

The Effects of Virtual Reality Training on Improving Hand Function and Activities of Daily Living in Patients Living Post-Stroke: A Pilot Study

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뇌졸중 후 환자의 일상생활활동 및 손 기능 개선에 대한 가상현실 훈련의 효과 : 예비 연구

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Abstract The virtual reality training has been suggested as an intervention to improve physical function. But, the effects of virtual reality training focused on improving ADL in patients with acute stroke are unclear. Purpose of this study was to examine the effect of virtual reality training on hand function and activities of daily living (ADL) in patients with acute stroke. Sixteen patients with acute stroke were included in this study. The experimental group (VRA group) received 30 minutes of virtual reality training focused on ADL for each session, while the control group received 30 minutes of conventional virtual reality training. To examine the hand function and ADL of the subjects, the study used Jebsen-Taylor Hand Function Test (JTHFT) and Korean Modified Barthel Index (K-MBI), respectively. Both groups showed significant improvements in hand function of affected and unaffected sides, and in K-MBI total score before and after the intervention. The experimental group showed significantly greater improvements in the self-care domain of K-MBI after intervention than the control group. These findings suggest that the virtual reality training focused on ADL may have a better effect on self-care than conventional virtual reality training in patients with acute stroke.

Key Words : Virtual Reality, ADL, Hand function, Stroke, Upper limb function

요 약 가상현실 훈련은 신체 기능을 개선하기 위한 중재로 제안되었다. 그러나 급성 뇌졸중 환자의 ADL 개선에 초점을 둔 가상현실 훈련의 효과는 명확하지 않다. 본 연구의 목적은 급성 뇌졸중 환자의 손 기능 및 일상생활활동(ADL)에 대한 가상 현실 훈련의 효과를 조사하는 것이다. 급성 뇌졸중 환자 16명이 본 연구에 포함되었다. 실험 군(VRA군)은 각 세션마다 ADL에 중점을 둔 30분의 가상현실 훈련을 받았으며, 통제군은 30분의 보편적인 가상현실 훈련을 받았다. 피험자의 손기능과 ADL을 조사하기 위해 JTHFT(Jebsen-Taylor Hand Function Test)와 K-MBI (Korean Modified Barthel Index)를 각각 사용했다. 두 그룹 모두 중재 후 마비측과 비마비측의 손기능 및 K-MBI 총점에서 유의미한 개선을 보였다. 실험군은 통제군보다 중재 후 K-MBI의 자기관리 영역에서 유의하게 큰 향상을 보였다. 이러한 결과는 급성 뇌졸중 환자에서 ADL에 중점을 둔 가상 현실 훈련이 기존의 가상 현실 훈련보다 자기관리에 더 나은 영향을 줄 수 있음을 시사한다.

주제어 : 가상현실, 뇌졸중, 상지기능, 손기능, 일상생활활동

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1. Introduction

1.1 Background

More than a half of stroke patients live with lifelong unilateral paralysis. These dysfunctions cause them to be dependent on others for activities of daily living (ADL) [1]. Weak upper limb functioning has an inverse relationship with independent ADL due to difficulties in managing self-care activities such as eating, dressing, washing, and bathing [2].

The use of hands in ADL varies depending on an individual's lifestyle. Hand function is often compromised when brain damage occurs within 25% of the entire area of the brain [3]. Because the post-stroke recovery of upper limb function is slower than that of the lower extremities, the onset of rehabilitation should be recommended faster for the arms and hands than that for the other body parts [4].

There are various reports on the intervention methods for upper limb function improvement of stroke patients, including task-oriented training [5], functional electrical stimulation [6], mirror therapy [7], strength training [8], robotic-assisted therapy [9], and virtual reality training [10]. Virtual reality training has been reported to have a positive effect on improving the cognitive function and psychological problems as well as improving the upper limb function in patients with various types of diseases [11].

Recently, a comparative study of virtual reality training and conventional training for the improvement of upper limb function in stroke patients was reported [12]. The results of previous study reported that virtual reality training was more helpful for the upper limb function improvement than conventional training, but a clear effect on ADL improvement was not found.

More recently, Howard's Meta-analysis [13] reported that virtual reality training has a greater effect on physical function than traditional

rehabilitation, but the mechanism responsible for its effectiveness is unclear. In addition, most virtual reality rehabilitation programs have focused on improving motor control, balance, gait, and strength. Improvement of ADL in stroke patients is closely related to social participation and quality of life [14]. Thus, the aim of this pilot study was to investigate the effects of virtual reality training focused on improving ADL in patients with acute stroke.

