

Virtual Reality-based Training Program Using Computer-human Interface for Recovery of Upper Extremity Use in Stroke Patients

Kyoung-Hee Lee, Ki-Chul Hwang

Dept. of Occupational therapy, Baekseok University

뇌졸중 환자에서 상지 회복을 위해 컴퓨터-인간 연동을 이용한 가상현실 기반 훈련 프로그램

이경희, 황기철
백석대학교 작업치료학

Abstract To identify virtual reality (VR) interventions used for upper extremity rehabilitation in stroke patients. The Medline database was searched up to February 11, 2015. Randomized controlled and clinical trials that included a VR intervention for upper extremity rehabilitation in stroke patients were included. The Physiotherapy Evidence Database (PEDro) scale was used to assess the quality of the included studies. In total, 8 studies were included. PEDro scores varied from 5 to 8/10. All studies showed significant improvement in outcomes in favor of the VR group. This review suggests that VR applications used for upper extremity rehabilitation in stroke patients predominantly mediate learning through providing task-oriented and graduated learning with variable and unpredictable practice.

Key Words : virtual reality, exercise, stroke, upper extremity, recovery

요약 본 연구는 뇌졸중 환자의 상지 재활에 사용되는 컴퓨터-인간 연동을 이용한 가상현실 기반 훈련 프로그램 중재의 효과를 알아보려고 하였다. 2015년 2월까지 Medline 데이터베이스에서 뇌졸중 환자의 상지 재활을 위한 가상현실 중재를 다루는 무작위 대조군 임상 연구들을 검색하였다. PEDro 스케일이 연구의 질을 사정하기 위해 사용되었다. 선정된 8개의 연구가 분석되어졌다. PEDro 스케일은 5 부터 8/10까지 다양했다. 모든 연구들은 가상현실 기반 훈련 그룹에서 상지 기능 회복에 유의한 결과를 보였다. 본 연구는 뇌졸중 환자의 상지 회복을 위해 사용되는 가상현실 기반 훈련 프로그램의 적용이 다양하고 예측할 수 없는 실행으로 구성된 과제 지향적이고 점진적인 학습을 제공함을 통해 특히 배움에 효과가 있음을 보여주었다.

본 연구에서는 가상현실 훈련 프로그램을 뇌졸중 환자의 상지 기능 재활에 탁월한 학습 효과를 기대할 수 있으며 과제-지향과 등급화된 학습을 제공하는데 효과적이다.

주제어 : 가상현실, 운동, 뇌졸중, 상지, 회복

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Corresponding Author: Ki-Chul Hwang
(Dept. of Occupational therapy, Baekseok University)
Email: otvision@bu.ac.kr

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1. Introduction

Upper extremity (UE) functional deficits after stroke have received much attention because they are strongly related to the quality of life in stroke survivors[1]. Such deficits occur in approximately 70% of patients in the acute phase and persist in about half of patients in the chronic phase after stroke[2, 3]. To reduce UL impairment, new therapeutic approaches, such as constraint-induced movement therapy, robotic arm training, and virtual reality (VR) therapy, have been used successfully over the last decade[4,5,6].

The current standard of care for stroke rehabilitation consists of physical therapy and occupational therapy that help with motor skills learning or relearning after a stroke[7]. VR technology is currently being explored because of its potential benefit as a therapeutic intervention for retraining coordinated movement patterns. This technology provides the capability to create an environment in which the intensity of feedback and training can be manipulated systematically and enhanced to create the most appropriate, individualized motor learning paradigm[8]. VR is a computer-generated interactive simulation that imitates reality and provides users with an artificial environment, including sensory information similar to the real-world experience. It was first used specifically in rehabilitation about 15 years ago[9]. VR-based rehabilitation programs have gained medical attention as novel therapeutic alternatives for motor recovery after strokes[10]. The objective of this systematic review was to identify VR training programs that have been used for upper extremity rehabilitation in stroke patients.

2. Research Method

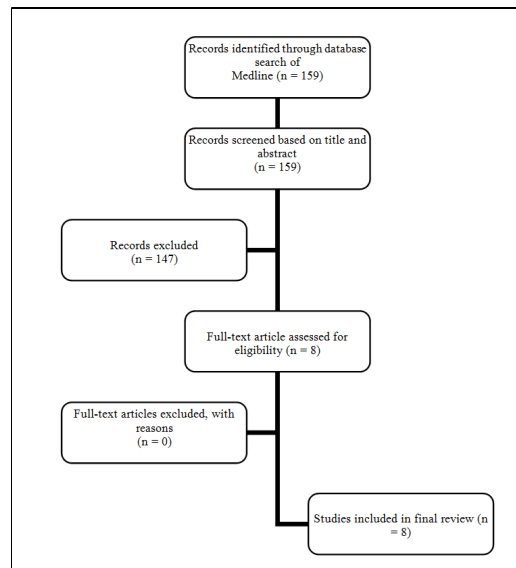
2.1 Search strategy

The major search terms were VR, stroke, and randomized controlled trial (RCT) and clinical study.

