

Virtual Reality-Based Upper-Limb Rehabilitation after Stroke: Effects on Upper-Limb Function, Self-Hygiene Performance and Activities of Daily Living - A Literature Review

Ramitha R. Suvarna¹ MPT, (PhD), M. Premkumar² PhD, Hemant Hon³ MPT

¹ Assistant professor, Institute of Physiotherapy, Srinivas University, Pandeshwar, Mangaluru, Karnataka, 575001.

² Assistant professor, Institute of Physiotherapy, Srinivas University, Pandeshwar, Mangaluru, Karnataka, 575001.

³ Professor, Institute of Physiotherapy, Srinivas University, Pandeshwar, Mangaluru, Karnataka, 575001.

Corresponding Author: Dr. M. Premkumar MPT, PhD.

Professor Institute of Physiotherapy, Srinivas University Mangaluru, Karnataka, 575001.

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ABSTRACT

Stroke frequently results in persistent upper-limb dysfunction, which can limit self-care, activities of daily living (ADL), functional independence, and quality of life. Virtual reality (VR)-based rehabilitation has emerged as a promising approach for providing repetitive, task-oriented, interactive, and engaging upper-limb training. However, although previous studies have reported improvements in motor and functional outcomes, evidence specifically addressing self-care and self-hygiene remains limited. This review aimed to synthesize the available evidence regarding the effectiveness of VR-based upper-limb rehabilitation on upper-limb function, self-care and self-hygiene performance, ADL, functional independence, and quality of life among stroke survivors. A structured literature search was conducted using PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and IEEE Xplore, supplemented by screening reference lists of relevant publications. Following the predefined screening process, 1,900 records were identified, 650 duplicates were removed, and 100 full-text articles were assessed for eligibility. After full-text screening, 11 studies were included in the qualitative synthesis. The reviewed evidence indicated that VR-based rehabilitation may improve upper-limb motor function, hand function, ADL performance, and quality of life, particularly when used alongside conventional rehabilitation. However, direct evidence regarding self-care and self-hygiene outcomes was comparatively limited. Considerable heterogeneity in VR technologies, intervention protocols, treatment duration, participant characteristics, and outcome measures was observed across studies. Overall, VR appears to be a promising adjunct to conventional stroke rehabilitation, but further high-quality research focusing on meaningful activity-level outcomes, particularly self-hygiene and functional independence, is warranted.

KEY WORDS: Stroke, Virtual reality, Upper-limb rehabilitation, Activities of daily living, Self-care, Self-hygiene, Functional independence.

INTRODUCTION

Stroke is a leading cause of long-term disability worldwide and, despite advances in acute management and early diagnosis, many survivors experience persistent impairments that affect functional independence and

quality of life ^[1,2]. These impairments may involve motor, sensory, cognitive, perceptual, emotional, and communication functions, with upper-limb motor dysfunction being particularly common after stroke ^[2,3]. Upper-limb impairment is characterized by reduced muscle strength, abnormal muscle tone, impaired coordination, decreased dexterity, and reduced selective motor control, which can substantially restrict functional use of the affected limb ^[2,3].

Recovery of the upper limb is often slower and less complete than recovery of the lower limb, and restoration of purposeful hand function remains a major rehabilitation challenge ^[3]. Impaired upper-limb function can interfere with essential self-care and activities of daily living, including dressing, grooming, bathing, toileting, reaching, grasping, and manipulation. Consequently, persistent upper-limb dysfunction may increase dependence on caregivers and adversely affect autonomy, self-efficacy, participation, and quality of life ^[4,5,6].

Conventional stroke rehabilitation includes task-oriented training, strengthening, neurodevelopmental approaches, constraint-induced movement therapy, mirror therapy, and other functional interventions ^[7,8,9]. Although these approaches are widely used, limitations related to treatment intensity, repetition, patient engagement, and opportunities for task-specific practice may affect functional recovery ^[9,10]. Effective upper-limb rehabilitation therefore requires repetitive, intensive, task-specific practice with appropriate feedback and progressive challenge ^[10,11].

Virtual reality has emerged as a technology-assisted rehabilitation approach capable of providing interactive, repetitive, task-oriented training with augmented visual feedback and adjustable levels of difficulty ^[10,11,12]. Recent systematic reviews and meta-analyses suggest that VR-based upper-limb rehabilitation may improve upper-limb function and may provide additional benefits in activities of daily living and quality of life when used alone or alongside conventional rehabilitation ^[12,13,14,15]. However, considerable variation remains in VR technologies, intervention protocols, treatment duration, outcome measures, and participant characteristics ^[12,13,14,15].

