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VIRTUAL REALITY BASE REHABILITATION IN STROKE FOR UPPER LIMB MOTOR RECOVERY

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ABSTRACT

Background of the study: The main cause of disability globally is stroke, with upper extremity motor impairment mostly involved. Virtual reality is an emerging technology that has been widely used in stroke rehabilitation with physical therapy for upper extremity functional restoration. The present systematic review is aimed at providing an evidence-based quality assessment of virtual reality based rehabilitation for upper extremity motor recovery in patients with cerebrovascular accident.

Methodology: A comprehensive search was conducted in major electronic databases including Medline (PubMed), Pedro, Embase, and CINAHL published articles between 2018 to 2023 whose full text was available. This review comprised 9 studies. With the use of the Cochrane risk of bias tool, the caliber of the included studies was evaluated.

Results: The current evidence suggests that VR-based interventions can significantly improve upper limb motor function. The systematic review featured few RCTs and fewer subjects, making generalization difficult, especially as most studies incorporated virtual reality with traditional therapy, and those focusing purely on virtual reality were similarly tiny. The review is the independent creation of authors.

Conclusion: VR-based therapies have the potential to be an efficient and secure method for stroke patients to regain upper extremity motor function. To provide standardized procedures and result metrics, as well as to solve the practical difficulties related to implementing VR in stroke therapy, further research is required.

Keywords: *Virtual reality, exergaming, hemiplegia, hemiparesis, stroke, upper extremity, upper limb.*

Introduction

Stroke still ranks third in terms of disability adjusted life years lost (DALY) and is the second leading common cause of mortality globally based on the most recent projections for 2019 from the Global Burden of Disease (GBD). The point approximations of the incident and prevalent strokes were higher in females than in males (6.4 million incident strokes and 56.4 million prevalent strokes), even though males (77.0 million) had more DALYs due to stroke than females (66.0 million) at the global level in 2019. Additionally, the number of stroke-related fatalities did had higher age-standardized mortality rates29. After the initial period, upper limb motor dysfunction frequently continues, leading to long-term impairment and poor health-related life

