people: a randomized clinical trial. Geriatrics (Basel). 2020;6(1).

23. Chen ZY, Yan HJ, Qi L, Zhen QX, Liu C, Wang P, et al. C-Gait for detecting freezing of gait in the early to middle stages of Parkinson's disease: a model prediction study. Front Hum Neurosci. 2021;15:621977.

24. Wang Y, Gao L, Yan H, Jin Z, Fang J, Qi L, et al. Efficacy of C-Mill gait training for improving walking adaptability in early and middle stages of Parkinson's disease. Gait Posture. 2022;91:79-85.