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Recent Physiotherapy Advances in Stroke Patient for Upper LimbTraining: A Literature Review

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ABSTRACT: Various advanced techniques are used in rehabilitation to improve arm and hand function, which are essential for independent daily life. These techniques include Virtual Reality, Robotic devices, Constraint-Induced Movement Therapy to Mirror Therapy. Telerehabilitation, biofeedback, and wearable sensor methods primarily target neurological impairments such as paresis and spasticity by activating neural circuits or influencing peripheral effectors. However, CIMT, particularly in its modified expression, restrains the non-affected arm and simultaneously trains the affected limb, which is most effective in improving upper limb function. Mirror Therapy, which may also be applied to severely paralyzed limbs, offers several benefits. Nonetheless, newer technologies are costlier and more complicated while simultaneously limiting access, particularly to patients residing at a distance. In this regard, tele-rehabilitation appears to be a functional alternative that uses telecommunication networks, making therapy affordable and accessible.

KEYWORDS: Biofeedback, CIMT, Robotic devices, Mirror therapy, Tele-rehab, Virtual reality.

INTRODUCTION

Stroke is a leading cause of morbidity and mortality worldwide. Activities of daily living and quality of life strongly depend on the upper limb function.[1] The goal of rehabilitation is to recover arm and hand functions and enable patients to perform activities of daily living independently.[2] Stroke can lead to brain damage and loss of motor function. Upper limb function is mainly involved, resulting in disability. Various advanced techniques have been developed to facilitate motor recovery of the upper limbs and improve functional ability and quality of life.[3] Technology-based approaches and treatments have been developed for rehabilitation, such as Virtual Reality (VR) and robotic devices, constraint-induced movement therapy (CIMT), mirror therapy, remote rehabilitation, tele-rehabilitation, biofeedback, and wearable sensors, which mostly target neurological impairments such as paresis and spasticity through the activation of neural circuits or by acting on peripheral effectors.[4] The principle of rehabilitation includes a functional approach that targets specific activities and frequent and intense practice and should start in the first few days or a few weeks after stroke.[5] In CIMT, the non-paretic arm is restrained, while the paretic limb undergoes task-based training.[6] It was created primarily to improve upper limb function and is possibly the most researched stroke rehabilitation method. Originally, the CIMT method limited the unaffected upper limb movements with a sling or support cast for 90% of the waking hours for 2 weeks, whereas the affected limb was intensively trained for 5–6 hours per day. In the mCIMT (modified CIMT), the training sessions were less intense and had better tolerance and acceptability.[7]

VIRTUAL REALITY and ROBOTIC DEVICES

Virtual reality is defined by interactive simulations produced by machines to enable people to interact in settings that closely mirror the real world, as opposed to robotic devices, which are machines capable of carrying out a sequence of complex activities automatically. Visual and multisensory feedback were crucial components of this simulation.[4] With the help of several Robotic Devices or VR technologies, a patient can walk more easily by improving muscle powerand motor function in the upper and lower extremities, where ADLs could be more independent. Gait training using these devices is more successful than training without them when combined with traditional physiotherapy.[8] The intensity and quantity of rehabilitative training increased when the robotic and VR technologies were combined.

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MIRROR THERAPY

Holding a mirror in the patient's midsagittal plane during mirror therapy reflects the motion of the unaffected side as if it were the affected side. For four–eight weeks, it is offered for 15–60 minutes, three–seven times per week. After mirror therapy that persisted for at least six months, a sustained mild-to-moderate-quality improvement in motor function, motor impairment, and ADLs was observed, mostly in the upper limb. However, discomfort and visuospatial neglect showed modest to negligible improvement. One of the benefits of mirror therapy is that it can be used even when the limb is severely or completely paralyzed. [9]

TELEREHAB

Newer rehabilitation technologies are more expensive, complicated, and difficult to access for patients from remote or rural locations. In addition, a lack of finances prevents patients from receiving extensive care and intense treatment at rehabilitation facilities. The provision of rehabilitation services via telecommunication networks and the Internet is referred to as tele-rehabilitation or e-rehabilitation.[10]

