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Virtual Reality-Enhanced Dual Task Training for Fall Risk Reduction in Stroke Patients: A Literature Review

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Abstract

Introduction: Stroke often results in motor and cognitive impairments, increasing the risk of falls, which can lead to long-term disability and greater healthcare costs. Dual Task Training (DTT) combined with Virtual Reality (VR) is a promising method to improve both motor and cognitive function, thereby potentially reducing fall risk in stroke patients. This literature review evaluates the effectiveness of VR-based DTT in fall prevention among stroke survivors.
Method: A structured literature search was conducted across major databases—Scopus, PubMed, Crossref, Google Scholar, Web of Science, Medline, ScienceDirect, ProQuest, SpringerLink, and Cochrane—for studies published from 2019 to 2024. Keywords included “Dual Task Training,” “Virtual Reality,” “fall risk,” and “stroke.” After screening, 22 studies that met the inclusion criteria were analyzed. Data extraction focused on study characteristics, intervention protocols, and outcomes related to balance, gait, and cognitive function.
Results: The review indicates that VR-based DTT significantly improves balance and cognitive performance, contributing to a reduced fall risk in stroke patients. Compared to conventional therapy, VR interventions showed better patient engagement and adherence, which may enhance rehabilitation outcomes. However, challenges remain, including variation in individual responses, limited access to technology, and a lack of standardized intervention protocols.
Conclusion: VR-based Dual Task Training offers a promising integrative approach to stroke rehabilitation by targeting both motor and cognitive deficits to reduce fall risk. Further studies are needed to refine intervention protocols and explore long-term effects to inform clinical guidelines.

Keywords: Dual Task Training; Virtual Reality; stroke; fall risk

Introduction

Stroke remains the leading cause of long-term disability worldwide. An estimated 50% of stroke survivors experience varying degrees of disability, from mild impairments to severe limitations in daily activities.[1,2] Globally, stroke affects approximately 15 million individuals each year and accounts for around 5.5 million deaths. Its impact on individuals and healthcare systems is profound, as stroke is responsible for more than 116 million disability-adjusted life years (DALYs) lost globally.[2–4]

Post-stroke complications often include motor deficits, cognitive decline, and a significantly increased risk of falls. Research indicates that 31.3% of individuals experience a fall after stroke, compared to 19.8% prior to the event.[5] This heightened risk is attributed to impaired mobility, balance disorders, and cognitive deficits common in stroke patients.[6,7] These falls pose serious consequences, such as physical injuries, psychological distress, and a diminished quality of life.

To address these challenges, various rehabilitation strategies have been proposed, with Dual Task Training (DTT) emerging as a promising approach. DTT involves performing physical and cognitive tasks simultaneously, reflecting real-life situations where dual-task performance is essential, particularly in stroke survivors with motor and cognitive impairments.[8,9] The primary aim of DTT is to improve motor skills, such as balance and gait, and cognitive domains like attention and executive functioning.[10] By integrating motor and cognitive components, DTT seeks to enhance coordination and reduce fall risk.

Recent technological developments— especially Virtual Reality (VR)—have introduced innovative ways to enhance rehabilitation. VR offers immersive, interactive environments that support safer and more engaging training experiences. This technology has been increasingly adopted in healthcare for both therapeutic interventions and professional education, allowing safe, controlled practice without risk to patients.[11–13]

Despite growing interest in both DTT and VR, much of the existing literature has focused on conventional, single-task interventions. Studies that specifically explore the combined application of DTT and VR remain limited, and there is currently no systematic evaluation of their impact on fall risk among stroke patients. This underscores a critical research gap: Is this combined approach more effective than traditional rehabilitation methods? Are current findings consistent or inconclusive?

Therefore, this review aims to synthesize and evaluate existing evidence on the effectiveness of Dual Task Training using Virtual Reality in reducing fall risk in stroke patients. This systematic review seeks to address the current gap by examining the outcomes of DTT integrated with VR compared to conventional therapies.