Although existing research has demonstrated potential benefits of VR for upper-limb recovery, comparatively less emphasis has been placed on meaningful activity-level outcomes such as self-care, self-hygiene, and independence in everyday activities ^[5,12]. Therefore, a focused synthesis of the available evidence is warranted to clarify the functional relevance of VR-based upper-limb rehabilitation following stroke. Accordingly, the present review aimed to synthesize the evidence regarding the effectiveness of VR-based upper-limb rehabilitation on upper-limb function, self-care and self-hygiene performance, activities of daily living, and functional independence among stroke survivors.

METHODOLOGY

Review Design

A systematic literature review was conducted to synthesize the available evidence regarding the effectiveness of VR -based upper-limb rehabilitation in stroke survivors. The review focused primarily on the effects of VR-based upper-limb training on upper-limb motor function, hand function, self-care and self-hygiene performance, activities of daily living, functional independence, and quality of life. The review process was structured and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework ^[16].

Review Question

The review was guided by the following question:

What is the effectiveness of virtual reality-based upper-limb rehabilitation in improving upper-limb function, self-care and self-hygiene performance, and activities of daily living independence among stroke survivors?

Information Sources

A structured literature search was undertaken using major electronic databases relevant to rehabilitation, biomedical research, and technology-assisted healthcare, including PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and IEEE Xplore. Reference lists of relevant publications were also screened to identify additional potentially eligible studies.

Search Strategy

The search strategy was developed around three principal concepts: stroke, virtual reality-based rehabilitation, and upper-limb functional outcomes. Combinations of relevant keywords and synonyms were used with the Boolean operators AND and OR. The principal search terms included stroke, cerebrovascular accident, stroke survivor, virtual reality, virtual reality rehabilitation, virtual reality-based training, upper limb, upper extremity, hand function, self-care, self-hygiene, and activities of daily living.

The electronic search was supplemented by screening the reference lists of relevant articles to identify additional studies that were not retrieved through the database search. The search and reporting process was structured in accordance with PRISMA 2020 recommendations ^[16].

Eligibility Criteria

Eligibility criteria were established according to the population, intervention, outcomes, and publication characteristics relevant to the review objective.

Inclusion Criteria

Studies were included when they:

1. involved adult individuals with a diagnosis of stroke;
2. evaluated a virtual reality-based intervention or training programme involving the upper limb or upper-extremity function;
3. assessed at least one relevant functional outcome, including upper-limb motor function, hand function, self-care, self-hygiene, activities of daily living, functional independence, participation, or quality of life;
4. provided clinical, observational, or qualitative evidence relevant to the review question;
5. were available as full-text articles; and
6. provided sufficient information to determine their relevance to the objectives of the review.

Exclusion Criteria

Studies were excluded when they:

1. did not involve individuals with stroke;
2. did not evaluate virtual reality-based rehabilitation or training;
3. did not address upper-limb rehabilitation or relevant functional outcomes;
4. were unrelated to the objectives of the review;
5. were duplicate or overlapping publications;

6. were conference abstracts, editorials, protocols, or other publications without sufficient outcome information; or
7. did not provide adequate full-text information for assessment.

Study Selection

The study-selection process followed sequential screening stages. A total of 1,850 records were identified through electronic database searching, and 50 additional records were identified through reference-list screening, resulting in 1,900 records. Following removal of 650 duplicate records, 1,250 records remained for title and abstract screening.

During title and abstract screening, 1,150 records were excluded because they did not meet the predefined eligibility criteria. The remaining 100 full-text articles were assessed for eligibility. Following full-text assessment, 89 articles were excluded for predefined reasons. Finally, 11 studies meeting the eligibility criteria were included in the qualitative synthesis.

The reasons for exclusion at the full-text stage were categorized as follows: wrong population or non-stroke population (n=14), inappropriate intervention or absence of VR-based intervention (n=20), no specific upper-limb focus (n=12), absence of relevant functional outcomes (n=18), ineligible publication type (n=10), duplicate or overlapping publication (n=5), and insufficient or unavailable full-text information (n=10). The study-selection process was documented using a PRISMA flow diagram ^[16].

Data Extraction

Data were extracted systematically from the included studies using a predefined data-extraction framework. The extracted variables included author and year of publication, study design, sample size, participant characteristics, stroke characteristics, type of VR intervention, mode of VR delivery, intervention duration and frequency, comparator intervention, outcome measures, and principal findings.