BIOFEEDBACK AND WEARABLE SENSORS

Functional evaluation and monitoring therapy conducted in a hospital or clinical setting lacks real-life, personalized situations in a comfortable setting, in addition to being time-consuming and biased. Wearable sensor technology allows home-based therapies to be monitored from a distance and addresses several of these restrictions. Technology has advanced significantly during the past two decades, and inexpensive miniaturized sensors have been developed that allow for objective, long-term observation of a patient's familiar surroundings.[11]

Materials and Methods

The search integrated a variety of sources including journals and computerized searches which were generally performed from the databases of Google Scholar, MEDLINE, PUBMED Central, and Science Direct. Articles in any language using the MeSH terms like Virtual reality, Tele-rehabilitation, virtual reality, and mirror therapy. The search time was limited from 2018 to 2023. Studies like randomized controlled trials, comparative studies, and pilot studies in English languages were included if they described virtual reality-based rehabilitation. All articles were read carefully, and data were extracted from articles based on VR or Tele-rehab.

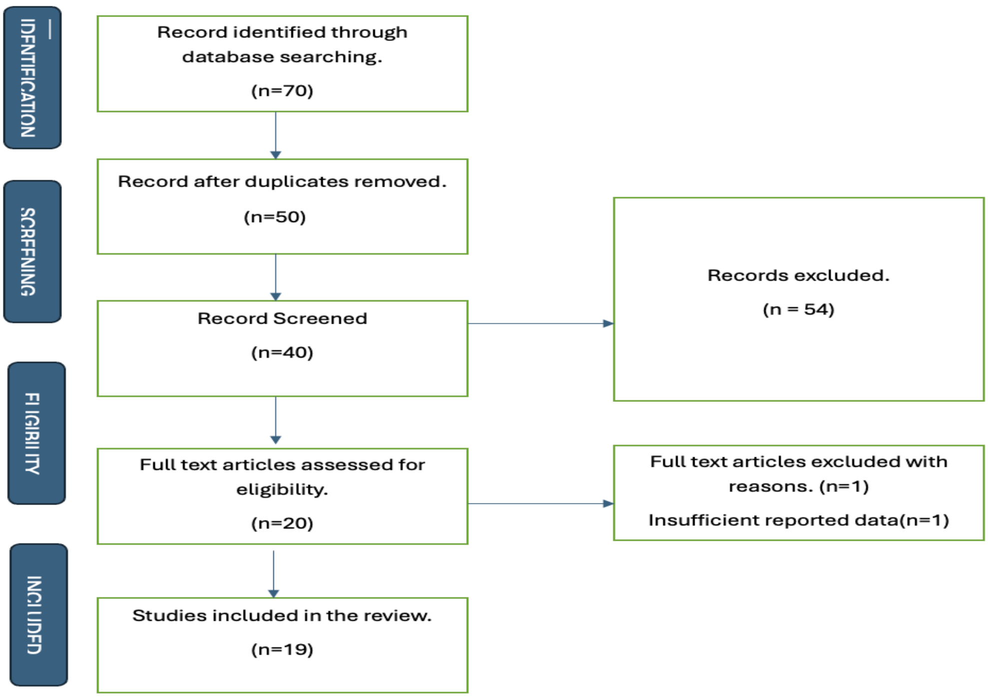

Figure: Flow Of Research Methodology

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RESULT

The results obtained from recent studies ***(Table 1)*** clearly show that virtual reality technology shows a massive improvement in upper-limb stroke rehabilitation compared to other recent advances. Virtual reality therapy can be performed more often than standard supervised physiotherapy sessions. This intervention fulfills the important principles of neurological rehabilitation needed in stroke patients for functional recovery by using goal-oriented tasks, enriched environments, and allowing highrepetition and intensity of therapy. Mirror therapy is another alternative treatment method that shows massive improvement in upper limb rehabilitation in patients with stroke. Studies have shown that the most common application of mirror therapy after stroke is to improve upper extremity function, and survivors do not need any preexisting movements to benefit from this therapy. Biofeedback has shown the least improvement in stroke rehabilitation because studies have shown that it does not improve the range of motion compared to other advances. However, biofeedback produced improvements in the motor power and functional recovery of the patient when compared to standard physiotherapy alone. Constraint-induced movement therapy people often go on to make significant improvements in hand function, which can have a profound effect on independence in everyday activities and quality of life. Wearable sensors track movement using deformable sensors embedded in clothes, allowing monitoring of the patient as they perform activities of daily living.