Methods

This study employed a systematic review methodology, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) and structured using the PICOS framework. The PICOS elements were defined as follows: the Population consisted of post-stroke patients experiencing balance and cognitive impairments; the Intervention involved Dual Task Training using virtual reality (VR) technology within a rehabilitation program; the Comparison was made against conventional Dual Task Training or standard rehabilitation without VR integration; and the expected Outcomes focused on improvements in balance, gait, and cognitive function, with the ultimate goal of reducing fall risk in stroke patients. The formulation of inclusion and exclusion criteria was guided by this PICOS framework to ensure that all selected studies were aligned with the research objectives.

A comprehensive search strategy was implemented to identify relevant literature, spanning multiple databases including Scopus, PubMed, Crossref, Google Scholar, Web of Science, Medline, Science Direct, ProQuest, SpringerLink, and Cochrane. The search targeted publications from 2019 to 2024, using the keywords "Dual Task Training," “virtual reality,” “stroke,” and “fall risk.” This initial search yielded a total of 1,280 documents. Following title screening and the removal of duplicates, 186 articles remained for further consideration. These were then assessed based on abstracts and full texts to determine their suitability. It is important to clarify that the figure of 1,280 refers to the initial pool of documents retrieved using keyword searches, while the 186 reflects the narrowed selection after filtering based on publication year, language, and open access availability.

The inclusion criteria encompassed peer-reviewed research articles that explored the effectiveness of Dual Task Training using Virtual Reality in mitigating fall risk among post-stroke patients. Articles had to be published between 2019 and 2024, written in English, accessible in full text, open access, and employ either quantitative, qualitative, or experimental research methodologies. Conversely, exclusion criteria were applied to non-research documents such as editorials, opinion pieces, or brief reports; studies published outside the defined date range; articles not available in English or not accessible in full text or open access; and literature reviews or other secondary research. It is also essential to note that the unit of analysis in this systematic review was published research articles rather than individual participants, ensuring clarity in the scope and analytical focus of the study. The article selection process followed PRISMA guidelines and is visualized using a PRISMA flow diagram (Figure 1).

