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Effects of virtual reality intervention on upper limb motor function and activity of daily living in patients with lesions in different regions of the brain

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Abstract. [Purpose] This study aimed to investigate whether a virtual reality (VR) intervention has an influence in improving the motor function and activities of daily living (ADLs) in patients with lesions in different regions of the brain. [Subjects and Methods] Eleven subjects with hemiplegic stroke were recruited in this study, which was conducted from January to February, 2017. They received a VR intervention once a day for 30 min, 5 times a week for 4 weeks. The Fugl-Meyer Assessment (FMA) and the Korean version of the Modified Barthel Index (K-MBI) were used to assess the post-stroke patients' motor function and ADLs, respectively. [Results] There were significant differences in pre- and post-test outcomes of the Arm and Coordination and Speed (CS) in the FMA and K-MBI in the middle cerebral artery group (MCAG). Moreover, there were significant differences in all sub-tests of FMA and K-MBI in the Basal ganglia group (BGG). In addition, there were significant differences in the pre-test outcomes of Arm and pre- and post-test outcomes of Hand in the FMA between the two groups. [Conclusion] This study revealed that VR intervention improved the upper limb motor function and ADLs of post-stroke patients, especially those in the BGG.

Key words: Activities of daily living, Upper limb motor function, Virtual reality

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INTRODUCTION

Although the number of stroke patients who continue to improve physically is increasing, it is still noted that a lot of survivors remain with functional deficits, which influence their quality of life and even constrain them from performing basic functions. Because a patient does not try to use the affected arm, regaining function of the upper extremity may be challenging. Moreover, increasing the upper limb function is not often the focus in the initial stage of rehabilitation for these patients; instead, therapy is more concentrated on their gait ability. A few studies have introduced quality interventions to improve the upper limb function after stroke, which entail task-oriented, repetitive, and specific task-training, such as constraint-induced movement therapy (CIMT), virtual reality (VR), and interactive video games[1]. VR, combined with an interactive video game, is becoming popular as a way to encourage repetitive movements, which are challenging for post-stroke patients. VR can offer task-oriented, random, and progressive learning training, and feedback concerning performance and results are increased, which stimulate and engage players[2]. VR, using feedback from vision, facilitates the patients to commit to the training because the patients are seeing their movements that help them adjust the center of their body, which has resulted from their body image deficit after stroke[3]. Moreover, VR provides a virtual background that is collaborative, and perceived

as related to the real world, which can stimulate sensory information[4]. Post-stroke patients need to be rehabilitated to improve their body balance to avoid falls, which is the most crucial complication after stroke. For these reasons, VR, which focuses on stimulating functional activities, can be an influential method for neurologic patients[5]. Although many papers have shown the effect of VR for the past several years, it would still be difficult to find a study that used VR on post-stroke patients, with subjects divided into groups, depending on the lesions in the different regions of the brain. Therefore, this study aimed to investigate whether a VR intervention has an influence in the improvement of motor function and activities of daily living (ADLs) in post-stroke patients with lesions in the different regions of the brain.

SUBJECTS AND METHODS

Eleven subjects with hemiplegic stroke were recruited from H hospital in Bucheon, Republic of Korea to participate in this study, which was conducted from January to February, 2017. Before the initiation of the study, all subjects provided a written informed consent. This study was granted ethical approval by the Ethics Committee of Gacheon University (IRB. No: 1044396–201701-HR-014–01). The inclusion criteria were as follows: (1) adults with hemiplegia with onset for the past 6 months, (2) no limited range of motion in the upper extremities, and (3) no visual deficit[6]. The subjects were divided into either the middle cerebral artery group (MCAG) or the basal ganglia group (BGG), depending on the region in which the lesion was detected in the brain. They received a VR intervention once a day for 30 min, 5 times a week for 4 weeks. Three of the 5 VR programs were randomly selected for the training (Fig. 1). Motion-controlled VR games, like the Nintendo Wii and Sports, were used in this study[2]. The Fugl-Meyer Assessment (FMA) and the Korean version of the Modified Barthel Index (K-MBI) were used to assess the patients' motor function and ADLs, respectively. The upper limb sub-tests of the FMA include the examination of sensation, range of motion, reflexes, synergy, and fine and gross hand movements. A 3-point scale was used to grade each movement, and the entire score for the upper limb ranges from 0 to 60 points. The higher score indicates a good function of the upper extremities. Reliability was good (intraclass correlation coefficient [ICC]=0.97)[7]. The K-MBI evaluates independence in ADLs in patients recovering from stroke. This test comprises 10 sub-tests in ADL. Depending on the amount of assistance needed, the sub-test is graded using a 5-point scale. The lowest total score is 0 and the highest total score is 100. The higher score shows more independence in ADL function. The K-MBI proved to have good inter-rater reliabilities (r=0.93–0.98) and internal consistency (Cronbach's alpha=0.84). In construct validation, each item of the K-MBI had a substantial association with the total score of K-MBI (r=0.54–0.78)[8]. Given that this study followed a normal distribution using the Kolmogorov-Smirnov test, a paired t-test and an independent t-test were used to compare the results of the pre- and post-interventions in a group and between the two groups, respectively, using SPSS.