Depending on the search engine, subject headings and keywords based around the search terms were used to identify relevant articles. The authors searched the databases Medline (from 2010 to February 11, 2015). An example of the Medline search strategy is presented in Figure 1(("Virtual Real"[Journal] OR ("virtual"[All Fields] AND "reality"[All Fields]) OR "virtual reality"[All Fields]) AND ("stroke"[MeSH Terms] OR "stroke"[All Fields]) AND ("rehabilitation"[MeSH Terms] OR "rehabilitation"[All Fields] OR ("rehabilitation"[All Fields] AND "therapy"[All Fields]) OR "rehabilitation therapy"[All Fields])) AND ("2010/02/10"[PDat] : "2015/02/08"[PDat]).

2.2 Study Selection

Studies published in English were deemed eligible if they met the following criteria. (a) Study Design. RCTs published in peer-reviewed journals. (b) Participant. All type of stroke was 18 years old and older. (c) Interventions. Studies with any form of VR-mediated therapy, including immersive, noimmersive, and off-the-shelf gaming system technologies. (d) Outcomes. Studies that included at least one validated measure of upper extremity motor function, activity, and recovery.



[Fig. 1] Flow diagram of study selection

(Table 1) Characteristics of the selected studies (N=8)

Citation	Sample	Experimental/ control intervention	Frequency, duration of intervention	Outcome measure(s)	Data collection	Main findings
Kiper et al., 2014 [13]	Reinforced feedback in virtual environment stroke group (n = 23) and traditional rehabilitation stroke group (n = 21) -mean age of 64.3±12.6 years -mean time from stroke of 4.2±3.1 months.	<i>Experimental:</i> Treatment with reinforced feedback in virtual environment • 1 h of TR and 1 h of RFVE <i>Control:</i> Treatment with traditional rehabilitation program • 2 h of TR	5 days weekly for 4 weeks.	Fugl-Meyer upper extremity scale (F-M UE), Functional Independence Measure scale (FIM), and kinematics parameters (speed, time, and peak)	Baseline, end of treatment, and 4-week retention	RFVE treatment is promising to reduce the impairment of the upper limb (P < 0.05).
Shin et al., 2014 [10]	-Chronic stroke patients (n = 7) -Acute or subacute stroke (n = 16)	<i>Experimental:</i> Chronic stroke received 30 min of RehabMaster intervention per day for 22 weeks; 10 sessions - Subacute or acute stroke: Conventional occupational therapy only (OT-only group) <i>Control:</i> conventional occupational therapy plus 20 min of RehabMaster intervention (RehabMaster + OT group)	30 min of RehabMaster intervention; per day for 22 weeks; 10 sessions	Fugl-Meyer Assessment score (FMA), modified Barthel Index (MBI) adverse effects, and drop-out rate	Baseline, end of treatment, and 2-week retention	RehabMaster is a feasible and safe VR system for enhancing upper extremity function in patients with stroke (P < 0.05).
Viana et al., 2014 [14]	-Virtual reality training + tDCS (n = 10) -Virtual reality training + sham tDCS (n = 10)	<i>Experimental:</i> Virtual reality training + tDCS <i>Control:</i> Virtual reality training + sham tDCS	-VRT was applied 3 days a week for 5 weeks, totaling 15 h - tDCS (2 mA) was applied for 13 min	-Fugl-Meyer assessment (FMA) -Wolf motor function test -Modified Ashworth scale -Hand-held dynamometry - Stroke specific quality of life scale	Post-training assessment and after 5 weeks	No group differences in motor function
Lee and Chun, 2014 [15]	-Cathodal tDCS group (n = 21) -VR group (n = 22) -Combination therapy (n = 21)	<i>Experimental:</i> combination cathodal transcranial direct current stimulation (tDCS) and virtual reality (VR) therapy <i>Control:</i> cathodal transcranial direct current stimulation (tDCS) - VR therapy	-tDCS intensity was 2 mA (20 min) -VR therapy was 15 sessions (30 min/d and 5 times/wk for 3 weeks)	Fugl-Meyer Scale K-MBI Korean-Modified Barthel Index) MFT (manual function test) MMT (manual muscle test)	Performed before and immediately after treatment (3 weeks)	Combination of brain stimulation using tDCS and peripheral arm training using VR could provide additional benefits to the training of UE recovery after stroke over those benefits achieved with either intervention alone (P < 0.05).
Sin and Lee, 2013 [16]	-stroke experimental group (n = 18) -stroke control group (n = 17)	<i>Experimental:</i> virtual reality training using Xbox Kinect and conventional occupational therapy <i>Control:</i> conventional occupational therapy alone	All interventions were 3 times per week for 6 weeks.	Fugl-Meyer Assessment -Box and Block Test	At baseline and after 6 weeks of intervention	After intervention, significant improvements from baseline values in range of motion of the upper extremity (P < 0.05).
Turolla et al., 2013 [17]	-Upper Limb Conventional (ULC) (n = 113) -Virtual Environment (RFVE) (n = 263)	<i>Experimental:</i> ULC + RFVE <i>Control:</i> RFVE	40 sessions of daily therapy provided 5 days per week, for 4 weeks.	-Fugl-Meyer Upper Extremity (F-M UE) -Functional Independence Measure (FIM) scales	At baseline and after 4 weeks of intervention	RFVE therapy yielded significantly better post-treatment F-M UE and FIM improvements than ULC therapy (P < 0.05).
Felipe et al., 2013 [18]	chronic stage stroke (least 6 months) (n = 8)	<i>Experimental:</i> Gesture (GT) Therapy	- virtual reality-based GT 20 sessions of 45 min	-fMRI -Fugl-Meyer Upper Extremity (F-M UE) -Motricity Index	before and after therapy	Overall significant improvements in motor skills (P < 0.05).
Kwon et al., 2012 [19]	26 individuals with acute hemiparetic stroke (14 males, 12 females, mean age 57.54±13.68) were recruited from a general teaching hospital in Seoul, Korea.	<i>Experimental:</i> Virtual Reality training in addition to conventional therapy (CT) <i>Control:</i> CT	- VR was provided for 30 min per day, 5 days per week for 4 weeks in addition to CT. - CT was provided for 70 min per day, 5 days per week for 4 weeks.	The Fugl-Meyer Assessment (FMA), the Manual Function Test (MFT), the Korean version of the Modified Barthel Index (K-MBI)	Pre-intervention, Post-intervention	VR training had the advantage of improving intended arm function during intensive training for individuals in the acutestage of stroke.