2. Methods

2.1 Subjects

This study involved 16 patients with acute stroke who received rehabilitation treatment in a I general hospital located in Incheon between January and May 2019. The criteria for selection were as follows: (1) a stroke diagnosed by a neurologist, (2) a stroke with an onset of 30 days or less, (3) a Korean Mini-Mental Status Examination score of 21, and (4) the ability to follow instructions. The exclusion criteria were as follows: (1) visual and auditory problems, and (2) severe apraxia. All subjects voluntarily agreed to participate in the study, and the research was conducted after obtaining written consent.

2.2 Outcome measures

2.2.1 Hand function measurement

Hand function was measured using the Jebsen-Taylor Hand function Test (JTHFT). In this study, measurements were performed on the affected and unaffected side of the hand. The subtests consisted of writing, simulated page turning, simulated feeding, stacking checkers, picking up large light objects, and picking up large heavy objects. The time required for each item was recorded in seconds and scored. The score range was from 0 to 105 [15]. The reliability of JTHFT is .67-.99 for the dominant hand and .60-.92 for the non-dominant hand [16].

2.2.2 ADL measurement

The Korean Modified Barthel Index (K-MBI) was measured to assess ADL in stroke patients [17]. K-MBI consists of 10 areas, including maintaining personal hygiene, self-bathing, feeding, toileting, stair climbing, dressing, bowel control, bladder control, ambulation, wheelchair and chair/bed transfer. For K-MBI, 100 points correspond to independent ADL, and 0 corresponds to dependent ADL. The inter-tester reliability of K-MBI is .93-.98 and the intra-tester reliability is .87-1.00 [17].

2.3 Intervention procedures

All subjects were assigned to experimental group (n=8) or control group (n=8). Pre-assessment was performed after placement. Both groups received conventional rehabilitation therapy for 30 minutes, 5 times a week, for a total of 4 weeks. Physical and occupational therapy were the main components of conventional rehabilitation therapy. Walking, strength training, and range-of-motion exercises were focused on lower extremity training. Occupational therapy included task-based training, upper limb strengthening exercises, and range of motion exercises. The experimental group (VRA group) received 30 minutes of virtual reality training focused on ADL for each session, while the control group received 30 minutes of conventional virtual reality training.

In this study, we used Moto Cog (Cybermedic, Korea), a virtual reality training program, for the VRA group, which received virtual reality training focused on improving ADL performance of the upper limbs. Moto Cog was developed to promote improvement of ADL-related upper limb functions and cognitive function. Moto Cog consists of a touch screen, a handle, and an electronic key. The program consists of three training courses: a hand function training course, a cognitive training course, and an ADL training course. The difficulty level of each training

program is divided into 5 levels. The hand function training course instructs on simple tasks such as turning on a gas stove, opening a door lock, opening an O-type handle, squeezing, opening the handle of an operator, and hammering. The ADL training course consists of activities related to ADL, such as washing, hair-washing, bathing, making cookies, and making pizza. The subjects in the VRA group received the hand function training course and the ADL training course except for the cognitive training course. The general virtual reality training performed in the control group performed a hand function training course that is a little less closely related to ADL, and they did not perform the ADL training course.

2.4 Statistical analysis

The statistical significance level of this study was set to .05 and the collected data were analyzed using SPSS 21. The general characteristics of the subjects were confirmed using frequency analysis. Mann-Whitney U test, Chi-square test or Fisher's exact test were used to compare the general characteristics, hand function, and ADL, while Wilcoxon signed rank tests was used to compare functions before and after the intervention.

3. Results

3.1 General characteristics, hand function, and ADL of subjects

Table 1 and Table 2 show the general characteristics, hand function, and ADL of subjects. There were no significant differences between the two groups in terms of general characteristics, hand function, or ADL of subjects before the intervention.

3.2 Changes of hand function and ADL within groups

Table 1. Characteristics of subjects

(N=18)

	VRA group (n=8)	Control group (n=8)	p
Age(yr)	64.88±11.63	58.00±10.66	.328
Gender(male/female)	5/3	5/3	1.000
Education level(middle/high/college)	1/4/3	4/1/3	.165
Affected side(right/left)	5/3	1/7	.119
Onset duration (days)	7.88±7.85	7.13±2.90	.442
K-MMSE	25.75±3.11	26.00±1.77	.790

VRA: Virtual reality focus on activities of daily living; K-MMSE: Korean-mini mental state examination.