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quality[6]. 80% of stroke patients, according to estimates, have upper-limb deficits, which reduce their quality of life in terms of health and restrict their capacity to participate in social activities[21]. Therefore, the upper limb needs to recuperate enough. According to published epidemiological research, 40% of stroke survivors still had significant upper extremity impairment, while 60% of survivors had motor dysfunction. Only 5% to 20% of stroke victims regained the use of their upper limbs, 25% did so only partly, and 60% were left with no upper limb use[6]. The ability to do daily chores including eating, dressing, and washing is impacted by upper extremity motor dysfunction since it makes it harder and difficult to reach and hold. Approaches for Active rehabilitation can accelerate the autonomous motor recuperation that takes place up to a year after a cerebrovascular accident. However, standard rehabilitation techniques have limited benefits, demanding the use of innovative treatment strategies.In stroke motor rehabilitation, bilateral upper limb training (BULT) is a well-known method that focuses on enhancing arm functions in hemiplegic patients. It includes a variety of techniques such as bilateral robotic assistance training, bilateral functional task training, and bilateral arm training with cueing in time to music. Utilizing the interlimb coupling effect, which allows movement in the damaged limb to be facilitated by movement in the unaffected arm, is the aim of BULT. The central nervous system and the cerebrum are stimulated by simultaneously using both arms. According to studies, training that involves both afflicted limbs activate the affected side's cortical area more than training that simply involves that leg. Clinical studies have shown that BULT is effective in enhancing hemiplegic arm functioning[28]. Bilateral arm training has demonstrated greater improvements in stroke patients' performance in activities of daily life (ADL) and upper limb function when paired with traditional occupational treatment. However, traditional training in repetitive bilateral upper limb movements can get boring and cause users to lose patience and enthusiasm. Therefore, there is a critical need to create and improve upper limb rehabilitation training tools that can increase the efficiency of bilateral upper limb training while also making it more enjoyable and simpler to continue over time[28]. A systematic study was conducted in which they found that most studies recruited acute and subacute participants and reported improvements in both intervention and control groups[25]. That means early intervention and treatment may positively impact stroke rehabilitation prognosis. Early discharge planning is essential and helps ease the transition of patients from inpatient rehabilitation to home. The development of neuroplastic alterations linked to post-stroke motor dysfunction and the innate healing mechanisms have been discussed in detail by researchers. Physio therapist has been found to have a significant role in improving neuroplasticity with respect to sensory and motor learning, with an emphasis on sensory input. The mirror neuron system's sensory regions are used to generate the changes in plasticity that the patient experiences as he or she watches their own motions[3]. By limiting the possibility of subsequent issues and improving patient independence despite impairment, stroke's physical therapy improves patient outcomes[27]. Innovative treatments such as virtual reality and video games are being developed in response to the advent of interactive technology. The use of these techniques for stroke rehabilitation has been the subject of several meta-analyses and the results are promising[19]. Virtual reality has also been used in post-stroke therapy that can add a more beneficial component in rehabilitation, with researchers investigating the clinical significance of commercial virtual reality games, the efficiency of virtual reality therapy on upper extremity motor function, and the efficiency of balance control, gait, and walking[7]. Adomaviciene A, et al. conducted a study in 2019 comparing examining the impact of new technology on post-stroke survivors. They discovered that these effects are positive for self-care, upper limb motor function (movements and dexterity, kinematic data, grip strength), helpful visual skills (complex commands, visuospatial abilities, attention and memory), and reduced apprehension levels[1]. Dedicated, intense (that is more movements and dosages), and repeated practicing are crucial for encouraging neuroplasticity and subsequently, motor recovery. There are various advantages to virtual rehabilitation in terms of therapy intensity and motivation. Virtual reality (VR) may boost task repetition (intensity) through gamification, which is described as "the process of accruing game principles and game-design elements to something (e.g., task) in order to boost the involvement."[16]. An important part of stroke treatment is motor control training, as it promotes motor recovery and neuroplasticity after stroke. However, the success of conventional rehabilitation methods may be limited by patient apathy and compliance. To address this and increase patient engagement and motivation, virtual reality (VR) rehabilitation exercises were developed.Upper Limb Scores typically measure disability using scales such as the Fugl-Meyer Upper Limb Assessment (UE-FMA) and activity (performing a specific task) using the Action Research Arm Test (ARAT) (Stinear et al,2019). Additionally, this piece of research aims to figure out the potential benefits of using virtual reality (VR) rehabilitation tasks on the motor functioning and overall QOL of patients suffering from Stroke in their upper limbs. The study also focusses to compare the efficacy of VR treatment with traditional rehabilitation methods on analyzing the different features, such as anxiety levels. Self-care, upper limb motor function, and visual ability. Furthermore, evaluation of therapeutic impact, use of VR games commercially and treatment in survivors is also the goal.

Methodology

Search strategy

PRISMA being knowns for report of systematic reviews and Meta-Analyses (PRISMA) are followed in our study. Electronic data bases PubMed in order to find systematic reviews with full text articles available that were published between 2018 and 2023 were used. A search strategy was developed based on the PICOT (Intervention, Outcome, Comparison, Population, and time) outline to compare the effect of virtual reality exercise programs on upper limb motor function in stroke survivor with those of traditional physical therapy treatment programs. The search included the keywords virtual reality, exergaming, stroke, hemiplegia, hemiparesis, upper extremity, upper limb with the Boolean operator "AND and OR". The algorithm obtained is as follows:
("virtual reality"[MeSH terms])) OR ("exergaming" [MeSH terms])) AND ("stroke" [MeSH terms]) OR ("hemiplegia" [MeSH terms])) OR ("hemiparesis "[MeSH terms])) AND ("upper extremity" [MeSH terms])) OR ("upper limb "[MeSH terms])).

