Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 March; 6 (3s): 165-171

Review of Implementation Fidelity on Home-Based Virtual and Robotic Rehabilitation Study for Stroke

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Received: 07-January -2023
Revised: 14-February -2023
Accepted:16-March-2023

Abstract

Background/Objectives: Stroke is a critical chronic health problem in rehabilitation.We aimed to review the fidelityof home-based virtualand robotic rehabilitation studies in stroke survivors.

Methods/Statistical analysis: We searched electronic databases such as NBASE, PubMed, Cochrane Library, ProQuest, and CINAHAL to find the relevant literature. Keywords or MeSH terms such as "stroke," "virtual reality," "augmented reality," and "tele* were searched for, and articles published before February 20, 2021, were included. A total of six published articles were reviewed; three studies used virtual therapies for home-based rehabilitation of stroke fighters, and the remaining three used robotic treatment.

Findings: In thesix studies selected for review, the FuglMeyer Assessment scale was frequently used to assess physical function. The intervention period, in general, was 20–45 minutes per session for eight weeks, but some studies were unrestricted. Virtual therapy has been shown to vary depending on personal conditions. However, this was like the regular application of 2–3 cycles per week. Intervention doses in robotic therapywere higher than those in virtual treatment. The findings indicate thatvirtual treatment improved upper limb function in all studies, whereas robotic home-based rehabilitation did not improve arm function.

Improvements/Applications: The frequency of use and dose of the virtual devicewas lower than those of the robot-assisted device but not inferior to those of the robot. Virtual and robotic devices can be helpful tools for home-based rehabilitation.

Keywords: Fidelity, Home-based, Rehabilitation, Review, Robotics, Virtual

1. Introduction

One of the most common reasons for permanent disability is a stroke. After the critical period, the patient's survival requires post-stroke rehabilitation [1]. Restoration seeks to restore a person's maximum functional capacity following a stroke,to help acquire an optimum level of independence, and to achieve the best possible quality of life [1]. Most rehabilitation programs are facilitated in hospitals during the few weeks following the acute period, followed by rehabilitation through facilities or outpatient treatment [2]. However, research shows that the most crucial element in any rehabilitation program is to customize a strategy for patients to practice skills in their homes because of theimpairmentdue to stroke [2,3]. Home environments, such as stairs and grab bars, can effectivelyrenderindependence and safety among stroke patients out of the acute stage [3]. Sometimes, patients can cooperate with family and friends or support social networks [4].

Virtual therapy (VT) occurs via phone, an app, video gaming, or a virtual reality device. In a Cochrane review study, upper limb function in stroke survivors improved when virtual reality and interactive video gaming were used [5]. Studies have reported that the advantages of VT home-based rehabilitation are repetitive, task-focused, challenging, and enjoyable use to promote patients' locomotor skills [3]. In a study by Liorens et al., a VT home-based rehabilitation program wasfound to be more effective in the balance recovery of individuals with hemiparesis after stroke when compared with an in-clinic program [3]. Thus, VT can be an effective customized method for the non-face-to-face home-based rehabilitation of stroke survivors.

A robot-assisted rehabilitation method was recently applied forhigh-intensity arm-hand training [6,7]. The goal of robotic rehabilitation in home situations is to improve the function of the affected arm-hand. However, there are controversial results regarding the extentof the use of mechanical support. In a study by Lemmenset al., robot-assisted task-oriented arm-hand training was ineffective in compliance with affected arm-hand help [7]. Although robotics did not directly change their arm-hand use, the motivation for arm-hand use was positively altered by robot-assisted home-based rehabilitation programs, as highlighted in a prior study [6]. Thus, robotics can be effective in certain situations as a tailored VT and automatedhome-based rehabilitation program.

Fidelity inapplication refers to "the degree to which an intervention is delivered as intended and is critical to successful translation of evidence-based interventions into practice" [8]. Carroll et al. proposed anabstract framework for application fidelity that affects the credibility and utility of an intervention [8].It also includes measurement of adherence (content, dose, frequency, and duration), i.e.,how well the people responsible for providing the intervention adhere to it, as described by the designer.Achieving implementation fidelity refers to the degree to which an intervention's planned content or frequency is carried out. The absence of these components has a significant adverse effect on the ability of an intervention to achieve its goals.

