J. Phys. Ther. Sci.
24: 339–343, 2012

Virtual Reality Reflection Therapy Improves Motor Recovery and Motor Function in the Upper Extremities of People with Chronic Stroke

Tae Sung In, PT, MS[1)], Kyung Sim Jung, PT, MS[1)],
Seung Won Lee, PT, PhD[1)], Chang Ho Song, PT, PhD[1)]

[1)] *Department of Physical Therapy, Sahmyook University: 26-21 Gongneung2-dong, Nowon-gu, Seoul, 139-742, Republic of Korea.*
TEL: +82 2-3399-1630, FAX: +82 2-3399-1638, E-mail: chsong@syu.ac.kr

Abstract. [Purpose] The main purpose of this study was to investigate the effects of Virtual Reality Reflection Therapy on motor recovery and motor function in the upper extremities of patients with chronic stroke. [Subjects] Nineteen participants patients with chronic stroke were randomly assigned to the experimental group (n=11) and the control group (n=8). [Methods] The experimental group performed a Virtual Reality Reflection Therapy program for 30 minutes a day, 5 days a week, during a 4 week period, in addition to conventional therapy. The control group received conventional therapy and performed sham program. All subjects were evaluated using by the Fugl-Meyer Assessment (upper limb section), the Modified Ashworth Scale (MAS), the Box and Block Test (BBT), the Jebsen-Taylor Hand Function Test and the Manual Function Test pre- and post-intervention. [Results] The experimental group and the control group effectively increased their upper-extremity motor recovery and motor function. Upper-extremity motor recovery and motor function of the experimental group showed more significant increases than those of the control group. [Conclusion] Virtual Reality Reflection Therapy (even as a home treatment) with a conventional program in the early stages of treatment might be beneficial for improving hand function. Future studies need to investigate the effectiveness of Virtual Reality Reflection Therapy with optimal patient selection or duration and intensity of training.
Key words: Stroke, Virtual reality, Mirror therapy

(This article was submitted Oct. 13, 2011, and was accepted Nov. 22, 2011)

INTRODUCTION

A Cerebrovascular Accident (CVA) usually results in loss of brain function(s) due to ischemia caused by blockage or hemorrhage in people over 65. As a result the brain is unable to function normally, and CVA is the leading cause of loss of social, mental, physical and functional abilities. Generally, 40% of patients with stroke are functionally challenged and 15–20% of stroke patients have several impairments[1, 2)]. Stroke patients tend to place 61–80% of their body weight on the sound side, leading to asymmetric posture, and 55–75% of patients experience functional limitation of their upper limbs[3)]. Patients with hemiplegia caused by CVA typically demonstrate abnormal muscle tone, primitive reflexes, flexed synergy patterns, and problems with coordination, as well as associated reactions and movement. Motor function on the affected side is noticeably decreased due to musculoskeletal system damage and sensory disorders[4)]. These inhibited abilities limit daily activities and lower the quality of life[5)]. There are several treatments for improving restricted abilities, including Functional Electric Stimulation (FES), training with auditory feedback, training with an assisting robot and Constraint-Induced Movement Therapy (CIMT). However, most stroke rehabilitation therapies address incompatibility by concentrating on facilitating functional abilities on the affected side. Most interventions also concentrate on facilitating functional abilities on the affected side[3)]. Stubeyaz et al.[6)] suggested a new method of treatment called mirror therapy, concentrating movement on the unaffected side. A therapeutic program with a mirror was first introduced by Ramachandran and Roger-Ramachandran in 1996, using a visual illusion as a cure for phantom limb pain for people with amputated limbs[7)]. Mirror therapy for stroke patients stimulates proprioceptive senses through visual information in which the motion of the sound side is reflected in a mirror placed beside the affected part of the body[8)]. Grasping power, actual motion of the hand, Range of Motion (ROM)[9)], velocity and dexterity[10)] were significantly improved as a result of motor imaginary training for chronic stroke patients. Funase et al.[11)] reported that the cortex and spinal cord are stimulated by the mirror neuron system, which is activated from observation and imitation of motions seen in the mirror. However, studies have investigated the selection of appropriate subjects, treatment period, duration, and intensity of programs[6)]. Tilting the neck toward the unaffected side to look at the mirror leads to asymmetric posture due to ignoring the median line of the body resulting in a crooked spinal column. In addition,