After the search, the author, connected universities, and enrollment periods were examined in the paper titles and abstracts to identify and delete duplicate publications. To decide if they will be counted in the final tally, articles in the "possible" category were jointly assessed. Each researcher noted the explanations for why an article was excluded. The inquiry was terminated for articles that did not use virtual reality for upper limb motor function.The key variable of interest was improving upper limb motor function by using virtual reality rehabilitation in stroke patients while improve level of cognition, memory, attention and decrease anxiety were secondary variables with respect to stroke rehabilitation. Outcome measure include Fugl–Meyer Assessment (FMA-UE) for measuring impairment, manual function test (MFT) evaluates manual performance, Box and Block test (BBT) for measuring unilateral gross manual dexterity, self-reported health status, active range of motion (AROM), Action Research Arm Test (ARAT) for measuring activity, National Institutes of Health Stroke Scale (NIHSS) to assess ischemic stroke severity (Stinear CM, et al 2019).

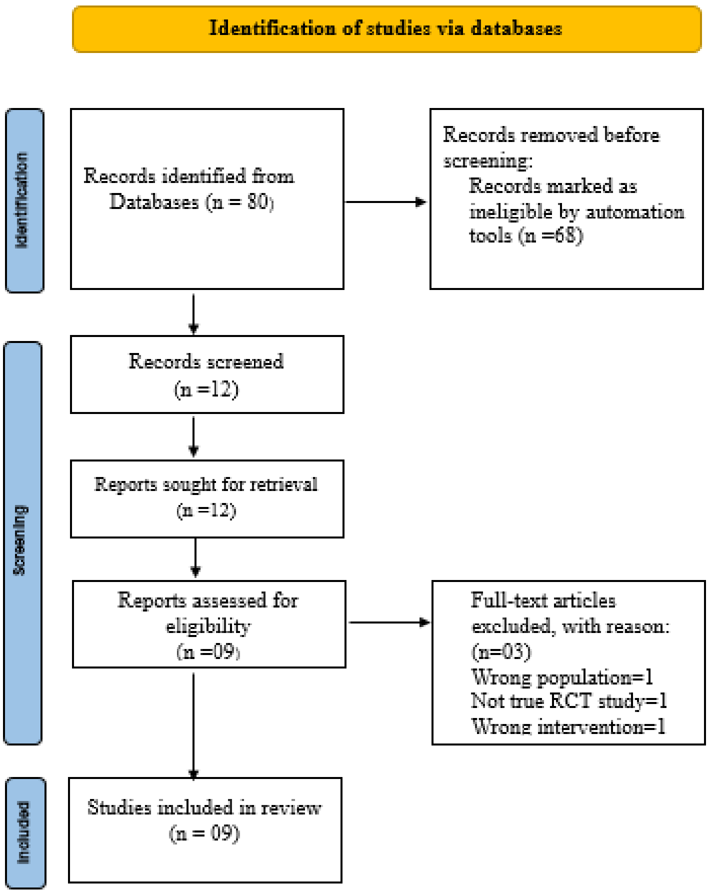

Figure 01: Studies Identification

Selection criteria

Inclusion criteria	Exclusion criteria
Randomized clinical trials. Articles issued in the last five years. Articles in the English language. Studies applying Virtual reality (VR) only or in association with conventional physical therapy as an intervention. Post-stroke patients. Upper limb motor training.	Systematic reviews, case reports, meta-analyses, and literature reviews. Studies that do not use virtual reality as an intervention. Patients other than stroke. Treatment involves lower limb or balance training.

Table 01: Details of the inclusion and exclusion criteria

Risk of bias and Article quality

Evaluation of RCT quality: All of the included RCTs had their quality, internal validity, and bias risk assessed. The Modified Cochrane Collaboration tool was utilized for this purpose to evaluate the bias risk for RCTs. considering the following criteria: (1) blinding of result measurements (detection bias); (2) results with incomplete data (attrition bias); (3) random selection of participants (selection bias); (4) participant and staff blinding (performance bias); (5) allocation concealment (selection bias); (6) selective reporting (reporting bias); and (7) other sources of bias. The risk of bias was classified as high, low, or unclear.