Table 2. Comparison of hand function and ADL before intervention (Mean ± SD)

(N=18)

	VRA group (n=8)	Control group (n=8)	p	
Hand function (score)	JTHFT (affected side)	32.38±23.49	37.00±22.18	.798
	JTHFT (unaffected side)	64.75±15.48	67.38±14.02	.645
ADL (score)	K-MBI total score	60.88±23.73	67.63±18.46	.713
	Personal hygiene	2.63±1.69	3.38±1.60	.505
	Bathing self	1.25±1.49	1.00±1.93	.574
	Feeding	6.13±3.09	8.63±1.77	.083
	Toileting	6.75±2.55	7.25±2.96	.645
	Stair climbing	3.88±3.44	2.88±3.60	.645
	Dressing	5.88±3.56	7.00±2.27	.574
	Bowel control	8.88±1.81	10.00±0.00	.234
	Bladder control	8.25±2.19	9.75±0.71	.195
	Ambulation / WC	7.00±5.07	6.00±4.17	.787
Chair/bed transfer	10.25±3.73	11.75±2.66	.505	

VRA: Virtual Reality focus on ADL; ADL: Activities of Daily Living; JTHFT: Jebsen-Taylor Hand Function Test; K-MBI: Korean Modified Barthel Index; WC: Wheelchair.

Table 3. Changes of hand function and ADL within groups (Mean ± SD)

(N=18)

		VRA group (n=8)		p	Control group (n=8)		p
		pre	post		pre	post	
Hand function (score)	JTHFT (affected side)	32.38±23.49	49.38±16.95	.012*	37.00±22.18	48.13±22.64	.012*
	JTHFT (unaffected side)	64.75±15.48	73.50±9.80	.010*	67.38±14.02	75.00±11.30	.012*
ADL (score)	K-MBI total	60.88±23.73	79.13±19.03	.012*	67.63±18.46	81.25±18.81	.018*
	Personal hygiene	2.63±1.69	4.00±0.76	.026*	3.38±1.60	4.00±1.41	.059
	Bathing self	1.25±1.49	3.50±0.53	.017*	1.00±1.93	3.38±1.60	.017*
	Feeding	6.13±3.09	8.50±0.93	.039*	8.63±1.77	8.88±1.81	.317
	Toileting	6.75±2.55	8.38±1.69	.066	7.25±2.96	8.88±2.47	.042*
	Stair climbing	3.88±3.44	5.75±3.01	.066	2.88±3.60	5.88±3.23	.041*
	Dressing	5.88±3.56	8.50±2.27	.027*	7.00±2.27	8.25±2.19	.063
	Bowel control	8.88±1.81	9.13±1.81	.317	10.00±0.00	10.00±0.00	1.000
	Bladder control	8.25±2.19	8.75±2.31	.157	9.75±0.71	9.75±0.71	1.000
	Ambulation / WC	7.00±5.07	9.88±5.00	.039*	6.00±4.17	9.38±3.89	.027*
Chair/bed transfer	10.25±3.73	12.75±4.17	.039*	11.75±2.66	12.88±3.18	.083	

*p<.05, **p<.01, VRA: Virtual Reality focus on ADL; ADL: Activities of Daily Living; JTHFT: Jebsen-Taylor Hand Function Test; K-MBI: Korean Modified Barthel Index; WC: Wheelchair.

Table 4. Comparison of Change score of hand function and ADL after intervention (Mean \pm SD) (N=18)

		VRA group (n=8)	Control group (n=8)	p
		Change values	Change values	
Hand function (score)	JTHFT (affected side)	17.00 \pm 13.01	11.13 \pm 8.48	.328
	JTHFT (unaffected side)	8.75 \pm 6.84	7.63 \pm 5.32	.798
ADL (score)	K-MBI total score	18.25 \pm 13.20	13.63 \pm 12.44	.382
	Personal hygiene	1.38 \pm 1.30	0.63 \pm 0.74	.234
	Bathing self	2.25 \pm 1.49	2.38 \pm 1.85	.878
	Feeding	2.38 \pm 2.67	0.25 \pm 0.71	.065
	Toileting	1.63 \pm 1.92	1.63 \pm 1.77	.959
	Stair climbing	1.88 \pm 2.23	3.00 \pm 3.34	.574
	Dressing	2.63 \pm 2.13	1.25 \pm 1.39	.234
	Bowel control	0.25 \pm 0.71	0.00 \pm 0.00	.721
	Bladder control	0.50 \pm 0.93	0.00 \pm 0.00	.442
	Ambulation / WC	2.88 \pm 3.09	3.38 \pm 3.25	.798
	Chair/bed transfer	2.50 \pm 2.45	1.13 \pm 1.55	.279

VRA: Virtual Reality focus on ADL; ADL: Activities of Daily Living; JTHFT: Jebsen-Taylor Hand Function Test; K-MBI: Korean Modified Barthel Index; WC: Wheelchair.