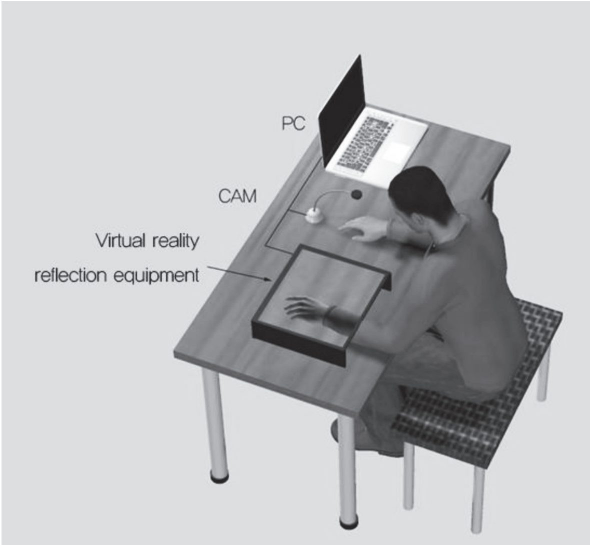

Fig. 1 . Virtual Reality Reflection Therapy

segmental movement of the trunk and limbs is challenged[12]. The ideal aim of rehabilitating people with stroke is to reduce asymmetry[13]. Therefore, there is a need for new types of intervention that differ from traditional mirror therapy. The objective of this study was to examine the effectiveness of using Virtual Reality Reflection Therapy equipment with a monitor on top of the affected limb, keeping an even posture, on the functional recovery of the upper extremities of individuals with stroke.

SUBJECTS AND METHODS

Participants were inpatients who had suffered a stroke at least 6 months previously, and were selected from among patients at the H rehabilitation center in Seoul. Patients were randomly assigned to an experimental group or a control group. Random allocation software (version 1.0) was used to minimize selection bias[14].

Subjects were included in the study if they were able to understand and follow simple verbal instructions, had a MMSE-K score over 21, had a Brunnstrom score between Stages I and IV, had no apraxia or hemineglect, and had no orthopedic conditions such as fractures or digital neuropathy of their upper extremities.

Subjects independently sat on a stool with their feet on the ground, with a gap of 8.4 cm between their heels, and a 9° eversion of the big toes. To avoid an asymmetric posture, an anterior pelvic tilt was assumed with the hip, knee and ankle joints flexed. In preparation for treatment, each patient in the experimental group had their affected hand put in the box while the other one was placed directly under the camera (Fig 1). Each participant then had to line up his or her arm with the image of the other one displayed on the screen and decide on a speed of motion that was comfortable. Patients had to look at the monitor during this assignment. Treatment was given to patients for 30 minutes a day, 5 days a week, for a total of 4 weeks. Completing the exercise meant a total of 3 sets of 10 repetitions. Patients performed the steps under the supervision of caregivers and had to fill out a checklist after finishing the exercise. The control group received the same treatment, except they had to look at their unaffected hand as the monitor was off.

A new therapeutic procedure for training was provided for the patients in the first week following suggestions by Stevens and Stoykov[10]. The program was designed with progressively harder tasks to complete as a way of maintaining participant interest. Detailed procedures were broken up into week-long segments. In the first week, the patients started with an easy program: wrist flexion and extension, forearm pronation and supination, and clenching and opening the hand. In the second week, the aim was to exercise gross movement of the hand with simple tasks like picking up cups of different sizes and weights. Fine hand motion was the aim of the third week. Patients had to complete these assignments: pegging clothespins, pushing buttons on a calculator, using chopsticks and opening a bottle. The fourth week was more complicated, as the patients had to put together a puzzle, draw a circle and square with a pen, and play a game of toy golf.

Outcome was measured in terms of upper-extremity motor recovery and motor function. Upper extremity motor recovery was evaluated using by the Fugl-Meyer Assessment (FMA) and the Modified Ashworth Scale. FMA was used to assess motor recovery of the 15 upper extremity items[15] dealing with shoulder·elbow·forearm: 5 with the wrist, 7 with the hand and 3 with coordination. The maximum score of the FMA is 66. Inter-rater reliability of upper extremity scale of FMA is r=0.99 and it has a test-retest reliability of r=0.9932. Spasticity was measured by the Modified Ashworth Scale (MAS). This is a subjective assessment and has verified validity[16]. The MAS is a 6-point scale (0, 1, 1+, 2, 3, 4), with a score of 0 indicating no resistance and 4 indicating rigidity.

Upper extremity motor function was the Box and Block Test, the Jebsen Hand Function Test, and the Manual Function Test (MFT). The Box and Block Test is a standard tool for measuring hand coordination and promptness of the upper limbs. It has a test-retest reliability of r=0.99 for the left hand and r=0.94 for the right. The inter-rater reliability is r=0.99 for the left and r=1.00 for the right. The components of the test are wooden regular cubes (2.54 cm × 2.54 cm × 2.54 cm) and a wooden box (53.7 cm × 8.5 cm × 27.4 cm) divided in the middle. The test measures the number of cubes transferred from the affected side to the other side in 1 minute[17].

