

Original Article

Effect of virtual reality games on stroke patients' balance, gait, depression, and interpersonal relationships

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Abstract. [Purpose] The purpose of the study was to determine the effects of training using virtual reality games on balance and gait ability, as well as the psychological characteristics of stroke patients, such as depression and interpersonal relationships, by comparing them with the effects of ergometer training. [Subjects] Forty stroke patients were randomly divided into a virtual reality group (VRG, N = 20) and an ergometer training group (ETG, N = 20). [Methods] VRG performed training using the Xbox Kinect. ETG performed training using an ergometer bicycle. Both groups received training 30 min per day, five times per week, for eight weeks. [Results] Both the VRG and ETG subjects exhibited a significant difference in weight distribution ratio on the paralyzed side and balance ability. Both the VRG and ETG patients showed significant improvement in psychological measures BDI and RCS, after the intervention, and the VRG showed a more significant increase in BDI than the ETG. [Conclusion] According to the result of this study, virtual reality training and ergometer training were both effective at improving balance, gait abilities, depression, and interpersonal relationships among stroke patients.

Key words: Stroke, Virtual reality, Ergometer

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INTRODUCTION

Patients with stroke have a number of physical impairments, including movement, cognitive, sensory, language, and visual disorders. Among them, movement disorders can limit muscle control and motion functions or mobility, as well as a degrade in balance control abilities. Hemiplegia is accompanied by an increase in postural instability, asymmetrical weight bearing, impairment of body weight transfer capabilities, and a decrease in postural stability¹⁾. As a result, many patients with stroke experience problems with daily activities requiring functional movements such as balance, climbing stairs, gait, and walking²⁾.

One study reported that since stroke patients experience hemiplegia, they become isolated in their daily lives from family members and society, and that as well as experiencing a loss of independence, more than 50% of stroke patients had depression³⁾. That is, many mental problems, such as depression, apathy, and anxiety, are prevalent in stroke patients, and depression not only has an adverse effect on appetite and sleep⁴⁾, but it is also a lives negative factor af-

fecting rehabilitation⁵⁾. In addition, due to the sense of loss and helplessness in their life, stroke patients have difficulties maintaining interpersonal relationships with others⁶⁾.

In terms of interventions that help stroke patients with their functional recovery, one of the most widespread methods is training using a MOTomed, which is done in a limited environment in a hospital. This training is known to bring about effective improvements in physical functions and increases in grip strength and leg muscle strength, leading to improvements in physical activity abilities and balance due to an increase in muscle strength⁷⁾. Moreover, this training integrates bilateral movements and assisted active training, thereby inducing alternate movements in the paralyzed leg side with the help of the lower extremity on the non-paralyzed side⁸⁾, which requires coordinated transfer of body weight between the two sides. This results in increase of physical strength in the lower extremity, as well as providing weight-bearing ability through practice of gait skills⁹⁾.

A great deal of attention has been paid to virtual reality training programs that involve various treatments providing virtual environments and simulating conditions using virtual reality tools. Since intervention methods using virtual reality have been demonstrated to be effective in the rehabilitation of stroke patients, whose physical and recreational activities are limited due to their physical disability and who experience problems carrying out activities of daily living in their environment¹⁰⁾, various studies have proposed this type of training. Moreover, positive improvements in the upper extremity functions¹¹⁾, balance¹²⁾, gait¹³⁾, and daily living

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movements¹⁴) of stroke patients have been reported.

Virtual reality training programs initially required much equipment; however, virtual reality home video games using consoles such as the Sony PlayStation 2 or Nintendo Wii Fit have been widely used since the mid-2000s, as these have penetrated our daily lives and can easily be placed in the home. In recent years, training using the Xbox Kinect has been employed as a virtual reality training program, which is quite different from the virtual reality computer programs that use a joystick or controller. This training involves playing a virtual reality game in which players move their bodies in front of the game screen by and 48 of their joint positions and motions are tracked via the Kinect sensors¹⁵). An intervention method using a virtual reality game enables immediate feedback about task performance, and visual and audible stimulation kindle interest¹⁶). It also generates motivation to engage in treatment, as participants enjoy themselves while actively carrying out tasks¹⁷). In addition, it can provide stability in activities of daily living that stroke patients are unable to accomplish or are limited in, thereby giving them an opportunity to explore independently and increase their autonomy¹⁸).