RESULTS

The general characteristics are shown in Table 1, and homogeneity between the two groups was present as proven using the χ^2 test.

There were significant differences in the pre- and post-tests outcomes of the Arm and Coordination and Speed (CS) in the FMA and K-MBI in the MCAG. Additionally, significant differences were also seen in all sub-tests of FMA and K-MBI in the BGG. Moreover, there were significant differences in the pre-test outcomes of Arm and pre- and post-test outcomes of Hand in the FMA between the two groups. The results are presented in Table 2.

DISCUSSION

VR equipment can be used to carry significant and appropriate stimulations to an individual's nervous system and thus take advantage of neuroplasticity to stimulate both motor and cognitive systems[2]. In a previous study, a significant progress in Arm and CS sub-test outcomes was detected in the VR group. Repetitive and concentrated task training commitment resulted in a precise progression, which better improved arm function than wrist and hand function in the FMA. Moreover, visual feedback may stimulate neurological changes that help recover motor functions, such as mirror neuron firing rates and cortical reorganization[6]. In this study, significant differences in Arm and Hand outcomes exist in the MCAG. Moreover, the BGG had more noticeable influences in all areas of the FMA. This effect was because patients with hemiplegia, caused either by hemorrhage or infarction in the middle cerebral artery, would have more serious functional disorders in the upper extremities. Motor and sensory homunculi have shown the somatotopic arrangement of the body in the brain, and the upper limbs are controlled by the lateral part of the brain, which is supplied with blood by the middle cerebral artery. In this manner, VR improved the upper limb function of patients in the BGG better than those in the MCAG. This result indicates that patients in the BGG have neuroplasticity in the brain, which is consistent with the results of the study conducted by Jang and colleagues who investigated the effects of VR therapy on cortical reorganization and motor recovery of 5 chronic stroke patients and demonstrated VR-induced neuroplastic changes using fMRI[9]. Moreover, K-MBI scores were significantly improved in the previous study. The score of the self-care items in the K-MBI improved considerably in each intervention group[6]. Broeren and colleagues reported that patients prefer to use the affected arm, and affected arm movements could be enhanced via VR. Thus, relevant ADL performance can be improved[10]. In this study, there were significant differences in the total score

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Fig. 1.   The virtual reality programs.

Table 1.   General characteristics in subjects (N=14)

		MCAG (n=6)	GSG (n=8)
Age, yrs ± SD		61.6 ± 9.9	53.1 ± 9.5
Gender, n (%)	Male	2 (33.3)	3 (37.5)
	Female	4 (66.7)	5 (62.5)
Hemiplegia side, n (%)	Right	2 (33.3)	4 (37.5)
	Left	4 (66.7)	5 (62.5)
Stroke type, n (%)	Infarction	1 (16.7)	4 (50.0)
	Hemorrhagic	5 (83.3)	4 (50.0)
Stroke onset period, months ± SD		18.1 ± 6.8	16.5 ± 9.5

MCAG: Middle cerebral artery group; BGG: Basal ganglia group; SD: Standard deviation.

Table 2.   Variations of pre- and post-intervention in a group and between two groups (N=14)

	FMA (score)								K-MBI (score)	
	Arm		Wrist		Hand		CS		Total	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
MCAG (n=6)	17.8 ± 9.7	22.8 ± 6.8[a]	5.3 ± 3.4	5.5 ± 3.6	8.2 ± 4.7	9.0 ± 5.1[a]	3.3 ± 0.8	3.8 ± 0.8	81.5 ± 5.4	83.3 ± 5.4[a]
BGG (n=8)	21.0 ± 4.5[b]	27.5 ± 4.7[a]	5.6 ± 1.6	6.9 ± 1.6[a]	7.9 ± 2.6[b]	11.9 ± 2.5[ab]	3.8 ± 0.9	4.6 ± 0.7[a]	79.6 ± 8.2	82.0 ± 8.1[a]

[a]p<0.05, significant difference in a group; [b]p<0.05, significant difference between the two groups; FMA: Fugl-meyer assessment, Mean ± SD; K-MBI: Korea modified barthel index, Mean ± SD; CS: Coordination and Speed; MCAG: Middle cerebral artery group; BGG: Basal ganglia group.

of K-MBI in both the MCAG and the BGG. This implied that VR brought about movements of the distal part of the body, resulting in better core stability, thereby increasing the sub-test scores in K-MBI. In general, this study revealed that the use of VR in the rehabilitation of post-stroke patients improved their upper limb motor function and ADL. In addition, patients with brain damage in the basal ganglia showed more improvement than those with brain damage in the MCA. A study with a computerized assessment tool, such as an fMRI or tractography, should be conducted in the future for better evidence.

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