The Jebsen Hand Function Test was developed to provide a standardized and objective evaluation of several major aspects of hand function using simulated everyday activities. There are 7 items to assess: writing short sentences, turning over cards, picking up small objects and putting them in a can, simulated feeding, stacking checkers, picking up large light objects and picking up large heavy objects. Scoring is determined by the time necessary to complete each subtest. It has a high test-retest reliability of r=0.99[18].

MFT is an upper limb function assessment measure for hemiparetic patients after stroke, developed by Sakai Rehabilitation Instruments, Japan. This test consists of 8 items: 4 items (flexion, extension, abduction, and adduction) for the shoulders, 2 for the hands (garbing, picking up) and 2 for the fingers (transferring cubes, pinning). The total MFT score can range from 0 (severely impaired) to 32 (full function). This assessment of the affected body has a test-retest reliability of r=0.994 and an inter-rater reliability of r=0.993[19].

All statistical analyses were performed using SPSS version 12.0 statistical software (SPSS Inc., Chicago, IL, USA). Results are presented as mean± standard deviation (SD). Prior to training, the normality of the data was assessed with the Shapiro-Wilk test. Chi-square analysis, the Mann-Whitney U test and the independent samples t-test were performed to examine the significance of differences for variables. The Wilcoxon Signed Rank test and the paired t-test were used to compare motor recovery and motor function before and after treatment. The Mann-Whitney U test and the independent samples t-test were performed to identify differences between groups. For all tests, statistical significance level was chosen as 0.05.

RESULTS

A total of 24 subjects participated in this study; 14 in the experimental group and 10 in the control group. Of this number, 5 dropped out from the study (3 from experimental, 2 from control) complaining of dizziness or were discharged from the hospital. The general characteristics of nineteen subjects with chronic stroke who fulfilled the inclusion criteria for study are summarized in Table 1. There were no significant differences in the baseline value between the experimental and control groups.

Fugl-Meyer Assessment scores increased significantly in both groups ($p<0.05$). In the comparison of the two groups, there was a significant difference in the score changes of the two groups ($p<0.05$) (Table 2). There were no significant differences in MAS in either group after therapeutic intervention. In addition, the difference in the score changes of the two groups was not significant (Table 3).

Table 1. General characteristics of subjects

	Experimental group	Control group
Gender (male/female)	11 (7/4)	8 (4/4)
Age (years)	63.45 ± 11.78	64.50 ± 12.69
Height (cm)	162.64 ± 10.35	164.38 ± 9.36
Weight (kg)	59.41 ± 12.14	60.81 ± 11.86
Affected-side (right/left)	5/6	4/4
Onset-time (months)	14.00 ± 4.88	12.75 ± 6.78
Lesion type (hemorrhage/ischemia)	4/7	5/3

Note. Values are expressed as mean ± standard deviation (SD). NS: not significant

Box and Block Test scores showed significant improvement in the experimental group ($p<0.05$), but not in the control group. There was no significant difference in the score changes of the two groups (Table 4). Jebsen Hand Function Test scores showed significant improvement in the experimental group ($p<0.05$), but not in the control group. There was no significant difference in the score change of the two groups (Table 5). Manual Function Test scores showed significant improvement in the experimental group ($p<0.05$), but not in the control group. However, there was a statistically significant difference in the score changes of the two groups ($p<0.05$) (Table 6).

DISCUSSION

Mirror therapy is a treatment for improving the movement of an affected extremity with proprioceptive information given through visual illusion instead of actual use of the extremity. With existing methods, patients need to watch the mirror, and this leads to asymmetric posture. This study was therefore designed to compensate for the limitations of virtual reality reflection equipment and investigate the effects of Virtual Reality Reflection Therapy on

Table 2. Fugl-Meyer Assessment: Pre- and Post-Training

		Experimental group	Control group
Fugl-Meyer Assessment	Pretraining	49.09 ± 11.53	46.57 ± 11.89
	Posttraining	59.45 ± 7.42	49.57 ± 12.95
	Post – Pre	10.36 ± 5.82*	3.00 ± 2.52*#

Note. Values are expressed as mean ± standard deviation (SD). *, significant change between pre and post MTP intervention. #, significant difference between the experimental group and the control group ($p<0.05$).