Table 3 shows the changes in hand function and ADL. Both groups showed significant improvements in hand function of affected and unaffected sides, and in ADL (K-MBI total score) before and after the intervention.

3.3 Comparison of hand function and ADL between two groups after intervention

Table 4 shows the change in values of hand function and ADL after the intervention. There was no significant difference in the change of hand function and ADL between the two groups.

4. Discussion

This pilot study investigated the effect of virtual reality training on hand function and ADL in patients with acute stroke. Both groups showed significant improvements in hand function and ADL before and after the intervention. These changes are presumed to be due to the combined effects of the neurological recovery and training after stroke. There are a

number of studies demonstrating improvement in the upper limb function of stroke patients who use virtual reality training [12–14]. However, the study by Broeren et al. [18] that tested the effect of virtual reality training for enhancing upper limb function to improve ADL before and after intervention was not positive. In this study, the performance of the upper limb function was improved by using haptic force feedback before and after intervention in 5 stroke patients, but only one patient was reported to improve his ADL.

In our study, we implemented virtual reality training focused on ADL to overcome the limitations mentioned above. Although there was no significant difference between the two groups in the hand function and K-MBI total score, the VRA group improved in four of the five self-care areas (personal hygiene, bathing self, feeding, toileting, and dressing) [19], while only two of the five areas in the control group improved. This is due to the effect of virtual reality training focused on ADL. The functional recovery of the two groups was estimated to be similar to that of two of the three locomotion areas. The reason for these findings is presumed to be that

self-care behaviors such as washing and bathing were performed more frequently in the VRA group than in the control group [20–23].

Based on the results of this preliminary study, a sample size calculation (G Power 3.1) was performed. After setting Alpha=.05 and beta=.80, the effect size of the hand function of affected side and the self-care five areas (sum score) of K-MBI were calculated. As a result, when the affected side hand function was set as the primary outcome, 44 subjects per group were required. When the self-care five area was set as the primary outcome, 33 subjects per group were required.

There are several limitations in this preliminary study. First, since the sample size is small, it is difficult to generalize the findings of this study with other populations. In addition, randomized controlled trials were not conducted. Second, although both groups received conventional rehabilitation treatment, the two groups did not follow the exact same schedule. Therefore, it is possible that these acted as confounding factors when comparing the results of the two groups. Considering these limitations, a randomized controlled trial should be conducted in the future.

5. Conclusion

The purpose of this pilot study was to examine the effect of virtual reality training focused on hand function training and ADL training in patients with acute stroke. The VRA group showed significantly greater improvements in the self-care domain of K-MBI after intervention than the control group. These findings suggest that virtual reality training focused on ADL may have a better effect on self-care of ADL than conventional virtual reality training in patients with acute stroke.

REFERENCES

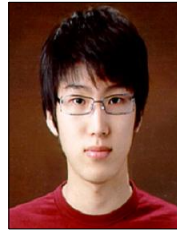
- [1] S. S. Bonita, N. Solomon & J. B. Broad. (1997). Prevalence of stroke and stroke-related disability. *Stroke*, *28*(10), 1898–1902. DOI : 10.1161/01.str.28.10.1898
- [2] C. Hofgren, A. Björkdahl & E. Esbjörnsson, et al. (2007). Recovery after stroke: cognition, ADL function and return to work, *Acta Neurologica Scandinavica*, *115*(2), 73–80. DOI : 10.1111/j.1600-0404.2006.00768.x
- [3] T. Elbert, C. Pantev & C. Wienbruch et al. (1995). Increased cortical representation of the fingers of the left hand in string players. *Science*, *270*(5234), 305–307. DOI : 10.1126/science.270.5234.305
- [4] G. Kwakkel, R. C. Wagenaar & J. W. Twisk et al. (1999). Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial. *The Lancet*, *354*(9174), 191–196. DOI : 10.1016/S0140-6736(98)09477-X
- [5] J. H. Moon, K. Y. Park & H. J. Kim et al. (2018). The Effects of Task-Oriented Circuit Training Using Rehabilitation Tools on the Upper-Extremity Functions and Daily Activities of Patients with Acute Stroke: A Randomized Controlled Pilot Trial. *Osong Public Health and Research Perspectives*, *9*(5), 225–230. DOI : 10.24171/j.phrp.2018.9.5.03
- [6] C. T. Freeman, A. M. Hughes & J. H. Burridge et al. (2009). Iterative learning control of FES applied to the upper extremity for rehabilitation. *Control Engineering Practice*, *17*(3), 368–381. DOI : 10.1016/j.conengprac.2008.08.003
- [7] M. Invernizzi, S. Negrini & S. Carda et al. (2013). The value of adding mirror therapy for upper limb motor recovery of subacute stroke patients: a randomized controlled trial. *European journal of physical and rehabilitation medicine*, *49*(3), 311–317.
- [8] M. M. Ouellette, N. K. LeBrasseur & J. F. Bean et al. (2004). High-intensity resistance training improves muscle strength, self-reported function, and disability in long-term stroke survivors. *Stroke*, *35*(6), 1404–1409. DOI : 10.1161/01.STR.0000127785.73065.34
- [9] A. C. Lo, P. D. Guarino & L. G. Richards et al. (2010). Robot-assisted therapy for long-term upper-limb impairment after stroke, *New England Journal of Medicine*, *362*(19), 1772–1783. DOI : 10.1056/NEJMoa0911341
- [10] G. Saposnik, L. G. Cohen & M. Mamdani et al. (2016). Efficacy and safety of non-immersive virtual reality exercising in stroke rehabilitation (EVREST): a randomised, multicentre, single-blind, controlled trial. *The Lancet Neurology*, *15*(10), 1019–1027. DOI : 10.1016/S1474-4422(16)30121-1
- [11] L. R. Valmaggia, L. Latif & M. J. Kempton et al. (2016). Virtual reality in the psychological treatment for