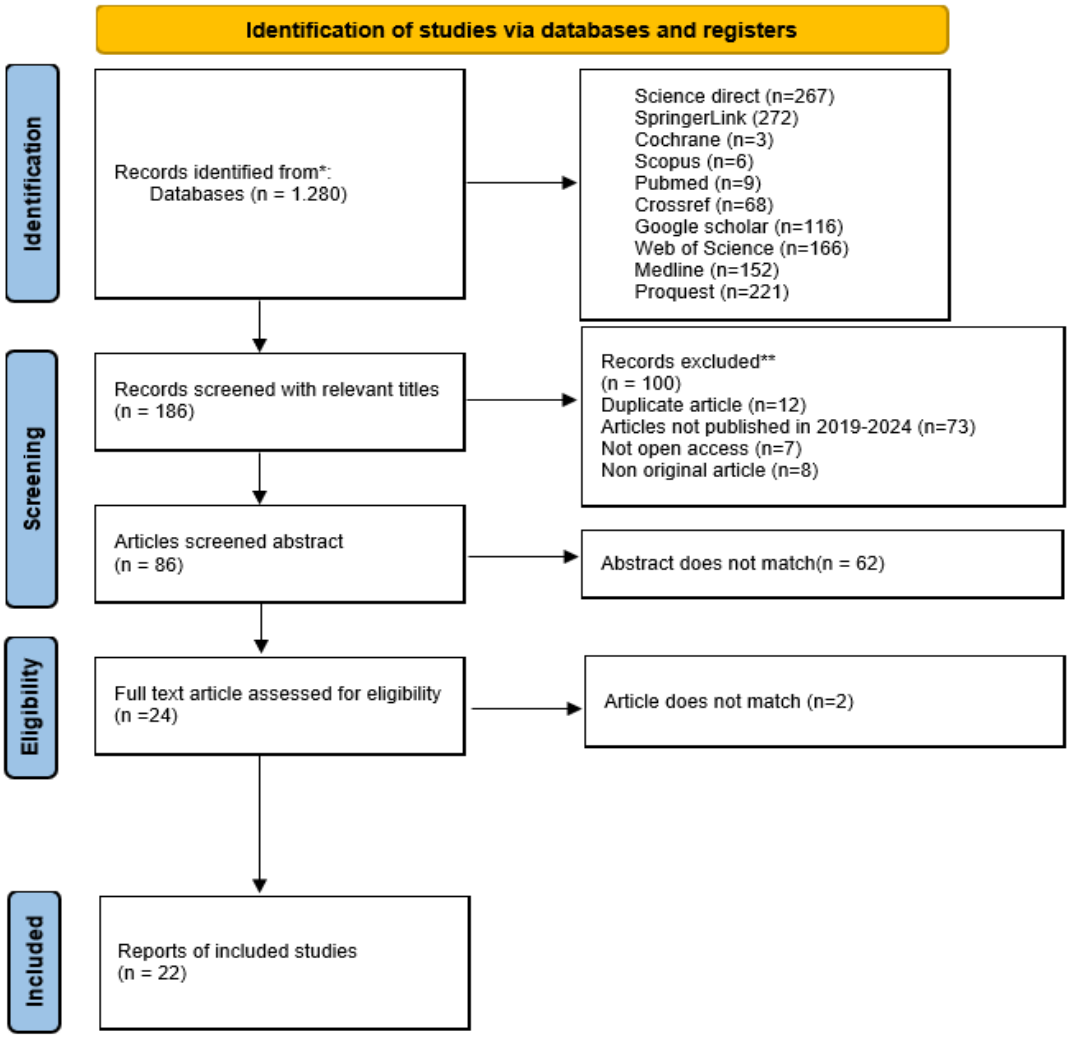

Figure 1. Flow diagram of the article extraction process

The screening and selection process for eligible studies were carried out independently by at least two reviewers to ensure objectivity and minimize bias. Any disagreements that arose during the selection process were resolved through discussion and consensus; when consensus could not be reached, a third reviewer was involved to make the final decision. In total, four researchers contributed to this systematic review—two were responsible for screening the articles, while the remaining two handled data extraction.

In the context of systematic reviews, research instruments typically include structured search protocols, standardized data extraction forms, and methodological quality appraisal tools. For this study, a structured data extraction form was utilized to collect and organize relevant information consistently across all included studies. To assess methodological quality, critical appraisal tools were selected according to the design of each study—clinical trials were evaluated using the PEDro scale, while observational studies were appraised using the JBI checklist. Although the quality assessments were not used as exclusion criteria, they served to evaluate the credibility and reliability of the included studies. Studies were only excluded on quality grounds if they exhibited significant methodological weaknesses that could compromise the integrity of their findings.

Given the variability in study designs, interventions, and measured outcomes, this systematic review adopted a narrative synthesis approach. A meta-analysis was not performed due to the heterogeneity among the selected studies. Instead, findings were grouped according to similarities in intervention type and outcome domains, such as balance, gait, cognitive function, and fall risk. These findings were then synthesized narratively to highlight consistent patterns, contrasts, and research gaps. Additionally, comparisons were drawn between the outcomes of Virtual Reality-based Dual Task Training and those of traditional Dual Task Training to better understand their relative effectiveness in post-stroke rehabilitation.

Results

A total of 1,280 articles were identified through database searching. After removing 100 duplicates and irrelevant titles, 1,180 articles remained for screening. Based on titles and abstracts, 86 articles were retained for further review, with 62 excluded for not meeting the inclusion criteria. Subsequently, 24 full-text articles were assessed for eligibility, and 22 articles met the criteria and were included in the synthesis (Figure 1).

