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Original Article

The effects of game-based virtual reality movement therapy plus mental practice on upper extremity function in chronic stroke patients with hemiparesis: a randomized controlled trial

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Abstract. [Purpose] The purpose of this study was to investigate the effects of game-based virtual reality movement therapy plus mental practice on upper extremity function in chronic stroke patients with hemiparesis. [Subjects] The subjects were chronic stroke patients with hemiparesis. [Methods] Thirty subjects were randomly assigned to either the control group or experimental group. All subjects received 20 sessions (5 days in a week) of virtual reality movement therapy using the Nintendo Wii. In addition to Wii-based virtual reality movement therapy, experimental group subjects performed mental practice consisting of 5 minutes of relaxation, Wii games imagination, and normalization phases before the beginning of Wii games. To compare the two groups, the upper extremity subtest of the Fugl-Meyer Assessment, Box and Block Test, and quality of movement subscale of the Motor Activity Log were performed. [Results] Both groups showed statistically significant improvement in the Fugl-Meyer Assessment, Box and Block Test, and quality of the movement subscale of Motor Activity Log after the interventions. Also, there were significant differences in the Fugl-Meyer Assessment, Box and Block Test, and quality of movement subscale of the Motor Activity Log between the two groups. [Conclusion] Game-based virtual reality movement therapy alone may be helpful to improve functional recovery of the upper extremity, but the addition of MP produces a lager improvement.

Key words: Game-based virtual reality, Mental practice, Stroke

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INTRODUCTION

Stroke remains a leading cause of adult disability in many countries. Though stroke can cause dysfunctions in a number of neurological areas, the most commonly affected area is the motor system[1)]. Up to 85% of stroke survivors experience motor dysfunction of the affected upper extremity (UE) after stroke[2)].

Traditional rehabilitative therapies can help improve the motor function of the UE[3)]. Recent studies indicate that repetitive task-oriented training of the affected UE is beneficial[4)]. However, traditional rehabilitative therapies that require repetitive and simple movements cause boredom and monotony, which may decrease the participant's motivation to achieve a successful goal in rehabilitation[3)]. Also, it is difficult for stroke patients to sustain the effect of interventions because it is impractical to observe how correctly interventions are being performed at home. Due to the limitations of interventions, novel approaches using virtual reality (VR) systems have been suggested and have begun to be used in clinical settings[3, 5, 6)].

Game-based VR is a novel approach that uses interactive simulation systems created by computer hardware and software to provide three dimensional environments that mimic the real life and enable users to be engaged in activities regardless of

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their physical disabilities[5, 6]. Game-based VR movement therapy provides easily controlled and graded purposeful task of the UE that can be practiced in a repetitive manner and thereby may improve motor function after stroke[7]. Several studies have shown the effectiveness of costly game-based VR movement therapy using the Sony PlayStation, EyeToy, and Nintendo Wii for functional recovery of the UE in patients with stroke[8–10].

In stroke rehabilitation, mental practice (MP) has been adopted to improve physical function and movement because of convenience in its use, cost effectiveness, and safety[11]. In addition, MP can be used as a method of performing additional practice attempts in rehabilitation settings, especially when physical activity is not possible due to severe impairment[12]. MP is a specific procedure in which stroke patients imagine the process of a given movement sequence task without actually performing physical movement[13]. Many studies indicate that MP is a promising addition to the conventional intervention for stroke patients with hemiparesis. Imagination of affected UE movement is helpful for facilitating learning of motor tasks[11].

Several studies have suggested that game-based VR movement therapy is an effective tool for rehabilitation[14], whereas there has been much less research on game-based VR movement therapy plus MP in stroke patients. The objective of this study was to investigate the effects of game-based VR movement therapy plus MP compared with game-based VR movement therapy only in chronic stroke patients with hemiparesis.

SUBJECTS AND METHODS

Subjects were recruited in a local rehabilitation hospital in Republic of Korea. Subjects were eligible for the trial if they were at least 6 months post stroke, were aged 18 to 80 years, were cognitively intact (score ≥ 24 points on the Korean version of Mini-Mental State Examination), had no experience with game-based VR, had mild to severe weakness of their affected UE (as assessed by scores of 4–60/60 points on the UE subtest of the Fugl-Meyer Assessment), and were without other neurological conditions or epilepsy. All subjects provided written informed consent prior to study inclusion according to the Code of Ethics of the World Medical Association (Declaration of Helsinki, version 2004).

