J Korean Soc Phys Ther Vol.26, No.6, December 2014 pISSN 1229-0475 · eISSN 2287-156X

The Journal of Korean Society of Physical Therapy

Original articles

Comparison of Balance and Fall Efficacy of Virtual Reality Program in Elderly Women with Fall Experience

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Purpose: The objective of this study was a virtual reality-based balance training program effective for improvement in physical function, examined the balance ability and fall efficacy of elderly women with experienced falls, intending to examine the program' s usefulness as an exercise program to prevent the recurrence of a fall.

Methods: The participants were 30 elderly women aged 65 or older who met the conditions. The participants were randomly assigned to either a balance training group (BT) or a virtual reality-based balance training group (VT) and received the training three times per week, 30 minutes per day, for six weeks. To measure static balance, the Tetrax Portable Multiple System (Tetrax Ltd, Israel) were used. To measure dynamic balance, the Berg Balance Scale (BBS) and functional reach test (FRT) was used, and regarding fall efficacy, the Korean Fall Efficacy Scale (K-FES) was used.

Results: Tetrax significantly improved after the intervention in both the BT group and the VT group ($p<0.05$). The comparison between the two groups was not significantly. BBS and FRT result significantly improved after the intervention in both the BT and VT groups ($p<0.001$), while K-FES was significantly ameliorated in the VT group only ($p<.05$). Comparing the groups, there were more significant changes in the BBS ($p<0.05$) and FRT ($p<0.01$) result of the VT group than the BT group.

Conclusion: A virtual reality-based balance training program is considered to be usable as an exercise program to prevent recurrence of falls in elderly women.

Key Words: Balance, Fall efficacy, Virtual-reality based balance training

I. Introduction

14.9% of the total elderly population in 2008 experienced fall down, and 17.2% of elders above 65 yr old experienced fall down with average 2.2 times of fall which implies the existence of risk of reoccurrence. Disorder in gait and balance predicts falls better than other risk factors such as damaged vision and drug.[1] In the precedent studies, elders performed various interventions including aerobic exercise,[2] resistance exercising using elastic band and muscular exercise using equipment,[3] to enhance the physical functions. However, muscular exercise had weaknesses such as low interest and participation rate, due to repetition of simple motions, spatial restrictions, and requiring equipment and apparatus for exercise.

Under a virtual reality (VR) program, one can interact with images on a screen rather than actual things, can move or operate virtual objects in a simulated environment, and can perform diverse motions,[4] overcoming temporospatial constraints.[5] In addition, such a program induces users' pleasure and interest, enabling continuous and voluntary exercise.[6] Recently, effects on users of interaction in Wii

Received Nov 10, 2014 Revised Dec 12, 2014
Accepted Dec 16, 2014
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SportsTM have become known, and enhancement in dynamic postural control ability through Wii FitTM video games has been reported.[7] In addition, the effect of functional improvement in elderly people with instability resulting from functional decline was also verified.[7] Interaction through VR allows a subject to receive tactile, olfactory, visual, and auditory feedback while acting within in a VR.[8] When elderly people perform the program in a standing position, it is effective as an exercise intervention to prevent their fall.[9]

In the rehabilitation field, VR systems are widely used for individuals with stroke,[10,11] those with spinal cord injury8 and those with neuromusculoskeletal conditions[12] as programs to improve gait and balance ability. In a recent study on center of pressure displacement measured by the Wii FitTM balance board, its high stability and validity were evidenced as a retraining rehabilitation tool aimed at enhancing postural control ability.[5] The Wii gaming system,[13] Wii Balance Board,[6] and PlayStation Eye Toy[14] may be utilized at home at a low cost, unlike pricey VR equipment, and their utilization value as tools to enhance the physical functions of elderly people is high. Among the elderly, compared to men, women undergo more drastic physical changes through climacterium and are more exposed to all kinds of diseases and accidents. Among these, a fall may be problematic to elderly people due to physical and psychological sequelae after it occurs; 2.3% to 32.6% of elderly people have been reported to experience actual damage after a fall.[15] Therefore, preventing recurrence of a fall as well as preempting it is important.

Accordingly, this study intends to examine the balance ability and fall efficacy of elderly women who have experienced a fall, using a VR-based program effective for improving physical functions, thereby looking at its usability as an exercise program to prevent the recurrence of a fall.

II. Methods

1. Subjects and Study periods

The participants of this study were elderly women aged 65 or older. The final participants were 30 participants from among 50 elderly women at the D welfare center (Donggu, G City), excluding 10 who refused to participate, 3 whose health became aggravated, and 7 who did not meet the participation criteria. The criteria for inclusion as participants were: those who did not have visual and auditory abnormalities; those who were able to walk independently; those who did not have a fracture or other orthopedic problems; and those who had experienced at least one fall in the recent six months. All participants sufficiently listened to explanations of this study and voluntarily consented to take part in it. Randomly by lot, all participants were assigned to either a balance training group (BT group, n=15) or a virtual reality-based balance training group (VT group, n=15). In this study, was conducted from August 1, 2014, for 6 weeks. The research was conducted three times per week, 30 minutes per day. There were no significant differences between the two groups in general characteristics of participants (Table 1). This study was reviewed by the Ethics Committee of the hospital.