Of the 22 included studies, 19 reported significant improvements following virtual reality (VR)-based dual-task training interventions, 2 reported no significant effects, and 1 study did not demonstrate any changes. Most studies explored outcomes related to balance, gait, cognitive function, or activities of daily living (ADLs**)**, using various VR modalities including immersive VR, exergaming, and task-specific simulations.

Table 1. Summary of Included Studies on Virtual Reality-Based Dual Task Training in Stroke Rehabilitation

Study (Author, Year)	Objective	Sample & Design	Methods	Key Findings
Arshad et al., 2022[14]	To compare exergaming with traditional balance training	40 chronic stroke patients, RCT	6-week intervention measuring BBS, TUG, and DGI	Exergaming was more effective in improving balance
Bourgeois et al., 2023[15]	To evaluate the effects of VR on cognitive rehabilitation	90 stroke patients, RCT	VR combined with conventional therapy	Improvements in cognitive function and mood
Chiaramonte, 2024[10]	To assess the effectiveness of proprioceptive dual-task training	35 subacute stroke patients, retrospective study	Dual-task proprioceptive training	Improved balance, but no significant change in ADL
Deblock-Bellamy et al., 2022[16,17]	To compare dual-task performance	12 stroke patients vs. 12 healthy controls	VR-based dual-task testing	Stroke patients showed cognitive impairments during dual-tasking
Fishbein et al., 2019[17]	To assess the impact of VR dual-task training on gait and balance	22 chronic stroke patients, RCT	Treadmill walking with/without VR	VR improved gait and balance
Fong et al., 2020[18]	To evaluate VR for upper limb function	20 chronic stroke patients	10 VR sessions assessing hand function	Significant improvement in upper limb function
Islam & Brunner, 2019[19]	Cost-effectiveness analysis of VR vs. conventional therapy	120 subacute stroke patients, RCT	4-week intervention	No significant difference in motor function
Kannan et al., 2019[20]	To assess cognitive exergaming on fall risk	24 stroke patients, RCT	Cognitive-motor training	Improvements in both balance and cognition
D. H. Kim et al., 2019[21]	VR with sensory stimulation for hand function and concentration	30 chronic stroke patients, RCT	8-week training	SMVR superior in improving AROM and concentration
M. J. Kim, 2020[22]	To evaluate 360° VR walking training	45 stroke patients, RCT	VR 360° walking training	Significant improvement in gait parameters
Lee et al., 2023[23]	To evaluate VR for daily activity performance	4 stroke patients, single-subject design	VR + cognitive-motor therapy	Improved upper limb and ADL function
Long et al., 2020[24]	To assess the effects of VR on occupational performance and self-efficacy	60 stroke patients, RCT	3-week intervention	Improved ADL performance and self-efficacy
Luca et al., 2019[25]	VR and relaxation for anxiety and cognition	1 chronic stroke patient	2 months of VR and relaxation training	Reduced anxiety, improved attention

Continuation Table 1. Summary of Included Studies on Virtual Reality-Based Dual Task Training in Stroke Rehabilitation

Study (Author, Year)	Objective	Sample & Design	Methods	Key Findings
Omon et al., 2019[26]	VR-based trunk training	1 elderly stroke patient	2 weeks of seated VR training	Improved walking distance, no change in strength
Pervaiz et al., 2023[27]	To compare VR and conventional balance therapy	30 stroke patients, RCT	6-week intervention	VR was more effective in improving balance
Quintas et al., 2021[28]	Validation of CogniViTra for dual-task training	57 rehabilitation experts	User validation and accuracy testing	Motion recognition accuracy exceeded 90%
Rieger, 2023[29]	Perturbation treadmill training for fall prevention	70 older adults at fall risk, RCT	4-week treadmill training	Reduced daily falls; no change in gait quality
Rogers et al., 2019	Effectiveness of Elements VR	21 subacute stroke patients, RCT	VR vs. conventional therapy	Improvements in motor and cognitive function with VR
Shahzadi et al., 2023[30]	VR for upper limb function	20 stroke patients	6-week VR + conventional therapy	Significant improvement in upper limb function
Singh & Dwivedi, 2024[31]	VR vs. Transfer of Training for cognition	30 stroke patients, pre-post design	12-week intervention	VR more effective in enhancing cognition
Victor et al., 2024[32]	Immersive VR for balance training	30 stroke patients	12 weeks of VR + gait training	Improvements in balance and stability
Yamaguchi et al., 2022[33]	VR trunk training for PPPD	Patients with PPPD, varied age groups	Trunk exercises using VR	Improved balance and reduced PPPD symptoms