Training programs using virtual reality games can also be effective at alleviating the psychological problems of stroke patients such as depression, helplessness, and difficult interpersonal relationships. Most studies of training programs for stroke patients have focused on physical aspects, but few have been conducted with a view to elucidating psychological and social factors related to rehabilitation. Therefore, this study aimed to determine the effects of training using virtual reality games on balance and gait ability, as well as the psychological characteristics of stroke patients, such as depression and interpersonal relationships, by comparing them with the effects of ergometer training.

SUBJECTS AND METHODS

The subjects of this study were 40 patients diagnosed with hemiplegia resulting from stroke by a rehabilitation doctor practicing at N Hospital located in Daegu, South Korea. They were randomly and equally assigned to a virtual reality group (VRG: 10 males, 10 females) and an ergometer training group (ETG: 12 males, 8 females). The mean \pm standard deviation (SD) age, height, and weight of the VRG were 51.37 \pm 40.6 years, 167.00 \pm 9.53 cm, and 64.12 \pm 13.12 kg, respectively. Eleven of the patients had right hemiplegia, and nine had left hemiplegia. The onset period was 14.75 \pm 6.06 months. The mean \pm SD age, height, and weight of ETG patients were 50.10 \pm 7.83 years, 169.20 \pm 9.21 cm, and 65.20 \pm 11.26 kg, respectively. Eight of the patients had right hemiplegia, and 12 had left hemiplegia. The onset period was 14.30 \pm 3.40 months.

The inclusion criteria were as follows: no visual field defect, no abnormality in the vestibular organs, no orthopedic disease, an unrestricted range of motion, ability to understand and perform the exercise as instructed by the researcher, and a score of 24 or higher on the Mini-Mental State Examination—Korean version. This study was approved by the university's Institutional Review Board and all of the subjects understood the purpose of this study and

provided their written informed consent prior to their participation in the study, in accordance with the ethical standards of the Declaration of Helsinki.

The VRG patients performed training using the Xbox Kinect for 30 minutes per session, five times per week, for a total of 8 weeks. In front of the Xbox Kinect sensor, the subjects moved their bodies to play the games. Various games such as Kinect Sport, Kinect Sport Season 2, Kinect Adventure, and Kinect Gunstringer were provided to kindle the subjects' interest and prevent boredom. During the intervention, subjects balanced their bodies and practiced using their bodies and limbs. Mostly, sport programs, such as 10-pin bowling, skiing, and golf, and programs such as ground walking, walking over obstacles, and climbing stairs were used for training.

The ETG patients performed ergometer bicycle training 30 minutes per session, five times per week, for a total of 8 weeks. Training was conducted for 30 minutes so as not to exceed 40% of subjects' heart rate reserve using a MOTomed Viva 2. The MOTomed provides detailed biofeedback, software-controlled therapy programs, and motivation and training games.

The subjects in the two experimental groups began training after being given the instruction, "Please start." In the early stage, the researcher provided help to ensure that the subjects maintained proper posture during the training. If a subject exhibited fatigue, abnormalities in breathing, changes in facial complexion, or complained of pain, training was stopped immediately.

For the measurement of balance ability, a biofeedback analysis system (AP1153 BioRescue, RM Ingénierie, Rodez, France) was used to determine weight bearing on the affected side, anterior range limit of stability (LOS), and posterior range LOS in a static standing position. For the measurement of gait ability, we used the timed up and go (TUG) test and the 10-m walking test.