In this research, we pointed to systematically reviewing the implementation fidelity components of home-based VT and robotic rehabilitation for stroke survivors.

2. Materials and Methods

2.1. Research questions

We asked the following research questions:

a) How many home-based VT and robotic rehabilitation studies have been conducted?
b) What were the criteria for inserting and omitting the study participants in the included studies?
c) Whatwas the frequency and dose of the intervention?
d) What were the primary outcomes, and was the intervention effective?

2.2.Methodology

The Preferred Reporting Items for Systematic Reviews or PRISMAguideline was used in this study.

2.2.1. Search strategy

To find the relevant literature, we searched electronic databases such as NBASE, PubMed, Cochrane Library, ProQuest, and CINAHL. Keywords or MeSH terms such as "stroke," "virtual reality," "augmented reality," and "tele* were searched for, and articles published before February 20, 2021, were included.

2.2.2. Inclusion and exclusion criteria

The original study on home-based rehabilitation using either non-face-to-face VT or robotics for stroke survivors was included. Full-text English articles were reviewed, but pilot studies or conference papers were not included in this study. If robots or VTswere applied face-to-face, they were excluded from the study.

2.2.3. Study extraction and analysis

The authors independently searched and extracted relevant studies and coded the study characteristics. The publication years, country, corresponding author names, frequency and dose of interventions, inclusion/exclusion criteria, primary outcomes, and measurements were coded.

Methodological quality was not considered in this study.

3. Results and Discussion

3.1. Included studies

From the five electronic databases, 9,540 studies were identified. After the removal of duplicates and ineligible articles, 36 articles were included. Review and feasibility or pilot test articles were excluded, and six papers were finally reviewed. Among these, three studies conducted VT, and three used robotics in home-based rehabilitation studies.

3.2. Intervention details for included studies

The intervention details are shown in Table 1.

The studies reviewed were published between 2014 and 2020. The threeVT studies were conducted in Australia, UK, and Spain. The definition of a VT device in studies was "the device regarding computing technologies to provide a virtual environment that simulates the physical environment," such as a game environment.

VT was applied in the upper arm in two studies and the lower extremities in one study. Robot-assisted devices were usedin the upper limb for all analyses.

Table 1. Intervention details forsix selected studies.

Author(s)	Year	Country	Types	Intervention detailsare stated as follows:
Johnson et al. [1]	2020	Australia	Virtual Therapy	"It was delivered via the Jintronix Rehabilitation System,which uses a Microsoft Xbox Kinect camera to detect limb movements, and a standard laptop connected to a television to display the exercises."
Standen et al. [2]	2016	UK	Virtual Therapy	"Virtual glove used a hand-mounted power unit, with four infra-red light emitting diodes mounted on the user's fingertips. The diodes were tracked using one or two Nintendo Wiimotes mounted by the monitor on which the games were displayed to translate the location of the user's hand, fingers, and thumb in three-dimensional space."
Llorens et al. [3]	2015	Spain	Virtual Therapy	"The virtual environment used in the experiment represented the participants' feet and their movements in an empty scenario, consisting of a checkered floor that facilitated the perception of depth, with a central circle representing the center of the virtual environment."
Linder et al. [4]	2015	USA	Robotics	"The Hand Mentor Pro robot-assisted device uses a pneumatic pump to facilitate active-assisted movement of the wrist and fingers. The device consists of a computer control box, arm unit, data collection device, and a communications module."
Wolf et al. [6]	2015	USA	Robotics	"Kinetic Muscles Inc's Hand Mentor (an upper-extremity (UE) a robotic device that added store-and-forward" communication and Web-based monitoring) program + home exercise program was provided to the experiment group. In the control group, a home exercise program was given."
Lemmens et al. [7]	2014	UK	Robotics	"The robotic system Haptic Master (MOOG, Nieuw-Vennep, NL) was used for the arm-hand training. Haptic Master is an end-effector-based robotic device with three active degrees of freedom. A gimbal was attached to the Haptic

				Master, connecting the patient's forearm with the Haptic Master, thereby adding three extra (non-actuated) degrees of freedom. This gimbal was designed explicitly for task-oriented training, allowing the hand to be free to grasp and manipulatnaturalal objects in the three-dimensional space."

