Original Article

The Effects of Virtual Reality-based Balance Training on Balance of the Elderly

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Abstract. [Purpose] The objective of this study was to determine the effects of virtual reality-based balance training on balance of the elderly. [Methods] The subjects were 32 healthy elderly people aged between 65 and 80, who were divided into a VR (virtual reality) training group (n=17) and a control group (n=15). The VR training group engaged in a 30-minute exercise session using Wii Fit three times a week for eight weeks, while the control group received no intervention. The balance of the two groups was measured before and after the intervention. [Results] According to the Romberg Test conducted to examine the effects of the training on balance, both the area covered by the body's center of pressure movement, and movement distances per unit area of the body's center of pressure envelope significantly decreased in the VR training group. Moreover, the two groups showed significant differences in balance. [Conclusion] Virtual reality training is effective at improving the balance of the healthy elderly. Thus, virtual reality training can be proposed as a form of fall prevention exercise for the elderly.
Key words: Virtual reality training, Balance, Elderly

INTRODUCTION

About 30% of the elderly aged 65 years or older experience a fall at least once a year, and 15% fall twice or more per year[1, 2]. A fall can result in serious injuries, such as fracture or dislocation, as well as minor injuries, such as contusion and sprain. Many elderly people who sustain a severe fracture do not recover to their prior functional level and some even die[3]. In addition, a fall restricts elderly people's activities of daily living, leading to loss of independence, hospitalization, increased medical costs, and a greater economic burden[4].

Recent technological advances have led to the introduction of new virtual reality-based exercise methods for performing diverse tasks[5]. Flynn et al.[6] observed that virtual reality provides interest and fun and motivates the user. Clark et al.[7] and Yamada et al.[8] noted that the reliability of virtual reality-based exercise regimes has been proven. Research on virtual reality is ongoing. Interactive virtual reality is defined as a tool for interaction between a user and his or her computer. Virtual reality makes it possible to perform a much larger range of activities and to create more diverse movements than in actual situations. Via virtual reality, users interact with created scenarios or environments through diverse sensory channels[9]. Sensory feedback (auditory, vision, and proprioception) can be provided in virtual environment exercise training programs, and the program can be tailored to each individual by changing the level of exercise according to the individual's degree of adaptation to the training[10]. Adamovich et al.[11] proposed that the rapid development of virtual reality technology raised the possibility of developing new exercise strategies.

Many previous studies have examined the use of virtual reality in treating various conditions, such as stroke[12], cerebral palsy[13], and traumatic brain injury[14]. The present study investigated changes in the balance ability of healthy elderly people following virtual-reality balance training for the prevention of falls.

SUBJECTS AND METHODS

The subjects were 32 healthy elderly people aged between 65 and 80 years who were randomly assigned to either a virtual reality training group (n=17) or a control group (n=15). The virtual reality training group received training three times per week for eight weeks with a Nintendo Wii Fit program, while the control group received no intervention. Those whose score on the Korean mini-mental status exam was lower than 23 and who had been diagnosed with an orthopedic disease, such as fracture, within the previous six months were excluded from this study. Additional exclusion criteria were the presence of any visual or auditory abnormality; the consumption of drugs, such as opiates or alcohol; the consumption of strepto antibiotics affecting balance prior to the examination; and the presence of a progressive disorder or neurological disturbance (e.g., Parkinson's dis-

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ease, Alzheimer's disease, multiple sclerosis, epilepsy, or stroke). All included patients understood the purpose of this study and provided their written informed consent prior to their participation in the study in accordance with the ethical principles of the Declaration of Helsinki.

Subjects' balance with their eye open and closed was measured using the Romberg test on a Bio-rescue (RM IN-GENERIE, France). For the starting position, the subjects placed their second toe on a diagonal line drawn on the foot plate, put their heels together, and maintained an angle of 30 degrees between the feet. Measurements were taken with the subject's eyes open for 60 seconds, and with their eyes closed for 60 seconds.

The Nintendo Wii Fit device used in the virtual reality training consists of a balance board and a CD. When a subject mounts the balance board, an avatar appears on the screen and imitates the subject's movements. The equipment not only provide visual and auditory feedback, but also tactile feedback through vibration the Wii remote control. The following balance games were used in this study: ski slalom, table tile, and balance bubble. The subjects took part in each of the programs for 10 minutes. When the subjects performed each program, they had to move their center of gravity without changing the position of their feet on the balance board.