For the assessment of patients psychology, we used the Beck Depression Inventory [BDI] and the relationship change scale (RCS). The BDI is a depression assessment tool which was developed by Beck in 1961 and adapted for use in Korea by Han et al. This tool consists of 21 questions divided into four sections, namely the cognitive, emotive, motivational, and physiological sections. Each question is measured on a 4-point Likert scale from 0 to 3. The possible score ranges from a minimum of 0 points to a maximum of 63 points. If an individual scores 0–9 points, he or she is not depressed; a score of 10–15 points represents light depression; 16–23 points, heavy depression; and 24–63 points, severe depression. The RCS tool consists of 25 questions divided into seven sections, as follows: understanding, openness, sensitivity, intimacy, trust, communication, and satisfaction. Each question is rated on a 5-point Likert scale from 1 to 5. The possible score is 25–125 points. The higher the score, the better the individual's interpersonal relationships.

The experimental results were statistically analyzed using SPSS 12.0 KO (SPSS Inc., Chicago, IL, USA). After the general characteristics of the subjects were determined, the paired t-test was used to compare the variations in weight bearing on the affected side when standing, the anterior LOS standing, and the posterior LOS standing. The significance

Table 1. Comparison of changes in the balance and gait functions of the training groups (mean \pm SD)

	VRG		ETG	
	pre	post	pre	post
Affected side WB	42.8 \pm 6.1	46.1 \pm 4.3* ^a	42.1 \pm 4.3	43.3 \pm 4.9*
Forward LOS (mm)	2732.9 \pm 3137.1	3311.7 \pm 3786.5* ^a	5670.8 \pm 4291.1	4322.6 \pm 3565.5*
Backward LOS (mm)	2072.7 \pm 2050.4	1895.9 \pm 2097.5* ^a	3971.7 \pm 2794.3	2889.7 \pm 2769.7*
TUG (s)	21.17 \pm 7.7	21.9 \pm 7.9* ^a	16.6 \pm 4.7	19.5 \pm 7.5*
10MWT (s)	18.3 \pm 2.2	21.4 \pm 8.9* ^a	14.3 \pm 2.1	19.1 \pm 8.8*

* significant difference from before therapy, $p < 0.05$. ^a significant difference in the gains of the two groups $p < 0.05$. VRG : virtual reality group, ETG: ergometer training group, WB : weight bearing ratio, LOS: limit of stability, TUG: timed up and go test, 10MWT: 10m walking test

Table 2. Comparison of the BDI and RCS scores of the two training groups (mean \pm SD)

	VRG		ETG	
	pre	post	pre	Post
BDI	21.2 \pm 3.8	14.1 \pm 2.4* ^a	19.6 \pm 3.2	17.5 \pm 2.7*
RCS	49.6 \pm 5.9	55.1 \pm 6.5*	49.2 \pm 7.5	54.1 \pm 6.9*

* significant difference from before therapy, $p < 0.05$. ^a significant difference in the gains of the two groups, $p < 0.05$. VRG : virtual reality group, ETG: ergometer training group, BDI: beck depression inventory, RCS: relationship change scale

of differences between the two groups was investigated using the independent t-test. Statistical significance was accepted for values of $p < 0.05$.

RESULTS

Both the VRG and ETG subjects exhibited significant improvements in the weight distribution ratio on the paralyzed side, anterior LOS, posterior LOS and TUG and 10-m walking times after the intervention ($p < 0.05$). In addition, the improvements comparison of the post-intervention improvements of the two groups revealed that the VRG showed more significant improvements in weight distribution ratio on the paralyzed side, anterior LOS, posterior LOS and TUG. And 10-m walking times than the ETG ($p < 0.05$; Table 1).

Both the VRG and ETG patients showed significant improvements in BDI and RCS scores after the intervention ($p < 0.05$). The comparison of the post-intervention improvements of the two groups revealed that the VRG showed a more significant increase in BDI than the ETG ($p < 0.05$; Table 2).

DISCUSSION

This study compared the effects of two training programs, virtual reality training and ergometer training, on the balance, gait abilities, depression, and interpersonal relationships of stroke patients. To determine balance and gait abilities, the weight distribution ratio on the paralyzed side, anterior LOS, posterior LOS, TUG, and 10 m walking test were conducted and their results reveal that both the VRG and ETG showed significant improvements in balance and gait abilities.