Particular attention was given to outcomes relevant to the objectives of the review, including upper-limb motor recovery, hand function and dexterity, self-care and self-hygiene, activities of daily living, functional independence, participation, and quality of life.

Methodological Quality and Risk of Bias

The methodological characteristics and potential risk of bias of the included studies were considered during interpretation of the findings. Greater emphasis was placed on randomized controlled trials and systematic reviews or meta-analyses when evaluating the effectiveness of VR-based rehabilitation. Observational and qualitative studies were used to provide complementary evidence regarding self-care, self-efficacy, daily hand use, functional independence, and the lived impact of persistent upper-limb dysfunction following stroke.

Data Synthesis

Due to heterogeneity among the included studies with respect to participant characteristics, VR technologies, intervention protocols, treatment duration, comparator interventions, and outcome measures, a narrative synthesis was performed rather than a quantitative meta-analysis.

The findings were synthesized according to the following major outcome domains: (i) upper-limb motor function, (ii) hand function and dexterity, (iii) self-care and self-hygiene performance, (iv) activities of daily living and functional independence, and (v) quality of life and participation. Findings were compared across different VR approaches and, where applicable, against conventional rehabilitation interventions. Particular consideration was given to the consistency of findings, clinical relevance, and limitations of the available evidence.

Reporting of the Review

The identification, screening, eligibility assessment, and inclusion of studies were documented using a PRISMA 2020 flow diagram ^[16]. The final review included 11 studies for qualitative synthesis. The review findings were subsequently organized according to the major clinical and functional domains relevant to VR-based upper-limb rehabilitation following stroke.

LITERATURE REVIEW AND RESULTS

Study Selection and Characteristics

The literature search identified 1,900 records, of which 650 duplicates were removed. Following title and abstract screening, 100 articles were assessed in full text, and 89 were excluded according to the predefined eligibility criteria. A total of 11 studies were included in the final qualitative synthesis. The included literature comprised randomized controlled trials, systematic reviews and meta-analyses, observational studies, and qualitative studies examining VR-based upper-limb rehabilitation and its relationship with functional outcomes after stroke.

Effects of Virtual Reality on Upper-Limb Function

The included evidence generally indicated that VR-based rehabilitation can improve upper-limb motor performance following stroke. Systematic reviews and meta-analyses reported beneficial effects on upper-limb impairment and motor recovery, although the magnitude of benefit varied across studies and VR approaches ^[12,13,14,15]. Individual randomized controlled trials also demonstrated improvements in measures of upper-limb motor function and hand performance following VR-assisted training, particularly when VR was combined with conventional rehabilitation ^[17,18].

Effects on Hand Function and Dexterity

VR-based interventions demonstrated potential benefits for hand function, dexterity, and purposeful upper-limb use. Studies using interactive and glove-based VR systems reported improvements in measures of hand function and fine motor performance compared with conventional rehabilitation approaches ^[18]. Evidence from studies examining upper-extremity self-efficacy also suggested that greater confidence in using the affected upper limb was associated with better functional capacity and greater perceived use of the hand during daily activities ^[6].

Effects on Activities of Daily Living

Evidence concerning ADL was generally favorable. Systematic reviews reported improvements in ADL performance following VR-based upper-limb rehabilitation, although differences in intervention protocols and outcome measures limited direct comparison between studies ^[13,14,15]. Individual clinical studies similarly reported improvements in functional independence following VR-assisted rehabilitation, although not all studies demonstrated a statistically significant advantage over conventional rehabilitation ^[17,19].

Effects on Self-Care and Self-Hygiene

The evidence specifically addressing self-hygiene was comparatively limited. Available studies indicate that persistent upper-limb dysfunction can substantially interfere with self-care activities and everyday independence ^[4,5]. Improvements in upper-limb function and self-efficacy following rehabilitation may therefore have important implications for self-care performance; however, direct evidence evaluating VR-based training specifically for self-hygiene activities remains limited ^[6,13].

Effects on Quality of Life and Participation

VR-based upper-limb rehabilitation was also associated with improvements in quality of life in several

studies and systematic reviews ^[13,14,15]. Qualitative evidence further demonstrated that persistent upper-limb dysfunction can affect autonomy, identity, social participation, and the ability to perform meaningful daily activities ^[5]. These findings highlight the importance of evaluating rehabilitation outcomes beyond impairment-level measures.