Eligible subjects were randomly assigned to control group (CG) or experimental group (EG) in accordance with a random number table. Random allocation was performed by a research assistant under blinded conditions. As in previous studies, all clinical measurements were administered to the subjects at two time points at baseline and after the intervention (after 4 weeks), by the same blinded rater[8, 9].

All subjects performed 20 sessions (5 days a week for 4 weeks) of game-based VR movement therapy using the Wii (Nintendo, Kyoto, Japan) for 30 minutes each session. Nintendo introduced a new style of VR by using a wireless controller that interacts with the player through an avatar and a motion detection system. The controller use embedded acceleration sensors responsive to changes in direction, speed, and acceleration that enable subjects to interact with the games while performing wrist, arm, and hand movements. A-2 point infrared light sensor, mounted on top of a television, captures and reproduces on the television's screen the movement from the controller as performed by subjects[9]. Subjects who could not grip the controller used a bandage to fix the controller onto the affected hand.

In the present study, the Wii Sports and Wii Sports Resort games, both of which contain a variety of games, were used. Based on previous studies on virtual reality movement therapy[10, 15], the bowling, table tennis, and canoeing games were used in this study. The arm movements involved in use of the Wii included shoulder flexion and extension (bowling), shoulder internal and external rotation, elbow flexion and extension, and forearm pronation and supination (table tennis and canoeing). All subjects were allowed to practice before playing the games and instructed to play the bowling, table tennis, and canoe game with their affected UE.

In addition to Wii-based VR movement therapy, EG subjects engaged in MP sessions. Before beginning to play the Wii games, the author described the goal of MP to each participant. MP was performed in a quiet room. During MP, one of the authors read a script to the subjects describing how to successfully play the Wii games for 5 minutes. According to the suggestions of previous studies[16, 17], authors implemented three phases of MP in this study. The three phases of MP were as follows: (1) 1 minute of relaxation time, (2) 3 minutes of Wii game imagination, and (3) 1 minute of refocusing on the room. The purpose of the relaxation time was to induce a mental response by regulating muscle tension and breathing rate. The Wii game imagination phase was aimed at facilitating Wii game performance by making subjects mentally practice task sequences. During this phase, subjects were asked questions to check whether they were actually following each process of the Will games. In the final phase, the authors asked the subjects to relax as they would normally.

UE function was assessed using the UE subtest of the Fugl-Meyer Assessment (FM) and Box and Block Test (BBT). The total maximum score of the FM is 66 points for the upper extremity section, which assesses impairment using a 3-point ordinal scale. The FM offers impressive test-retest reliability (total=0.98 to 0.99; subtest=0.87 to 1.00)[18]. The BBT was used to assess gross dexterity by having the subjects move as many blocks as possible from one place to another in 60 seconds. A change of 5 or 6 blocks between before and after an intervention seems to be the smallest detectable difference. The test-retest reliability of the BBT was reported to be r=0.95 for the left hand and r=0.98 for the right hand; the intra-rater reliability was reported to be r=0.99 for the left hand and r=1.00 for the right hand[19]. The quality of movement subscale of the Motor Activity Log (MAL-QOM) was used as index to confirm transfer of therapy-induced improvement to the performance of activities of daily living. The MAL-QOM has been shown to reflect how well the affected extremity is used in activities of daily living, and the 30 items of the MAL-QOM were completed daily. Scores for each task range from 0 to 5[20].

Table 1. Subjects' characteristics

Characteristic	CG (n=15)	EG (n=15)
Gender		
Male	7	9
Female	8	6
Etiology		
Hemorrhagic	8	9
Ischemic	7	6
Lesion side		
Right	8	7
Left	7	8
Age (years)	62.0 (4.29)	61.6 (5.34)
Clinical measures (M±SD)		
FM	48.9 ± 1.4	49.3 ± 1.2
BBT	11.5 ± 1.6	12.1 ± 1.5
MAL-QOM	62.4 ± 0.9	62.9 ± 1.6

BBT: Box and Block Test; CG: control group; EG: experimental group; FM: Fugl-Meyer Assessment; M: mean; MAL-QOM: quality of movement subscale of Motor Activity Log; SD: standard deviation

Table 2. Subjects' scores on the FM, BBT, and MAL-QOM before and after the interventions