The means and standard errors of all variables were calculated using SPSS 20.0 KO (IBM, IL, USA). The independent t-test was carried out to determine statistical variations between the groups. In addition, the paired t-test was conducted to verify changes within each group prior to and after the virtual reality training. Statistical significance was accepted for values of $p<0.05$.

RESULTS

Comparison of the general characteristics of the two groups showed no significant differences (Table 1). The results show that body center of pressure movement area of the virtual reality training group with their eyes open significantly improved ($p<0.05$) after the intervention, while that of the control group did not ($p>0.05$; Table 2). Body center of pressure movement area of the virtual reality training group with their eyes closed significantly improved ($p<0.05$) after the intervention, while that of the control group did not ($p>0.05$; Table 2).

DISCUSSION

Young et al.[15] proposed that virtual reality training for the elderly is safe and economical, and that it may encourage user interest. Interventions using virtual reality may improve the balance and gait of patients and develop their fine motor function, gross motor function, and coordination[16]. In addition, virtual reality training is a safe and useful tool for enhancing the sensorimotor functions of Down's syndrome patients[17], and for improving stroke patients' balance and gait during rehabilitation treatment. It is an effective alternative to physical therapy at home[18].

Balance training is considered to be an important aspect of a fall prevention program. Balance training has been

Table 1. General characteristics of the subjects

	VR (n=17)	Control (n=15)
Age (years)	73.1±1.1	71.7±1.2
Height (cm)	164.2±2.5	162.3±2.8
Weight (kg)	63.7±3.0	64.4±3.0

VR: Virtual reality training group, Control: Control group

Table 2. Center of pressure excursion area of each group with eyes open and closed   (Unit: cm)

		Pre	Post
		(Mean±SE)	
Eyes open	VR	95.1±10.7	44.9±6.6***
	Control	99.6±41.6	114.5±51.2
Eyes closed	VR	104.1±20.4	35.6±7.6**
	Control	109.9±15.3	72.5±20.9

Mean±SE: Mean±Standard Error **$p<0.01$, ***$p<0.001$

shown to improve the different aspects of postural control[19]. balance training is effective individually or in combination with other types of treatment approaches. Specific balance training alone has been reported to result in a significant reduction in the rate of falls among the elderly[20]. A meta-analysis of exercise interventions for fall prevention also recommended exercises that challenge the balance[21]. Balance control or normal postural control is essential for mobility as well as stability during functional activities. Deficits in balance can lead to falls by the elderly, limiting their activities. Therefore, balance assessment is very important for older adults, and balance training should be an integral part of the management of older adults.

The total area over which the center of pressure moved was reduced after the virtual reality training, suggesting that the balance ability of the subjects had improved. The deviation of the center of pressure depends on proprioceptive information, the vestibular system, and visual signals[22]. For a person to maintain balance without swaying in a standing position, the center of mass of the body must remain within the base of support established by the movement of the center of pressure[23]. Postural stability in a static standing position may be quantified using the movement of the center of pressure, the point of the vertical component of the ground reaction force, on the base of support. In the virtual reality programs used in the present study, feed-forward strategies are used to control the movements of the avatars. The subjects in the virtual reality training group showed center of pressure excursion decrease, a result reflecting an improvement in feed-forward strategies achieved through adjusting the avatars by moving weight from one leg to the other. In a study by Van Ooteghem et al.[24], the subjects' excursion of center of mass also decreased on a platform while vibration continued. This result is consistent with that of the present study. The subjects who participated in the virtual reality training learned postural control responses by observing their avatar on a screen. According to the results of the measurements of the subjects' balance with their eyes open and

closed, the virtual reality training improved their balance ability, both with and without visual information . Balance requires the integration of proprioception, and vestibular system, and visual information. In the elderly, postural stability and balance may not be functioning properly due to problems with visual feedback[25]. Subjects'dependence on visual input for balance decreases because of age-related eyesight degeneration[26]. In the present study, eyesight deterioration did not seem to be a major factor in balance impairment. Regular exercise by the elderly, whose physical functions decline as they grow older may be effective at preventing falls. When regularly used, the Nintendo Wii-fit program represents an accessible, fun, and economical method which can help to improve the balance of, and prevent falls by the elderly.

Some limitations need to be considered when interpreting the results of the present study. First, the control group did not engage in any training for 8 weeks. Therefore, the effectiveness of virtual reality training was not evaluated against other balance training methods. It is possible that simply doing any form of training was better than doing none for these older adults. However, the main goal of this study was to assess whether the virtual reality training would be effective at improving the balance control of older adults. Second, we did not compareresults among the age groups, for example, 65–69, 70–74 and 75–80. These two things should beresearched in the future.

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