Table 1: Findings of Studies Included in the Review.

Sl. No	Author	Study Design	No. of patients	Treatment applied	Outcome measures	No. of Sessions	Follow up	Result
1.	Norouzi-Gheidari et al (2019)	RCT	18	Intervention Group (n = 9), which received both traditional rehabilitation services and at least eight supplement sessions of training with the VR exergaming system Control Group (n=9) which received traditional rehabilitation services only	Fugl–Meyer Assessment-UE (FMA-UE), Box and Block test (BBT), Stroke Impact Scale (SIS), Motor Activity Log (MAL)	two to three times a week, 21 minutes per session being the actual duration spent using the exergames, for four weeks	3-month post-intervention	Clinical efficacy measures revealed positive advances in the ADL assessment; that is, MAL-QOM and the SIS total score (stroke impact scale) difference between the intervention and control group after the intervention
2.	Kim et. al (2018)	Single Blinded RCT	24	The experimental group received extra training using VR games plus the usual rehabilitation and the control group received the usual	Manual Function Test (MFT), Fugl-Meyer Assessment (FMA), Stroke Impact Scale (SIS)	five times per week, and thirty minutes per session for 12 weeks	52 weeks	Results showed relatively higher scores attained in the SIS and significant improvements in ADLs after training for

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				rehabilitation services only				participants in the experimental group. Upper extremity function outcomes were nearly the same in both groups.
3	Llorens et al (2021)	RCT	29	The experimental group received combined tDCS and VR-based intervention and conventional physical therapy, respectively. control group who received conventional physical therapy based on passive and active assisted ROM exercises only	The Fugl-Meyer Assessment. and Wolf Motor Function Test.	30 minutes a day, for 3-5 weeks	Post-interventio n	Improvement of UE motor function was observed throughout all motor measures in the experimental group but not in the control group. Both groups exhibited similar limited effects after the sensory function assessment was completed.
4.	Qian et al (2019)	Comparativ e Study	30	The Hand group received motor training with NMES-robotic support to the distal finger joints, and the Sleeve group received support to the proximal wrist-elbow joints	Fugl-Meyer Assessment (FMA), Action Research Arm Test (ARAT), and Modified Ashworth Scale (MAS)	60 minutes	Post-interventio n	Improvement of FMA shoulder/elbow (FMA-SE) and ARAT scores were found in both groups, whereas advancements in FMA wrist/hand (FMA-WH) and MAS scores were only observed in the hand group. A

								significant decrease in EMG parameters (EMG activation level and CI index) was seen in both groups.
5.	Takebayashi et al (2022)	RCT	129	Conventional self-training plus conventional therapy (n=42), robotic self-training plus conventional therapy (n=44), and robotic self-training plus constraint-induced movement therapy (n=43).	FMA-UE, MAL, and Coordination scores (Action Research Arm Test Score, Motricity Index, Modified Ashworth Scale) and Stroke Impact Scale	1 hour per session, three times each week for 10 weeks	Post Intervention	Findings revealed no significant differences in the Fugl-Meyer Assessment for upper-extremity scores between groups. The RT versus control (per-protocol set) improved significantly in the FMA-UE shoulder/ elbow/forearm score. Per-protocol set outcomes suggest that robotic self-training may be effective when combined with conventional therapy.
6	Terranova et al (2021)	RCT	51	Constraint-induced movement Therapy combined with conventional physiotherapy for one group and Robot-Assisted	Wolf Motor Function Test (WMFT) and Fugl-Meyer Assessment —Upper Extremity (FMA-UE) assessed	60 minutes per session for 12 weeks	Post-intervention	Both training groups showed significant improvement in UE function, and no differences in the statistical outcomes were