	FM		BBT		MAL-QOM	
	Pre	Post	Pre	Post	Pre	Post
CG (n = 15)	48.9 (1.4)	53.1** (2.4)	11.5 (1.6)	17.2** (2.5)	62.4 (0.9)	80.7** (1.3)
EG (n = 15)	49.3 (1.2)	54.4** (1.9)	12.1 (1.5)	20.4** (2.0)	62.9 (1.6)	82.5** (1.8)

**p< 0.001

Table 3. Comparison of the changes in the FM, BBT, and MAL-QOM from before to after the interventions between groups

	CG (n = 15)	EG (n = 15)
Clinical measures (M ± SD)		
FM	4.2 ± 1.4	5.2 ± 0.9*
BBT	5.7 ± 1.7	8.2 ± 0.9**
MAL-QOM	18.3 ± 0.9	19.5 ± 1.3**

*p< 0.05; **p< 0.001

All data analyses were performed using IBM SPSS Statistics version 20.0. The χ^2 test and Mann-Whitney U test were used to compare differences in the participants' characteristics between the two groups. The Mann-Whitney U was used to test differences in the FM, BBT, and MAL scores between the two groups. The Wilcoxon signed-rank test was used to test differences in continuous variables within groups. Statistical significance was accepted for values of $p < 0.05$.

RESULTS

The demographic characteristics of the subjects did not show significant differences between the groups (Table 1). The 30 subjects successfully completed their respective interventions. None of the 30 subjects experienced any adverse events during the study period.

Table 2 summarizes the observed means (standard deviation) and other statistics for all measurements at baseline and at the end of the interventions. Clinical improvement were found in the CG and EG subjects. In particular, using the Wilcoxon signed-rank test, significant improvement was found in the FM ($p < 0.05$), BB ($p < 0.05$) and MAL-QOM ($p < 0.05$) in both groups. There were significant differences in the changes between the two groups in the FM ($p < 0.05$), BBT ($p < 0.05$) and MAL-QOM ($p < 0.05$) (Table 3).

DISCUSSION

The results of this study suggest that game-based VR movement therapy may be effective for functional recovery of the UE in chronic stroke patients and that the effects are further increased when the therapy is performed in conjunction with MP. Consistent with previous VR studies[9, 10, 15, 21], all subjects showed improvement in the outcome measures. Furthermore, the changes were clinically significant, with the changes transferring to the ability to perform activities of daily living (reflected by increased MAL-QOM scores).

In this study, the basic intervention for functional recovery of the UE was a game-based VR movement therapy that was performed using the Wii. The therapy was performed by completing each task displayed on a television screen by using the affected UE, and the tasks required diverse UE movements. This may help to improve functional recovery of the UE by increasing UE movement. Birkenmeier et al. reported a proof-of-concept study of a high-repetition dose of UE task-specific training[22].

Combs et al. also indicated that repetitions of goal-directed movements using game-based VR can facilitate UE repetitions in a fun and motivating manner[23]. Higher motivation is associated with better intervention outcomes, which may reduce problems with intervention compliance[24]. All subjects in this study had no experience with game-base VR before participating in the study and were unfamiliar it. Such an unfamiliarity facilitated interest, promoting motivation through visual feedback such as the avatars and VR environment presented on the screen. In addition, the performance of the subjects in each game was recorded daily and used to redefine intervention goal to facilitate motivation and intervention compliance.

The EG subjects showed larger improvements in the FM, BBT, and MAL-QOM than the CG subjects. These results are consistent with those of other studies in which MP was combined with other interventions for the affected UE[25–30]. MP has been shown to independently produce neural changes[25]. In particular, the combination of MP and a specific intervention can provide more opportunities for neuroplasticity to occur than in the case of a specific intervention alone. In addition, MP, including imaging the procedures of each game task in detail and training the task mentally in advance, is effective for learning motor skills because it enhances the ability to control UE movement and self-confidence when performing the task[31].

There were several limitations in this study. Although this study adopted a randomized controlled trial design, the relatively small number of subjects limits the ability to make definitive conclusions about the efficacy of game-based VR movement therapy plus MP. Therefore, in future study, randomized controlled trial with a larger sample size are needed to clarify the clinical benefits of game-based VR plus MP as a rehabilitation approach for UE function in chronic stroke patients. In addition, because stroke patients were able to use game-base VR at home without the constant supervision of a therapist, the use of game-based VR movement therapy as a form of telerehabilitation needs to be examined.

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