3.3. Inserting and omittingcriteria of included studies based on subject

Table 2 presents the inserting and missingmeasures of study participants.

Age, stroke duration, and physical function were the most common inclusion criteria. Among the included studies, three were on adults, and the others did not describe the details. The most frequent time in the included studies was six months after stroke. In most studies, VT or robotic assistive devices were administered to participants with normal cognitive function. Physical ability was evaluated using the Fugl-Meyer Scale (FMA). The Mini-Mental State Test was used to assess mental state (MMSE). Patients with severe neurogenic or aphasic conditions or those with neglect symptoms were excluded.

Table 2. Inserting and omittingcriteria of each study

Author(s)	Types	Inserting criteria	Omitting criteria
Johnson et al. [1]	Virtual Therapy	≥18 yr, Fugl–Meyer Upper Extremity (FMUE) Score 25–45, Mini-mental State Exam (MMSE) >24, at least three months post-stroke	Other neurological conditions, upper extremity joint pain
Standen et al. [2]	Virtual Therapy	Residual arm dysfunction	Severe symptomatic arm or shoulder pain, unable to sit for 30min
Llorens et al. [3]	Virtual Therapy	≥40 aged≤75, >6m, Berg Balance Scale (BBA) 7-12, MMSE>23	Severe aphasia, hemispatial neglect, ataxia
Linder et al. [4]	Robotics	Stoke within 6m, Fugl–Meyer Assessment (FMA)11-55	Modified Rankin scale (MRS) >1, anti-spastic injection,
Wolf et al. [6]	Robotics	Stoke within 6m, FMA11-55	MRS >1, anti-spastic injection, etc.
Lemmens et al. [7]	Robotics	18-85 aged, first-ever stroke, MRC grade2-4, post-stroke time≥12m, MMSE≥26,	Severe neglect, severe spasticity, aphasia, apraxia

3.4. Frequency and dose of intervention

Table 3 shows the frequency and doses of the interventions.

Five reviewed studies applied VT and robot-assisted device interventions to the upper extremities. Only one VT program was provided to improve gate balance.

The duration of the intervention was eight weeks. However, the time of application in each session differed in each study. It lasted at least 20–45 min, and some studies were unrestricted. VT has been shown to vary between studies. However, this was like the regular application of 2–3 cycles per week. The robot-aided device had larger intervention dosages than the VT.

Contrarily, usual care, clinical rehabilitation, and home exercises were applied as counter-interventionsin the same manner.

Table 3. Frequency of intervention and types of counter interventions.

Author(s)	Intervention(n)	Target	Duration of intervention	Counter intervention(n)
Johnson et al. [1].	Virtual Therapy	Upperextremity	Eight weeks (45min, twotimes/week)	Usual care
Standen et al. [2].	Virtual Therapy	Hand	Eight weeks (20min, threetimes/d)	Usual care

Llorens et al. [3]	Virtual Therapy	Gait	Eightweeks (45min, threetimes/week)	The same rehab in the clinic
Linder et al. [4]	Robotics	Hand	Eight weeks (5d/week, 3h)	Home exercise & phone call:8weeks, fived/week, threeh
Wolf et al. [6]	Robotics	Wrist and finger	Eight weeks (5d/week, 3h. total 120h)	Home exercise & phone call:8weeks, fived/week, threeh
Lemmens et al. [7]	Robotics	Arm-hand	Eight weeks (4times/week) 2*30min/d)	Task-oriented training

3.5. Primary outcome measurement and its results

Table 4 presents the primary outcomes and the main results of each study.

Most studies used physical function, such as motor function and balance, as the primary outcome. The effectiveness of the VT or robotic intervention was determined by measuring changes in quality of life, ADLs, and depression from the beginning through the conclusion of treatment.In a study by Lemmens et al. [7], We measured effectiveness based on how long and hard the patient had to utilize their injured arm and hand.The robot-assisted device was used as a tool to increase motivation for compliance.

The results from VT studies were improved regarding physical function, but no between-group difference in the robot-assistive device was found in the studies.