Study, year of publication	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Rodrígue-Hernández et al, 2023	+	?	+	-	+	+	+
Chen et al, 2022	+	+	+	+	+	+	+
Huang et al, 2022	+	+	+	-	+	+	+
Norouzi-Gheidari et al, 2019	?	+	+	+	+	+	+
Park et al, 2019	+	+	-	+	?	+	+
Choi et al, 2019	+	+	-	-	+	+	+
Hung et al, 2019	+	+	-	+	?	+	+
Schuster-Amft et al, 2018	?	+	+	+	+	+	+
Lee et al, 2018	+	?	+	+	?	+	+

Table 02: Risk of bias and Article quality

Results

Out of 80 articles retrieved, 41 were available as full-text RCTSs done from 2018-2023. After further screening, 12 studies were included for systematic review out of which 3 articles were further excluded as they did not meet the inclusion criteria. That means 09 (11.25%) studies met the eligibility criteria and were reviewed.Attributes of RCT in the review: 309 people participated in total. (range of sample size 18-54). Characteristics of intervention: Overall, 5(55.55%) studies reported a comparison between virtual reality alone or in combination with conventional therapy or occupational therapy being the active intervention and conventional therapy as the control group therapy (Rodrígue-Hernándezet al, 2023) (Chen et al, 2022) (Norouzi-Gheidari et al, 2019) (Schuster-Amft et al, 2018) (Lee et al, 2018). 2(22.22%) study used a comparison between occupational therapy combined with virtual-based intervention group and occupational therapy in the control group (Huang et al, 2022) (Park et al, 2019). 2(22.22%) studies showed a comparison between gesture recognition mirror therapy, kinect2scratch games with their control group being treated with conventional therapy, sham treatment, and ADL's activities respectively (Choi et al, 2019) (HungS et al, 2019). All studies showed an improvement in upper limb motor skills and functions with experimental interventions focused on virtual reality than their control groups being the conventional therapy methods. Studies also gives the evidence of improve patients' memory, cognition, and attention.Risk of bias: All the RCTs reviewed were evaluated for risk of bias. 7 RCT (77.77%) describes low risks of bias and 2 involved unknown biases.

Author, year of publication	Population, design, and sample size	Exp&, Control group	Intervention	Duration (weeks)	Frequency	Time	Outcome
Rodríguez-Hernández Et al, 2023	46 post-stroke patients, RCT	EG: n=23 CG: n=23	**Experimental group:** CRT+ VR **Control group:**CRT	3 weeks	5 days/week	150 minutes (CRT for 100min/session and 50 min/session for SVR device)	Improve upper limb motor skills and function
Chen et al, 2022	36 post-stroke patients, RCT	EG: n=18 CG: n=18	**Experimental group:** VR **Control group:**CRT	2 weeks	5 days/ week	60 minutes	Improve upper limb motor skills and function
Huang et al, 2022	30 post-stroke patients, RCT	EG: n=15 CG: n=15	**Experimental group:** OT+ VR- based intervention **Control group:**OT	5 weeks	2-3 days/week	60 minutes	Improve upper limb motor skills and function
Norouzi-Gheidari et al, 2019	18 post-stroke patients, RCT	EG: n=09 CG: n=09	**Experimental group:** CRT + exergaming sessions **Control group:**CRT	4 weeks	2- 3 days/week	30 minutes	Improve upper limb motor skills and function
Park et al, 2019	25 post-stroke patients, RCT	EG: n=12 CG: n=13	**Experimental group:** OT+ smart board intervention **Control group:** Conventional OT	4 weeks	5 days/week	60 minutes (SB intervention for 30 mins + OT for 30 mins)	Improve upper limb motor skills and function
Choi et al, 2019	36 post-stroke patients, RCT	EG: n=12 CG 1: n=12 CG 2: n=12	**Experimental group:** GR recognition mirror therapy **Control group 1:** CMT **Control group 2:** Sham therapy	5 weeks	3 days/week	30 minutes	Improve upper limb motor skills and function
HungS et al, 2019	33 post-stroke patients, RCT	EG: n=17 CG: n=16	**Experimental group:** Kinect2Scratch games+ training for activities of daily living+ conventional hand function training **Control group:** therapist-based interventions+ training for activity of daily living+ conventional hand function training	12 weeks	2-3 days/week	30 minutes	Improve upper limb motor skills and function
Schuster-Amft et al, 2018	54 post-stroke patients, RCT	EG: n=22 CG: n=32	**Experimental group:** VR-based training **Control group:** Conventional therapy	4 weeks	4 days/week	45 minutes	Improve upper limb motor skills and function
Lee et al, 2018	31 post-stroke patients, RCT	EG: n=16 CG: n=15	**Experimental group:** CRT+ VR canoe paddling training **Control group:**CRT	5 weeks	3 days/week	30 minutes	Improve upper limb motor skills and function