In a study by Bateni¹⁹⁾, BBS improvements were shown by elderly patients after using the Nintendo Wii Fit. More-

over, Vernadakis et al.²⁰⁾ conducted virtual reality balance exercise using the Xbox Kinect for male soccer players in their teens who had experienced injuries. On average, the participants showed improvements in the overall stability index (OSI) and LOS. A study by Choi²¹⁾ conducted virtual reality training for stroke patients using the Nintendo Wii Fit and reported that execution times of the timed up and go test and 10-m walking test decreased. A study by Lee¹⁵⁾ also reported that chronic stroke patients exhibited a significant decrease in execution times of the timed up and go test and 10-m walking test after completing a virtual reality exercise program. In the present study, both the VRG and ETG showed significant improvements in balance and gait abilities after training. This result was obtained because patients' motivation was increased through the virtual reality games, encouraging their active participation and improving their concentration²²⁾. Moreover, this enabled the successful performance of repetitive training exercises for the damaged. In addition, errors of movement in the lower extremity regarding task performance were shown through accurate visual and auditory sensory feedback, thereby achieving re-education of movements of the lower extremity²³⁾. This feedback contributed to postural stability improvements, which increased dynamic balance and gait abilities. In the case of ergometer training, alternate movements were induced on the paralyzed side with the assistance of the lower extremity on the non-paralyzed side, and active training could be achieved⁸⁾. This resulted in increased muscle strength of the lower extremity on the paralyzed side and the creation of collaborative movements between both lower extremities, leading to improvements in balance and gait abilities.

Our study results reveal that the VRG patients showed more significant improvements in balance and gait abilities than those in the ETG. Virtual reality games such as bowl-

ing, skiing, and golf involve many movements in which the body weight is supported by the lower extremity while playing the game, and trunk stability was required during movements, as well as accurate control of the movements. Therefore, this training improved patients' balance abilities significantly, and gait exercises such as ground walking, walking with obstacles, and walking over stairs were carried out repeatedly. Visual and auditory feedback was also provided while performing exercises, thereby encouraging correct posture and facilitating greater improvement of gait abilities than was observed in the ETG group.

This study also used the BDI and RCS to evaluate depression and interpersonal relationship factors. Lee et al.²⁴⁾ reported that when virtual reality games were used by elderly persons, their depression decreased. Moreover, Lim et al.²⁵⁾ also reported that balance training performed by stroke patients significantly their BDI scores decreases. Lee and Hong²⁶⁾ conducted a game-like group art therapy program for elderly stroke patients and reported improvement in interpersonal relationships in the subjects who carried out the group art therapy.

In the present study, both the VRG and ETG subjects showed significant improvements in balance and gait abilities after training. In particular, the achieved VRG patients exhibited a more significant improvement in BDI scores than those in the ETG. This result was achieved due to the virtual reality training, in which achievement and satisfaction increased because of active performance of exercises which kindled patients' interest. In addition, the ETG performed bicycle riding, which is a bilateral exercise, and affects BDI scores through achievement of exercise on the paralyzed side. Kim and Kim²⁷⁾ proposed that physical activities elderly persons can improve not only physical health, but also happiness and quality of life, and this proposal is supported by our results. However, there was no significant difference in the RCS scores of the two groups. The reason for this is the two groups did not perform their exercise with other people, but did so alone using either the virtual reality training program (Xbox) or ergometer exercise tool.

A limitation of this study was that it was difficult to exclude various variables that can affect psychosocial factors such as depression or subjects' interpersonal relationships. In future research, it will be necessary to conduct a study with larger numbers of patients, and include various psychosocial factors such as fear of falling and self-esteem.

Our study results show that training using virtual reality programs or an ergometer is effective at improving balance, gait abilities, depression, and interpersonal relationships of stroke patients. Therefore, virtual reality training and ergometer training should be used to improve these characteristics.

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