Table 3. Modified Ashworth scale: Pre- and Post-Training

		Experimental group	Control groupe
Modified Ashworth scale	Pretraining	0.82 ± 0.56	1.00 ± 0.46
	Posttraining	0.64 ± 0.51	1.00 ± 0.46
	Post – Pre	0.18 ± 0.33	0

Note. Values are expressed as mean ± standard deviation (SD).

Table 4. Box and Block Test: Pre- and Post-Training

		Experimental group	Control group
	Pretraining	14.82 ± 9.48	15.14 ± 9.92
Box and Block Test	Posttraining	16.91 ± 9.76	16.29 ± 10.55
	Post – Pre	2.09 ± 2.66*	1.14 ± 1.46

Note. Values are expressed as mean ± standard deviation (SD). *, significant change between pre and post MTP intervention.

Table 5. Jebsen Hand Function Test: Pre- and Post-Training

		Experimental group	Control group
	Prettrainig	126.62 ± 68.32	134.54 ± 68.90
Jebsen Hand Function Test	Posttraining	100.28 ± 43.47	131.11 ± 70.29
	Post – Pre	26.35 ± 32.09*	3.43 ± 7.67

Note. Values are expressed as mean ± standard deviation (SD). *, significant change between pre and post MTP intervention.

Table 6. Manual Function Test: Pre- and Post-Training

		Experimental group	Control group
	Prettraining	18.73 ± 4.80	20.71 ± 4.46
Manual Function Test	Posttraining	22.36 ± 3.98	21.00 ± 4.97
	Post – Pre	3.64 ± 2.25*	0.29 ± 1.25#

Note. Values are expressed as mean ± standard deviation (SD). *, significant change between pre and post MTP intervention. #, significant difference between the experimental group and the control group (p<0.05).

the upper extremities of people with stroke. Rothgangel et al.[20] reported the necessity of detailed treatment protocols that should focus on standardized outcome measures. To that end, we devised a detailed plan based on the gradual learning method of Stevens and Stoykov[10], utilizing the Jebsen Hand Function Test and the Manual Function Test. Patients received gradual Virtual Reality Reflection Therapy for 4 weeks with apparent improvement showing in the Box and Block Test and the Jebsen Hand Function Test. There were significant differences between the two groups in the Fugl-Meyer Assessment and the Manual Function Test. After 4 weeks' mirror therapy, subjects with sub-acute stroke showed significant improvement in Brunnstrom grade and Functional Independence Measure (FIM)[3]. Moreover, studies of chronic stroke patients have also reported apparent improvement in Fugl-Meyer Assessment and Jebsen Hand Function Test scores, grasping power, wrist ROM, and MAS[10, 21]. There was betterment of performance times as well in the functional actions of bringing a cup up from the table to the mouth, picking up a pen and putting a towel on the shoulder[22]. These improvements came from the mirror neuron system. A mirror neuron is a visual-motor neuron stimulated by observation and imagination of movement as well as actual movement itself[23]. The primary motor cortex is facilitated by paying attention to movement during the task[24]. Garry et al.[25] reported that the primary motor cortex is activated in healthy adults through mirror therapy resulting in transcranial magnetic stimulation. Although Miltner et al.[21] reported 4 weeks of mirror treatment decreased muscle rigidity in chronic stroke patients, no significant improvement was found in the MAS in this study. Minor rigidity of participants pre-intervention was considered to be the reason for the MAS result. Most studies of mirror therapy show different time periods between stroke and treatment, with no standard protocol[20]. Moreover, there needs to be investigation of the effects of mirror therapy on patients with hemineglect[3]. The present study has demonstrated the efficacy of Virtual Reality Reflection Therapy on speed and accuracy of upper extremity function. However, there is no evidence of improvement for people with hemineglect. More research is needed in that area. Furthermore, the possibility that Virtual Reality Reflection Therapy can help maintain a balanced posture should be studied through weight distribution and motion analysis. More practical types of intervention need to be found for those above Stage IV on the Brunnstrom scale and those with lower functional ability.