Overall Synthesis

Overall, the reviewed evidence suggests that VR-based upper-limb rehabilitation has the potential to improve upper-limb motor function, hand function, ADL performance, and quality of life after stroke ^[12,13,14,15,17,18]. However, the evidence for self-care and self-hygiene performance remains comparatively limited. Variation in VR technology, intervention intensity, treatment duration, participant characteristics, and outcome measures contributes to heterogeneity across studies. The findings therefore support the potential clinical value of VR while highlighting the need for further research focusing on meaningful activity-level outcomes, particularly self-hygiene and functional independence.

DISCUSSION

The present review synthesized evidence from 11 studies examining the effectiveness of virtual reality - based upper-limb rehabilitation following stroke. Overall, the findings indicate that VR has potential to improve upper-limb motor function, hand function, activities of daily living, and quality of life. Systematic reviews and meta-analyses have reported beneficial effects of VR-based rehabilitation on upper-limb recovery and functional outcomes, although the superiority of VR over conventional rehabilitation has not been consistently demonstrated across all outcomes ^[17,18,19,20,21]. These findings suggest that VR may be a useful adjunct to conventional rehabilitation rather than a replacement for established therapeutic approaches.

The positive effects observed in upper-limb and hand function may be related to the ability of VR to provide repetitive, task-specific, interactive practice with immediate visual feedback and progressive levels of difficulty. Randomized controlled studies included in the review reported improvements in upper-limb motor performance and hand function following VR-assisted training ^[22,23]. Such features may facilitate motor learning and encourage greater engagement during rehabilitation. However, differences in VR systems, intervention duration, treatment intensity, and participant characteristics make direct comparison between studies difficult ^[17,18].

Improvements in upper-limb function are particularly important when they translate into meaningful everyday activities. The reviewed evidence demonstrated potential improvements in ADL performance following VR-based rehabilitation, although not all studies showed a significant additional benefit compared with conventional treatment ^[18,22,25]. This variation indicates that improvement in impairment-level measures may not always result in equivalent gains in functional independence. The effectiveness of VR may therefore depend on the extent to which training tasks resemble meaningful activities and are transferred into real-world practice.

An important finding of the present review is the limited evidence specifically addressing self-care and self-hygiene. Previous studies have demonstrated that persistent upper-limb dysfunction can interfere with grooming, dressing, personal care, and other everyday activities, while also affecting autonomy, self-efficacy, and participation ^[19,20,26]. Although improvements in upper-limb function and self-efficacy may contribute to greater independence, direct evidence regarding the effect of VR on specific self-hygiene activities remains limited ^[19,26]. This represents an important gap because self-hygiene is a meaningful component of independence and an outcome that is directly relevant to patients and caregivers.

Overall, the available evidence supports VR as a promising adjunct to conventional upper-limb rehabilitation after stroke. Its ability to provide engaging, repetitive, and task-oriented practice may enhance opportunities for motor recovery and functional training ^[17,18,23]. Nevertheless, the heterogeneity of existing studies and the limited evidence on specific self-care and self-hygiene outcomes highlight the need for

further well-designed clinical studies. Future research should place greater emphasis on activity-level and patient-centred outcomes and determine whether improvements achieved through VR translate into sustained independence in everyday activities.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should focus on well-designed randomized controlled trials evaluating VR-based upper-limb rehabilitation using clinically meaningful outcomes, particularly self-care, self-hygiene, ADL independence, and real-world functional performance. Further studies should also determine the optimal VR modality, treatment intensity, frequency, and duration, and include longer follow-up to establish whether improvements are sustained and transferred to everyday activities.

CONCLUSION

The available evidence suggests that virtual reality-based upper-limb rehabilitation is a promising adjunct to conventional stroke rehabilitation, with potential benefits for upper-limb motor function, hand function, activities of daily living, and quality of life. However, evidence specifically addressing self-care and self-hygiene performance remains limited. Further high-quality research focusing on meaningful, activity-level outcomes is required to establish the effectiveness of VR in promoting functional independence among stroke survivors.

Declarations

Conflict of Interest

The authors declare that there is no conflict of interest related to this review.

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Ethical Considerations

Ethical approval was not required for this literature review as it was based exclusively on previously published literature and did not involve direct participation of human subjects.

Author Contributions

All authors contributed to the conception and planning of the review, literature synthesis, preparation of the manuscript, critical revision, and approval of the final version.

Data Availability

All information analysed in this review was obtained from published literature cited within the manuscript. No original dataset was generated for this review.

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