Table 03: Description of Studies

Discussion

The goal of this systematic review is to examine the most recent scientific data on the impact of virtual reality-based rehabilitation on stroke patients' recovery of upper limb motor function. Nine RCT studies were analyzed and reviewed which include 309 participants, with sample sizes ranging from 15 to 54 post-stroke patients. Only one study includes 54 participants while seven studies include 25 to 46 participants. Only 18 people made up the study with the least number of participants. After applying the Cochrane risk of bias tool to nine RCTs, a total of seven indicated low risk of bias and two revealed an unknown bias[23]. The effectiveness of virtual reality-based rehabilitation among post stroke patients with upper limb motor function was assessed and time, frequency, and duration were studied. About 80% of stroke survivors experience motor impairment, which generally limits the independent movement of the arm, leg, and trunk on the afflicted side of the body. Only 38% of stroke survivors with weaker upper extremities regain some degree of expert hand dexterity, and only 11% fully recover their function. The effective performance of self-care tasks, writing, leisure, quality of life, opinion expression, and labor are all closely correlated with upper extremity function. To maximize functional recovery and restore independence, increasing upper extremity function after a stroke is, therefore, a crucial component of therapy[14]. The systemic review shows that four articles (44.44%) used conventional rehabilitation treatment with virtual reality (Rodríguez-Hernández, Et al, 2023), (Norouzi-Gheidari et al, 2019),(Hung et al, 2019),(Lee et al, 2018) while two studies (22.22%) used occupational therapy along with virtual reality (Huang et al, 2022), (Park et al, 2019) and three studies (33.33%) employed just virtual reality to treat stroke patients' upper extremity function (Chen et al, 2022), (Choi et al, 2019), (Schuster-Amft et al, 2018)[5,9,12,13,18,19,20,21,24].Statically studies were evaluated, and post-intervention outcome value was compared with the outcome value of the convention treatment group. All the studies show positive outcomes and improved motor function of the upper extremity. Four studies showed significant improvement in Fugl–Meyer Assessment (FMA-UE) (Rodríguez-Hernández et al, 2023), (Huang et al, 2022),(Park et al, 2019),(Hung et al, 2019), Only 2 trials, however, failed to find a difference between the intervention group and the control group (Chen et al, 2022, Norouzi-Gheidari et al, 2019)[5,12,13,19,20,21].Action Research Arm Test (ARAT) was improved in two studies (Rodríguez-Hernández et al, 2023), (Chen et al, 2022)[5,21]. No significant difference was seen in Box and Block test (BBT) (Norouzi-Gheidari et al, 2019), (Schuster-Amft et al, 2018)[19,24]. Manual function test (MFT), active range of motion (AROM), significantly improved in 5 studies (Huang et al, 2022), (Park et al, 2019), (Choi et al, 2019), (Hung et al, 2019), (Lee et al, 2018) [9,12,13,18,20]. As a supplement to traditional therapy, Virtual rehabilitation systems have been demonstrated to produce greater results. For instance, the mirror therapy-based Neuro Rehab system displays the user's vision reflected in a virtual environment, with a virtual arm substituting for the damaged arm. The electromyography (EMG)-based human-computer interface causes the virtual arm to move in response to the user's attempts to physically move the damaged arm. Another illustration of how traditional therapeutic methods have advanced with the use of VR is the virtual Nine-Hole Peg Test (9HPT). To complete the job in this exam, the user solely interacts with the screen[15].The review of this article shows the importance of virtual reality-based rehabilitation in the treatment of stroke patients. The above finding indicates that VR training may promote upper limb motor function more effectively than traditional treatment. A comprehensive evaluation found a small to moderate effect in favor of VR intervention when compared to conventional therapy[5]. VR not only stimulate patients' interest in the virtual reality gaming programme, which may be used by those with severe paralysis, to improve the patient's psycho-emotional condition as well as to boost their desire to engage freely. Virtual reality-based games must adhere to the four fundamental tenets of post-stroke rehabilitation: they must be intense, task-oriented, feedback-focused, and motivational. Numerous research indicates that gamification boosts participation in therapeutic exercise[2]. The implication of virtual gaming also improves patients' cognition, memory, and attention[1].The amount of time a participant spends engaging in exercise can make a difference and improve upper limb motor function[11]. Neural plasticity after stroke is greater in the acute and sub-acute phase compared to chronic phase. Use of the affected limb repeatedly and intensively may benefit neuroplasticity, resulting in improved motor function. Since patients get continuous visual, auditory, and verbal input in addition to that from the virtual world, the physiotherapist's ongoing presence serves as the primary cue for improving motor outcomes. Even if the virtual teacher is hidden, they collectively form a special enhanced environment important for promoting neuroplasticity and motor learning[22]. Unsupervised home-based VR treatment can also improve upper extremity motor function[17]. Due to the urgent need for efficient methods, different therapy modalities are increasingly being studied using innovative methodologies. Recently developed with different varieties of novel technologies are now more easily available to rehabilitation facilities. Virtual reality (VR) in particular is viewed as a possible therapeutic tool with properties that may promote therapist participation and stroke patients' functional recovery. In order to provide people, the chance to interact with surroundings that seem and feel like real-world objects and events, "virtual reality" (VR) is described as "the use of interactive simulations made with computer hardware and software." Users may operate virtual objects in a virtual world using controllers, joysticks, or a computer mouse. Additionally, an avatar that mimics the user's actions using motion capture technology may be used to represent them in the virtual world. More precisely, by immersing stroke patients in a virtual environment and supplying them with visual, audio or tactile sensory input, VR systems may enable stroke patients to practice goal-oriented tasks in environments similar to the real world[4].Although VR significantly affects upper extremity motor learning in stroke patients, it can also be used to improve gait, balance, and lower extremity strength. Since gait impairment is one of the most prevalent symptoms following a stroke, restoring walking ability is essential to enhancing patients' capacity for self-care and quality of life. Innovative virtual reality technology, whose efficacy and safety have been extensively proven, has been employed extensively in post-stroke therapy. To far however, there has been little study on the effects of immersive virtual reality on stroke-related gait rehabilitation. In order to contrast it with traditional rehabilitation, this research explains the use of immersive VR-assisted treatment for stroke patients' gait recovery[8].

Limitations

The number of RCTs included in this systematic review was less. Further generalizing the result is difficult because the number of subjects was small. Most of the studies focus on virtual realityprogramme along with conventional rehabilitative treatment, studies only focusing on virtual reality treatment were small.

Conclusion

In conclusion, this systematic review highlights the increased interest in virtual reality-based stroke therapy, notably for enhancing hand motor function and lowering spasticity. Benefits from virtual reality include improved task-oriented training and patient involvement, which may improve neuroplasticity and functional recovery. Virtual reality treatment shows promise as an effective intervention, with potential for improved results and higher quality of life. However, further study is needed to investigate broader applications beyond upper limb function and refine methods.

AUTHORS' CONTRIBUTION:

The following authors have made substantial contributions to the manuscript as under:

Conception or Design: Muhammad Haris Raza, Saba Qayyum

Acquisition, Analysis or Interpretation of Data: Muhammad Amjad Khan

Manuscript Writing & Approval: Muhammad Adnan Khan

All authors acknowledge their accountability for all facets of the research, ensuring that any concerns regarding the accuracy or integrity of the work are duly investigated and resolved.

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