mental health problems: a systematic review of recent evidence. *Psychiatry research*, 236, 189-195.
DOI : 10.1016/j.psychres.2016.01.015

- [12] K. E. Laver, S. George & S. Thomas et al. (2015). Virtual reality for stroke rehabilitation. The Cochrane Library.
- [13] M. C. Howard. (2017). A meta-analysis and systematic literature review of virtual reality rehabilitation programs. *Computers in Human Behavior*, 70, 317-327.
DOI : 10.1016/j.chb.2017.01.013
- [14] F. J. Carod-Artal, D. S. Trizotto & L. F. Coral et al. (2009). Determinants of quality of life in Brazilian stroke survivors. *Journal of the neurological sciences*, 284(1-2), 63-68.
DOI : 10.1016/j.jns.2009.04.008
- [15] J. H. Kim, I. S. Kim & T. R. Han. (2007). New scoring system for jebsen hand function test. *Journal of Korean Academy of Rehabilitation Medicine*, 31(6), 623-629.
- [16] R. H. Jebsen, N. Taylor & R. B. Trieschmann, et al. (1969). An objective and standardized test of hand function. *Archives of Physical Medicine and Rehabilitation*, 50(6), 311-319.
- [17] H. Y. Jung, B. K. Park & H. S. Shin et al. (2007). Development of the Korean Version of Modified Barthel Index (K-MBI): Multi-center Study for Subjects with Stroke. *Journal of the Korean Academy of Rehabilitation Medicine*, 31(3), 283-297.
- [18] J. Broeren, M. Rydmark & K. S. Sunnerhagen et al. (2004). Virtual reality and haptics as a training device for movement rehabilitation after stroke: a single-case study. *Archives of physical medicine and rehabilitation*, 85(8), 1247-1250.
DOI : 10.1016/j.apmr.2003.09.020
- [19] H. S. Woo, W. K. Park & T. H. Cha. (2012). Correlation Between Korean-WMFT Functional Score and Activities of Daily Living. *Korean Journal of Occupational Therapy*, 20(3), 95-104.
- [20] T. Lee. (2019). The Effect of Virtual Reality based Intervention Program on Communication Skills in Cafe and Class Attitudes of Students with Intellectual Disabilities. *Journal of the Korea Convergence Society*, 10(3), 157-165.
- [21] T. S. Lee & K. Y. Joo. (2019). Comparative Analysis on Special Teachers' Perception toward Virtual Reality based Intervention Program for students with disabilities. *Journal of the Korea Convergence Society*, 10(6), 113-120.
- [22] S. H. Park, B. S. Kim & M. M. Lee. (2019). The Effect of Trunk Control Training Using Virtual Reality Game-based Training Program on Balance and Upper Extremity Function of Subacute Stroke Patients. *Journal of Convergence for Information Technology*, 9(5), 172-179.
- [23] T. S. Park, J. H. Kang & I. B. Kim. (2018). Analysis of Muscle On-set Time of Fully Immersive Virtual Reality Motions and Actual Motions in Healthy Adults. *Journal of Convergence for Information Technology*, 8(1), 173-177.

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