2. Measurement methods

1) Experimental procedure

The VT group used the Ski Slalom Wii sports program and the Soccer Heading program.[16] For each game, the participant stood on a balance board composed of two force plates with bilateral feet and adjusted the force of both feet. A therapist who was well-acquainted with the program supervised the subjects for fall prevention, standing beside them while they performed the games.

The BT group trained the hip joint, knee joint, and ankle joint of the lower limbs using elastic bands (Thera-band, The Hygenic Corp, USA) and balance pad. Standing on the balance pad was repeated flaxion and extention, rotation movement while maintaining the elasticity of the elastic band. The exercise was composed of three sets, ten times for each set. After the three sets were finished, the participants had a resting time for two minutes. Prior to and after the exercise, the subjects conducted breathing exercises and stretching, each for five minutes.

2) Measurement instruments

(1) Static balance test

In order to measure static balance ability, the Tetrax Portable Multiple System (56 Miryam St, Tetrax Ltd, Ramat Gan,

Table 1. General characteristics of subjects

	BT group (n=15)	VT group (n=15)	t
Age (yrs)	73.32(5.73)[a]	74.63(6.24)	0.73
Height (cm)	157.38(4.47)	157.21(5.27)	0.71
Weight (kg)	55.73(2.28)	55.13(4.27)	1.03
BMI (kg/cm2)	24.53(4.21)	24.67(4.04)	0.74

[a]means(SD)
BT: Balance training
VT: Virtual reality-based balance training
BMI: Body mass index

Israel, 2006) (Fig 1) were used. Four of the vertical pressure applied to force plate is detected at a rate of 34㎐ by way the respective pressure transducer, to measure the variation in pressure aspect. Participants put both feet on Tetrax devices force plate and carried out in two ways in the attitude of the line immediately. 32 seconds (including preparation time) was measured by open eyes in standing (normal eye open, NO) and close eyes in standing (normal eye close, NC).[17] The lower score means stable. Through the aspect of pressure fluctuation stability index was calculated.

Figure1. Tetrax Portable Multiple System

(2) Dynamic balance test
In order to measure dynamic balance ability, the Berg Balance Scale (BBS) and the Functional Reach Test (FRT) were used. The BBS consisted of 14 items applying activities of daily living, with a 5-point scale from a minimum of zero point to a maximum of four points; the lower the scale was, the higher the risk of a fall.[18] The BBS had high intra-rater (r=.99) and inter-rater (r=.98) reliability and internal validity.[18] The FRT involved stretching the arms toward the front in a standing position and measuring the distance, which enabled a measurement of the limit of stability.[19] After sufficient explanation by one measurer, the measurement was taken three times, and the average value was obtained.

(3) Fall efficacy test
In order to measure fall efficacy, the Korean Fall Efficacy Scale (K-FES) was used. The fall efficacy scale by Tinetti et al.[20] was adapted into the K-FES.[19] K-FES shows fall-related self-efficacy and is composed of a 10-point scale, from a minimum of one point to a maximum of 10 points. The higher the score, the higher the fall-related self-efficacy. Higher self-efficacy mean was low fall risk.[18] The Reliability of the K-FES was α=0.84.[21] One measurer recorded the result, one-to-one.

3. Statistical analysis

The data collected through the measurements were analyzed using Windows SPSS Ver. 17.0. An independent t-test was used to examine the homogeneity of the participants. A paired t-test was conducted to look at changes within each group after the intervention, and an independent t-test was carried out to examine differences between the two groups. A significance level was set at α=0.05.

Ⅲ. Results

Significant difference between the VT group and the BT group in the dynamic balance(BBS, FRT) and static balance(Tetrax Portable Multiple System), falls efficacy(K-FES) pre-test was not ($p>0.05$) (Table 2,3).

Table 2. Comparison of static balance in BT group and VT group

	BT group (n=15)		t^a	VT group (n=15)		t^a	t^b
	Pre-test	Post-test		Pre-test	Post-test		
NO (score)	21.41(3.97)[c]	19.47(2.91)	3.80*	19.66(2.78)	18.93(2.44)	2.53*	-2.08
NC (score)	31.63(5.83)	29.16(5.41)	2.85*	27.21(6.72)	25.57(5.43)	2.71*	-0.78

[a]Within group comparison, [b]Between group comparison, [c]Means(SD)
BT: Balance training
VT: Virtual reality-based balance training
NO: Normal eye open
NC: Normal eye close
*p<0.05

Table 3. Comparison of dynamic balance and falls efficacy in BT group and VT group