REFERENCES

1) Duncan PW, Horner RD, Reker DM, et al.: Adherence to postacute rehabilitation guidelines is associated with functional recovery in stroke. Stroke, 2002, 33: 167–178. [Medline] [CrossRef]
2) Kwon S, Hartzema AG, Duncan PW, et al.: Disability measures in stroke: relationship among the Barthel Index, the Functional Independence Measure, and the Modified Rankin Scale. Stroke, 2004, 35: 918–923. [Medline] [CrossRef]
3) Yavuzer G, Selles R, Sezer N, et al.: Mirror therapy improves hand func-

tion in subacute stroke: a randomized controlled trial. Arch Phys Med Rehabil, 2008, 89: 393–398. [Medline] [CrossRef]

4) Prange GB, Jannink MJ, Groothuis-Oudshoorn CG, et al.: Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke. J Rehabil Res Dev, 2006, 43: 171–184. [Medline] [CrossRef]
5) Yang YR, Chen YC, Lee CS, et al.: Dual-task-related gait changes in individuals with stroke. Gait Posture, 2007, 25: 185–190. [Medline] [CrossRef]
6) Sütbeyaz S, Yavuzer G, Sezer N, et al.: Mirror therapy enhances lower-extremity motor recovery and motor functioning after stroke: a randomized controlled trial. Arch Phys Med Rehabil, 2007, 88: 555–559. [Medline] [CrossRef]
7) Ramachandran VS, Rogers-Ramachandran D: Synaesthesia in phantom limbs induced with mirrors. Proc Biol Sci, 1996, 263: 377–386. [Medline] [CrossRef]
8) Stevens JA, Stoykov ME: Using motor imagery in the rehabilitation of hemiparesis. Arch Phys Med Rehabil, 2003, 84: 1090–1092. [Medline] [CrossRef]
9) Altschuler EL, Wisdom SB, Stone L, et al.: Rehabilitation of hemiparesis after stroke with a mirror. Lancet, 1999, 353: 2035–2036. [Medline] [CrossRef]
10) Stevens JA, Stoykov ME: Simulation of bilateral movement training through mirror reflection: a case report demonstrating an occupational therapy technique for hemiparesis. Top Stroke Rehabil, 2004, 11: 59–66. [Medline] [CrossRef]
11) Funase K, Tabira T, Higashi T, et al.: Increased corticospinal excitability during direct observation of self-movement and indirect observation with a mirror box. Neurosci Lett, 2007, 419: 108–112. [Medline] [CrossRef]
12) Carr JH, Shepherd RB: Investigation of a new motor assessment scale for stroke patients. Phys Ther, 1985, 65: 175–180. [Medline]
13) Wall JC, Turnbull GI: Walking asymmetries in residual hemiplegia. Arch Phys Med Rehabil, 1986, 67: 550–553. [Medline]
14) Saghaei M: Random allocation software for parallel group randomized trials. BMC Med Res Methodol, 2004, 4: 26. [Medline] [CrossRef]
15) Duncan PW, Propst M, Nelson SG: Reliability of the Fugl-Meyer Assessment of Sensorimotor Recovery Following Cerebrovascular Accident. Phys Ther, 1983, 63: 1606–1610. [Medline]
16) Pizzi A, Carlucci G, Falsini C, et al.: Evaluation of upper-limb spasticity after stroke: A clinical and neurophysiologic study. Arch Phys Med Rehabil, 2005, 86: 410–415. [Medline] [CrossRef]
17) Mathiowetz V, Volland G, Kashman N, et al.: Adult norms for the box and block test of manual dexterity. Am J Occup Ther, 1985, 39: 386–391. [Medline]
18) Jebsen RH, Taylor N, Trieschmann RB, et al.: An objective and standardized test of hand function. Arch Phys Med Rehabil, 1969, 50: 311–319. [Medline]
19) Miyamoto S, Kondo T, Suzukamo Y, et al.: Reliability and validity of the Manual Function Test in patients with stroke. Am J Phys Med Rehabil, 2009, 88: 247–255. [Medline] [CrossRef]
20) Rothgangel AS, Braun SM, Beurskens AJ, et al.: The clinical aspects of mirror therapy in rehabilitation: a systematic review of the literature. Int J Rehabil Res, 2011, 34: 1–13. [Medline] [CrossRef]
21) Miltner R, Netz J, Hömberg V: Cognitive treatment of sensomotor dysfunctions. Pt Z Physiotherapeuten, 2000, 52: 954–964.
22) Sathian K, Greenspan AI, Wolf SL: Doing it with mirrors: a case study of a novel approach to neurorehabilitation. Neurorehabil Neural Repair, 2000, 14: 73–76. [Medline] [CrossRef]
23) Cattaneo L, Rizzolatti G: The mirror neuron system. Arch Neurol, 2009, 66: 557–560. [Medline] [CrossRef]
24) Fadiga L, Craighero L: Electrophysiology of action representation. J Clin Neurophysiol, 2004, 21: 157–169. [Medline] [CrossRef]
25) Garry MI, Loftus A, Summers JJ: Mirror, mirror on the wall: viewing a mirror reflection of unilateral hand movements facilitates ipsilateral M1 excitability. Exp Brain Res, 2005, 163: 118–122. [Medline] [CrossRef]