Overall, most studies (n = 19) demonstrated positive effects of VR-based dual-task training on stroke rehabilitation outcomes, particularly in enhancing balance, gait performance, and cognitive function. Several studies highlighted the superior impact of immersive VR and exergaming platforms compared to conventional therapy, especially for dynamic balance and fall risk reduction. Nevertheless, studies such as Islam & Brunner (2019) and Long et al. (2020) found no significant differences between VR and traditional interventions, indicating that contextual factors (e.g., training duration, patient characteristics) and targeted outcomes may influence the effectiveness of VR.

The diversity in study designs, VR systems used, duration of interventions, and outcome measures (e.g., BBS, TUG, MMSE, Lawton IADL) limited direct comparisons across studies. However, the consistent trend of improvement across various domains suggests that VR-based dual-task training can be a promising complementary approach in post-stroke rehabilitation, particularly for enhancing motor and cognitive integration.

Discussion

Effectiveness of Dual Task Training in Fall Risk Reduction

Dual Task Training (DTT) has been found to significantly improve cognitive function and reduce the risk of stroke in stroke patients, particularly among individuals with chronic conditions and older adults. This type of training involves incorporating cognitive tasks into physical activities, which helps improve attention, executive function, and dual-task performance. DTT can effectively enhance both cognitive function and physical performance in stroke patients, as demonstrated by Kannan et al. (2019).[20] Mundada et al. (2022) found that DTT using conventional repetitive tasks can improve physical performance without imposing excessive cognitive demand.[34] Chaparro et al. (2020) highlighted that environmental factor in stroke training influence outcome variability, suggesting modifiable elements that can be optimized in therapeutic programs.[35]

Unlike conventional rehabilitation that isolates motor or cognitive tasks, DTT merges both simultaneously, yielding superior outcomes in balance, cognitive flexibility, and functional independence.[20,30] From a neurorehabilitation perspective, DTT promotes neuroplasticity by engaging the prefrontal cortex, basal ganglia, and cerebellum—brain regions responsible for cognitive control, motor coordination, and balance, which are often disrupted after stroke.

The integration of technology, especially Virtual Reality (VR), has extended the potential of DTT. Kwon and Kim (2023) found that VR-based daily exercise activities can enhance both cognitive function and daily living performance in stroke patients, reducing fall risk.[36] VR offers a stimulating and adaptive environment that encourages active participation and engagement. These findings align with previous studies and extend the evidence base by demonstrating that VR-enhanced DTT may yield better adherence and cognitive engagement, especially in long-term rehabilitation settings.

Comparison of Virtual Reality and Traditional Dual Task Training Methods

Comparative studies between VR and conventional rehabilitation methods demonstrate several advantages of VR, especially in stroke recovery. Traditional approaches often use repetitive physical exercises or cognitive drills in isolation, which may reduce patient motivation. In contrast, VR offers immersive, interactive experiences that simulate real-life scenarios, improving engagement and motivation during rehabilitation.[15,32,37]

VR allows for personalized training that can adapt to individual performance in real time (Long, Ouyang, & Zhang, 2020; Victor, Arunachalam, & Angel, 2024).[24,32] Neurophysiologically, VR-based tasks stimulate sensorimotor integration and cognitive-motor coordination, potentially enhancing brain connectivity and functional outcomes.