2.3 Study Quality Assessment

The Physiotherapy Evidence Database (PEDro) scale was used to assess the quality of the studies that met the inclusion criteria. The PEDro scale is an 11-item scale designed to rate the methodological quality of RCTs [11]. A total score (range = 0 - 10) is calculated by summing the individual scores of the 10 items. Studies with scores lower than 6 are considered low quality[12].

3.3 Quality Assessment

<Table 2> details the quality assessment for each study. The scores ranged from 5 to 8/10. All studies randomly allocated the treatments, although evidence for concealed allocation was unclear in most studies [14]. Some subjects and clinicians were supposedly blinded, although this would not appear possible [13,14,15,16,17,18]. Only one study included all randomized subjects in the final analysis (i.e., either no drop-outs or intention-to-treat analysis)[19].

3. Results

3.1 Data synthesis

The initial search yielded 159 papers. After duplicates were removed, 8 potential articles were identified. The two authors independently evaluated the title and abstract of each of the 8 articles against the study inclusion criteria. Finally, the 8 articles were found to meet the inclusion criteria.

3.2 Characteristic of included studies

<Table 1> summarizes the characteristics of the included studies.

4. Conclusions

The results of this review show that variable training was present in the design of most VR interventions used for upper extremity rehabilitation in a stroke population. This suggests that VR may enhance learning predominantly through providing a task-oriented and graduated learning under variable and unpredictable practice. VR training programs cover a wide range of occupational therapy as a part of rehabilitation. Occupational therapy is required for various conditions, including damage to the central nervous system and stroke. The range of rehabilitative treatments, including occupational therapy, has been expanded.

<Table 2> Quality assessment of selected studies using the physiotherapy evidence database scale (9) (N=8). 1= yes; 0= no.

	Kiper et al., 2014 [13]	Shin et al., 2014 [10]	Vina et al., 2014 [14]	Lee and Chun, 2014 [15]	Sin and Lee, 2013 [16]	Turolla et al., 2013 [17]	Felipe et al., 2013 [18]	Kwon et al., 2012 [19]
Random allocation	1	1	1	1	1	0	1	1
Concealed allocation	0	0	0	0	0	0	0	0
Baseline comparability	1	1	1	1	1	1	1	1
Subject blinded	0	0	0	0	0	0	1	1
Clinician blinded	0	0	0	0	0	1	0	0
Assessor blinded	0	1	1	1	1	1	0	1
Data for at least 1 outcome from >85% of subjects	1	1	0	1	1	1	1	1
No missing data or if missing, intention-to-treat analysis	0	0	0	0	0	0	0	1
Between-group analysis	1	1	1	1	1	1	0	1
Point estimates and variability	1	1	1	1	1	0	1	1
Total score (/10)	5	6	5	6	6	6	5	8

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이 경 희(Lee, Kyoung Hee)



- 2005년 2월 : 포항대학교 작업치료과(보건전문학사)
- 2008년 8월 : 대구대학교 재활과학대학원(이학석사)
- 2013년 8월 : 건국대학교 일반대학원 의학과(의학박사)
- 2013년 3월 ~ 현재 : 백석대학교 작업치료학과 교수

- 관심분야 : 신경계 작업치료, 재활의학, 신경과학
- E-Mail : otprin38@bu.ac.kr

황 기 철(Hwang, Gi Chul)



- 2001년 2월 : 연세대학교 작업치료학과(보건학사)
- 2004년 2월 : 창원대학교 교육학과 특수교육학전공(교육학석사)
- 2007년 8월 : 대구대학교 일반대학원 재활과학과(이학박사)
- 2012년 3월 ~ 현재 : 백석대학교 작업치료학과 교수

- 관심분야 : 재활과학, 작업치료학
- E-Mail : otvision@bu.ac.kr