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				Therapy combined with conventional physiotherapy for another group.	upper limb function and an assessment of ADLs			found. This suggests that robot-assisted therapy is effective for UE stroke rehabilitation
7	Klinkwan et al (2022)	Randomized controlled trial assessor-blinded control study	20	Neuro restoration protocol	Fugl-Meyer Assessment (FMA) upper extremity score, Brunnstrom recovery stages (BRS), Modified Ashworth Scale (MAS), and Muscle Strength	30–60 min, 20 sessions per cycle, and 2 Cycles each day for 12 weeks	Post-intervention	This study suggests that 12 12-week program of MT alone accompanied by daily home exercises, is more effective for motor and functional recovery of the upper extremity and ADLs in acute stroke patients than conventional therapy (traditional rehabilitation protocols) if it's started early.
8.	Chinnavan et al (2020)	RCT	25	Both groups received training sessions and conventional therapy, but the experimental group received conventional therapy plus mirror therapy	Fugl-Meyer Assessment (FMA) upper extremity score	Three days per week for 45 minutes.	6 months	Results revealed relatively significant statistical improvement in the experimental group than the control group. Hence, this suggests that when mirror therapy is combined with conventional therapy, it

								produces greater outcomes in UE motor recovery among hemiplegic patients.
9	Bai et al.(2019)	Pilot RCT	34	Movement-based mirror therapy for one Group (MMT) task-based mirror therapy (TMT) for the second group and Conventional Physiotherapy	Fugl-Meyer Assessment (FMA), Wolf Motor Function Test (WMFT), and hand grip strength were used to assess upper limb functions. While the modified Ashworth scale (MAS) and modified Barthel index (MBI		Post-intervention	The findings of the study showed better outcomes in MMT on improving FMA-UE than in CT and TMT groups. No significant effect in WMFT, hand grip strength, MAS, and MBI was recorded. This study suggests that movement-based mirror therapy (MMT) is more effective than TMT in improving UE functions in stroke rehabilitation.
10	Abdullahi, (2018)	RCT	48	Group A received old/lore therapy only, while Group B was trained with mCIMT, Group C received 300 repetitions of shaping practice, and Group D received 600 repetitions of shaping practice.	Fugl-Meyer Assessment (FMA) was in use to assess UE function while the Motor Activity Log (MAL), Wolf Motor Function	5 times each week for 4 weeks	Post-intervention	Results found significant improvements in Group B, C, and D upper limb motor function but greater outcomes were observed in Group C and D. This suggests

					Test, and upper limb self-efficacy test			that the number of repetitions of shaping practice notably improves UE motor functionality in stroke rehabilitation.
11	Abba et al (2020)	RCT	60	Constraint-Induced Movement Therapy (CIMT) and Proprioceptive Neuromuscular Facilitation (PNF	Fugl-Meyer assessment (FMA-UE)	three times a week for six weeks	Post-interventio n	Results showed significant improvement in the groups (A & B) after the intervention; nevertheless, CIMT showed better outcomes than PNF. This study suggests that one would rather opt for CIMT as a treatment protocol for UE rehabilitation in chronic stroke patients.
12	Garrido M et al (20023)	RCT	70	Transcranial direct Current Stimulation (tDCS) in combination with modified Constraint-Induced Movement Therapy (mCIMT	FMA-UE, WMFT, and grip strength		Post-interventio n	Findings revealed significant improvements in UE function in both treatments; however, better effects were seen when the active tDCS was combined with mCIMT. This study suggests that combining mCIMT with

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								bi-hemispheric trans-cranial Direct Current Stimulation in acute-sub-acute hospitalized stroke patients promotes UE motor function recovery.
13	Tamburella et al. (2019)	Randomized cross-over pilot trial study	12	Electromyographic biofeedback (EMGb) and joint torque biofeedback (Rb)	The modified Ashworth Spasticity Scale	40 minutes per session, and 3 sessions per week	Post-intervention	The results showed that Lokomat training was advantageous in improving gait rehabilitation in both groups, but EMGb was better in reducing spasticity than Rb. In a nutshell, the study suggested that EMGb is more effective in gait rehabilitation but also Rb is easily acceptable and effective to patients.
14	Najafi et al. 2018	RCT	60	Routine physical exercises, while the case group received biofeedback training	balance, ability to walk, spasticity, and hand muscle strength	20 minutes twice a week for 8 weeks	Post-intervention	The results showed greater improvement in balance and muscular strength for participants in the intervention group. Finally, this study