VR has also proven more effective in cognitive rehabilitation than conventional paper-based tasks, thanks to gamification elements that improve memory, attention, and executive function.[30,31,38] This is especially relevant given the high prevalence of post-stroke cognitive impairment, which severely impacts independence and quality of life.[39]

Although VR requires higher initial investment, it has been associated with improved outcomes and reduced therapy duration, offering a cost-effective solution in the long term.[19,24] In conclusion, VR offers an attractive alternative

to traditional rehabilitation methods, providing increased engagement, personalized training, and improved cognitive and motor outcomes for stroke patients.

For physiotherapists, the implementation of DTT with or without VR requires tailored assessment tools to determine cognitive-motor demands and adjust training intensity accordingly. Educational programs and workshops for physiotherapists should be developed to ensure competency in operating VR-based systems.

Limitations of Dual Task Training with Virtual Reality

One major challenge in applying DTT through VR is the complexity of the program design. While the goal is to enhance the ability to perform cognitive and motor tasks simultaneously, the cognitive load introduced by VR environments may exceed patients' capabilities, especially in older adults or those with severe cognitive deficits. Studies have reported that although VR-guided DTT can improve gait and balance, it may also result in task disengagement due to frustration or mental fatigue.[17,36]

Additionally, the requirement for individualized program design that accounts for each patient's cognitive and physical condition further complicates the implementation.[28,33] Moreover, high-quality VR setups may not be accessible in low-resource settings, limiting the scalability and equity of VR-based rehabilitation.[19,37] The need for trained personnel to operate these systems imposes further logistical and financial burdens.[37]

While this review provides a comprehensive summary of recent findings, the heterogeneity of study designs and small sample sizes in included studies may limit the generalizability of the conclusions. Additionally, individual variability in response to VR training presents a challenge in standardizing protocols and assessing efficacy.[16,40] Potential side effects, such as cybersickness, discomfort, or disorientation, can reduce patient tolerance and adherence. Future research should focus on standardized protocols and adaptive VR interfaces to mitigate variability in patient responses and improve accessibility.

Implications for Physiotherapy Practice and Future Research

The evidence indicates that DTT, especially when supported by VR technology, can significantly enhance both motor and cognitive rehabilitation in stroke patients. However, successful implementation requires not only access to appropriate technology but also trained professionals and context-specific adaptations. For clinical physiotherapy practice, integrating DTT into existing protocols can improve outcomes if cognitive load is carefully calibrated and the exercises are tailored to patient capabilities.

For physiotherapists, incorporating VR-based DTT into practice requires competency in both neurological assessment and technology use, highlighting the need for continuous education and practical training. In clinics with limited resources, simplified versions of DTT using low-cost tools or mobile-based VR platforms could be piloted and scaled.

Future randomized controlled trials with larger and more diverse samples are needed to assess long-term outcomes, cost-effectiveness, and the impact of DTT on quality of life. Exploring how DTT and VR affect brain structure and functional reorganization through neuroimaging could further advance our understanding of their mechanisms in neurorehabilitation.

Conclusion

Dual Task Training (DTT) using Virtual Reality (VR) effectively reduces the risk of falls in stroke patients. This intervention improves balance, gait, and cognitive performance—three critical domains associated with fall prevention. These enhancements are particularly valuable for stroke survivors, who often face multifactorial impairments. Despite the positive outcomes, there are ongoing challenges, including limited accessibility, high costs, and the necessity for personalized training programs. Future research should focus on optimizing VR-based dual-task training protocols to enhance efficacy and accessibility. It should also aim to refine and standardize these protocols, evaluate long-term outcomes, and explore strategies for integration across various clinical contexts. Clinical application of VR-based DTT should consider patient-specific needs and resource availability to maximize therapeutic benefits.

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