Table 4. Primary outcomes and its findings

Author(s)	Types	Primary outcomes measure	Findings
Johnson et al. [1]	Virtual Therapy	Fugl–Meyer Upper Extremity (FMUE) & the Action Research Arm Test (ARAT)	The FMUE showed statistically significant variations across groups, but the Action Research Arm Test showed no such differences.
Standen et al. [2]	Virtual Therapy	The Nottingham Extended Activities of Daily Life, the Motor Activity Diary, the Wolf Motor Function Test, and the Nine-Hole Peg Test	Strength on the midway Wolf Grip and two final subscales of the Motor Activity Log showed a substantially more significant improvement from baseline in the intervention group.
Llorens et al. [3]	Virtual Therapy	Balance testing with the Berg Balance Scale.	Berg Balance Scale scores increased significantly from baseline to posttreatment for both groups, and home-based rehabilitation was effective.
Linder et al. [4]	Robotics	Stroke Impact Scale Depression Scale	On the Stroke Impact Scale and the Depression Scale, both groups showed statistically significant improvements in every category save one.
Wolf et al. [6]	Robotics	The Wolf Motor Function Test and the Action Research Arm Test, along with the Fugl-Meyer Assessment	All measures of success in the upper extremities went raised in both groups.
Lemmens et al. [7]	Robotics	What kind of services were performed for how long and how intensely with the injured arm and hand	The training could have appreciably altered the time spent using, or the intensity with which, the afflicted arm and hand.

3.6. Discussion

In this review, we asked four questions and answered them through a systematic analysis.

The answer to the first question, “How many home-based rehabilitation studies have been conducted?” was that six were VT studies, and the others were robot-assisted device home-based rehabilitation program studies. Home-based rehabilitation for stroke survivors has been widely administeredasa more patient-centered and tailored therapy in a natural environment [9-10]. With the recent development of the IT environment, studies using virtual environments, such as VT, have been conducted, and their effectiveness has been reported. A systematic review by Chen et al. discovered that between 2004 and 2017, a wide range of home-based technology for stroke therapy was available[10]. Playing games, telecommunication programs, robotic devices, virtual reality, patients' exercise movement sensor systems, and mobile devices were included in home-based technologies [10]. Six to seven studies on VT or robotics have been found among them.

The answer to the second question,"What were the criteria for inclusion and exclusion of participants?" was similar among the studies. Adult age was a standard inclusion criterion in all included studies. After six months of stroke, most studies were selected as subjects. Moreover, the general inclusion criteria included cognitive function, intact status, and minimal physical function. However,patients with symptoms of neglect and aphasic states were not included in any of the selected studies.

The answer to the third question, "What was the frequency and dose of the intervention?" differed according to the study environment. The frequency and dose of VT were lower than those of the robot-assisted device. Laver et al. suggested more than 15 h of VT dose (total) to improve upper limb function [11]. The total dose of robot-assisted device intervention was 120 h in one study [6], which was longer than that in the VT study. However, Assistive robots often need a sizable amount of free floor space in the home and can be a pain to set up [11-13].

The answer to the last question,"What were the primary outcomes, and was the intervention effective?" was inconsistent. The study findings differed according to the study environment, intervention types, and participants' status. However, most studies used physical function as the primary outcome. Between-group differences were rare, whereas within-group differences were found regarding physical function and muscle strength in the intervention group. These findings are like those of previous studies. For example, Laver et al. reported that virtual reality could help improve the functions of upper extremities and activities of daily living when used as an adjunct to usual care through the Cochrane Review [11].

This review investigated intervention types such as VT and robot-assisted devices and their characteristics to obtain information regarding new home-based technological rehabilitation in non-face-to-face rehabilitation.

However, several limitations of this study should be considered when interpreting the results. We did not perform any meta-analysis to calculate the effective sizes of VT and robot-assisted device interventions. A rigorous systematic search strategy should be used in future studies[14-17].

4. Conclusion

From this implementation fidelity review, the frequency and dose of VT werelower than those of robot-assisted devices but not inferior to the robot's physical function. However, the long-term effects should be considered, such as caregiver support, technical limitations, and cost-effectiveness. Home-based VT and robot-assisted device rehabilitation are required to verify the effectiveness of arm function in stroke survivors.Further research on the efficacy and impact size of non-face-to-face treatments in community rehabilitation for a physical role should focus on conducting systematic reviews and meta-analyses of high-tech home-based rehabilitation.

5. Acknowledgment

This study was made possible by funding from Chungnam National University.

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