	BT group (n=15)		t^a	VT group (n=15)		t^a	t^b
	Pre-test	Post-test		Pre-test	Post-test		
BBS (score)	49.73(3.02)[c]	50.57(2.64)	-4.08 ‡	49.37(3.14)	51.96(2.04)	-8.03 ‡	2.46*
FRT (㎝)	10.78(1.08)	11.65(1.03)	-5.06 ‡	10.84(1.17)	12.58(1.27)	-13.22 ‡	3.32 †
K-FES (score)	65.08(2.9)	64.34(4.75)	0.87	47.86(2.94)	45.54(4.38)	2.30*	-1.00

[a]Within group comparison, [b]Between group comparison, [c]Means(SD)
BT: Balance training
VT: Virtual reality-based balance training
BBS: Berg balance scale
FRT: Functional reach test
K-FES: Korean falls efficacy scale
*p<0.05, † p<0.01, ‡ p<0.001

1. Change made in static balance

Normal eye open is BT group has changed 21.41 ± 3.97 into 19.47 ± 2.91 after intervention, VT group has changed 19.66 ± 2.78 into 18.93 ± 2.44 which show statistical significance (P〈0.05) (Table 2). The post-test comparison between the two groups was not significantly (Table 2). Normal eye close is BT group has changed 31.63 ± 5.83 into 29.16 ± 5.41 after intervention, VT group has changed 27.21 ± 6.72 into 25.57 ± 5.43 which show statistical significance (P〈0.05) (Table 2). The post-test comparison between the two groups was not significant (Table 2).

2. Change made in dynamic balance

BBS is BT group has changed 49.73 ± 3.02 into 50.57 ± 2.64 after intervention, VT group has changed 49.37 ± 3.14 into 51.96 ± 2.04 which show statistical significance (p〈0.001) (Table 3). In the comparison between groups improved significantly VT group than BT group (p〈0.05) (Table 3). FRT is BT group has changed 10.78 ± 1.08 into 11.65 ± 1.03 after intervention, VT group has changed 10.84 ± 1.17 into 12.58 ± 1.27 which show statistical significance (P〈0.05) (Table 3). In the comparison between groups improved significantly VT group than BT group (p〈0.01) (Table 3).

3. Change made in fall efficacy

K-FES is BT group has changed 65.08 ± 2.9 into 64.34 ± 4.75 after intervention which show no significance, however VT group has changed 47.86 ± 2.94 into 45.54 ± 4.38 which show statistical significance (P〈0.05) (Table 3). The post-test comparison between the two groups was not significant (Table 3).

Ⅳ. Discussion

This study examined the effect of a virtual reality-based balance training program effective for physical function improvement in elderly women who had experienced a fall. The virtual reality-based balance training program was more effective than balance training for enhancement in balance ability and fall efficacy.

Elderly people control their balance depending on visual feedback,[22] and their instability greatly increases when visual information is reduced or removed.[23] According to the present study result, the VT group saw more significant improvement in the BBS and FRT. This was consistent with the result of research by Kim et al.[24] and Jung et al.[25], who reported significant improvement in the balance ability of ordinary elderly people after virtual reality-based balance training. In the Ski Slalom and Soccer Heading programs selected by this study, the subject looked at the monitor and naturally moved the weight on the bilateral lower limbs with the two feet, with improvement in the balance ability. The result of a study by Rogers and Mille[26] and Jung and Chung,[27] who observed that muscle strength around the hip joints was needed for balance control, supports this. Therefore, the virtual reality-based balance training program decreased the elderly people's degree of dependence on visual feedback, enhancing their balance control ability.

Significant improvement in the VT group in the K-FES was consistent with the result of a study by Banez et al.[28], who reported that a 12-week fall prevention program reduced the subjects' risk of a fall and heightened their self-efficacy. The reason why the present study result is all the more meaningful is that although it was performed for a short period of six weeks, it verified that VT group was more effective than BT group. Michalski et al.[16] also noted that repetitive exposure to visual, auditory, and mechanical stimuli through VR resulted in participants' learning the effects of motor control strategies, heightening their degree of involvement by responding to stimuli with active enjoyment.

When balance training is performed in a standing position, it is helpful for coordination training, it heightens movement speed and responses according to postural changes, and it requires active movement concentration and rapid response of the whole body, thereby increasing voluntary movements and weight supporting ability in the lower limbs.[29] Therefore, exercises using VR were found to be more effective than ordinary balance training. This occurred due to the stimulation of different sensory organs of the human body, through adjustment strategies by the elderly depending more on vision than in ordinary balance training, and VR exercise may be applicable as an exercise program to prevent recurrence of a fall. Also, the falls are frequent in unpredictable conditions in the course of activity in activity daily of living. Therefore, in this study the dynamic balance of virtual reality training showed significant results I think a more effective training method for fall prevention.

The limitation of this study is that the subjects were elderly women who had experienced a fall, and therefore, it is difficult to generalize the results to all elderly women. In addition, this study failed to examine the sustainability of the effect. Research that complements these points is considered necessary. Also, we need to be applied to a variety of participants.

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