								describes biofeedback as a hopeful treatment protocol for improving the motor–muscular situation of patients post-stroke.
15	Yan et al., 2020	RCT	80	Chinese herbal medicine fumigation and myoelectric biofeedback therapy	FMA, The High Coast Shoulder Joint Function Rating Scale		.	Results showed significant effectiveness in the treatment protocol given to the JIG cluster; FMA scores recorded were notably higher than the ones in the EFG cluster. In conclusion, combining traditional Chinese medicine fumigation and EMG biofeedback therapy is a promising approach for injured players with shoulder-hand syndrome post-stroke because it improves joint function, promotes healing, and relieves pain
16	Cramer et al., 2019	RCT	124	Arm Motor Therapy home-	Fugl- Meyer assessment	70 minutes		The study suggests that

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				based telerehabilitation and traditional in-clinic settings.		for 8 weeks		home-based telerehabilitation is not inferior to traditional in-clinic therapy and may be as effective for improving arm function and promoting stroke education in adults post-stroke, and may be an accessible option for some patients.
17	Uswatte et al., 2021	RCT	24	Telehealth CIMT and in-clinic CIMT	Motor Activity Log Arm (MAL)	Both Groups received 35 hours of Treatment		Results showed that both groups had significant improvements in arm function. Finally, the study suggests that Tele-AutoCITE is feasible and produces good outcomes in stroke rehabilitation of chronic upper-arm extremity hemiparesis patients that are similar to those attained in in-clinic CIMT.
18	Allegue et al., 2020	2-arm feasibility clinical trial	11	Virtual reality exergames combined with a telerehabilitation app (VirTele) versus conventional therapy	Fugl-Meyer Assessment-UE, Motor Activity Log, Stroke Impact Scale, and Treatment Self-	30-minute session for 5 days a week for 8 week		Results showed a significant impact in both groups as measured by the Fugl-Meyer assessment and Motor Activity Log. The

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					Regulation Questionnaire			control group was recorded to have a high SIS score while the experimental group showed an increase in the autonomous motivation score. In conclusion, the VirTele intervention may be as effective as conventional therapy in designing a rehabilitation protocol for chronic stroke patients.
19	Crema et al., 2021	RCT	26	Task-driven NMES grasp rehabilitation with one hour of conventional physiotherapy	Action Research Arm Test (ARAT), and the secondary outcome measures were the System Usability Score (SUS) and Total Active Motion (TAM) scores.	27 sessions for nine weeks.		Findings revealed significant improvements in ARAT scores from the experimental group compared to the control group. In conclusion, the use of reactive exercises with interactive objects was found to be effective in improving hand rehabilitation post-stroke.

DISCUSSION

Recent achievements and developments in physiotherapy for the upper-limb training of stroke patients are extremely multifaceted.

Although the most part is extremely promising, there are recurring problems in the domain. Therefore, The synthesized scholarly highlights suggest the following. Among the reviewed interventions, CIMT, mirror therapy, VR training, and robot-assisted therapy are beneficial techniques and do help advance motor recovery and specific movement pattern learning after a stroke. Moreover, many of the techniques imply a specific adjustment to the patient's condition and as many sensations involved as it is humanly possible. Moreover, the technology used in these strategies expanded the horizon of clinical performances and facilitated therapy through VR platforms, as well as telerehabilitation and home-rehabilitation activities with the use of wearable devices. Despite the high potential of these advancements, there are several challenges, including limited access to highly specialized services, the variability in the response to treatment, and the shortfall of support. It is vital to overcome the mentioned challenges and gain a comprehensive understanding of the neurobiological underpinnings of rehabilitation interventions to improve the practice of stroke rehabilitation. In conclusion, by benefiting from recent achievements, physiotherapists can serve stroke survivors through the practical application of interdisciplinary efforts, evidence-based decisions, and patient-centered measures to reach the best functional outcome, independence, and quality of life.

CONCLUSION

In this study, different interventions were overlooked for the upper limb in stroke patients, in which Virtual Reality had some optimistic improvements in upper limb function training compared to other methods. However, mirror therapy also resulted in a remarkable improvement in upper limb training in stroke patients. Likewise, other interventions like biofeedback and CIMT had significance in improving the upper limb functioning for acute post-stroke patients.

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