Tohoku J. Exp. Med., 2016, **238**, 1-8

A New Approach to Improve Cognition, Muscle Strength, and Postural Balance in Community-Dwelling Elderly with a 3-D Virtual Reality Kayak Program

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Aging is usually accompanied with deterioration of physical abilities, such as muscular strength, sensory sensitivity, and functional capacity. Recently, intervention methods with virtual reality have been introduced, providing an enjoyable therapy for elderly. The aim of this study was to investigate whether a 3-D virtual reality kayak program could improve the cognitive function, muscle strength, and balance of community-dwelling elderly. Importantly, kayaking involves most of the upper body musculature and needs the balance control. Seventy-two participants were randomly allocated into the kayak program group (n = 36) and the control group (n = 36). The two groups were well matched with respect to general characteristics at baseline. The participants in both groups performed a conventional exercise program for 30 min, and then the 3-D virtual reality kayak program was performed in the kayak program group for 20 min, two times a week for 6 weeks. Cognitive function was measured using the Montreal Cognitive Assessment. Muscle strength was measured using the arm curl and handgrip strength tests. Standing and sitting balance was measured using the Good Balance system. The post-test was performed in the same manner as the pre-test; the overall outcomes such as cognitive function ($p < 0.05$), muscle strength ($p < 0.05$), and balance (standing and sitting balance, $p < 0.05$) were significantly improved in kayak program group compared to the control group. We propose that the 3-D virtual reality kayak program is a promising intervention method for improving the cognitive function, muscle strength, and balance of elderly.

Keywords: cognitive function; elderly; kayak; postural balance; virtual reality
Tohoku J. Exp. Med., 2016 January, **238** (1), 1-8.

Introduction

Falls in the elderly is a major social issue, as they can lead to physical health, social, and psychological problems. The incidence rate of falls increases with age and may affect 45% of the elderly population older than 75 years (Rubenstein 2006). The consequences of fall are a reduction in functionality reduction, loss of independence, and in some cases, death (Gazzola et al. 2006). Moreover, falls lead to increased healthcare costs and define social problems (Masud and Morris 2001). The biomechanical limitations associated with aging correlate strongly with the cognitive function, muscle strength, and balance in the elderly (Horak 2006). An inactive lifestyle and the physiological changes related to aging, such as sarcopenia and the progressive decline in muscle strength, joint range of motion, reaction time, and the sensory system can lead to reduced physical performance and increased risk of falling (Borah et al. 2007; Howe et al. 2007). Moreover, cognitive disorders are common in the elderly and strongly associated with falls. The incidence of falls in people with cognitive impairment is estimated to be twice that of older adults with intact cognitive ability (Shaw 2002). A later study of the effects of cognitive and emotional statuses on physical functioning found that having severe depression and low cognitive function was associated with poor physical performance (Raji et al. 2002). Moreover, according to a more recent studies, declining grip strength (Rogers and Jarrott 2008) and gait speed (Fitzpatrick et al. 2007) are associated with increased risk of cognitive disorders.

In recent years, greater technological developments have led to the introduction of new intervention methods using virtual reality to performing diverse tasks (Bryanton et al. 2006). Virtual reality enables people to have virtual experiences that are similar to reality (Zhang et al. 2001). In virtual reality, people perform diverse tasks and accomplish predetermined goals using technological simulated scenes by reacting as if they are performing the actions in reality (Holm and Priglinger 2008). This method provides an interesting and fun therapy, increasing motivational effects (Rand et al. 2008). Virtual reality provides visual, auditory and proprioceptive, and can also

Received September 25, 2015; revised and accepted November 9, 2015. Published online December 9, 2015; doi: 10.1620/tjem.238.1.
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stimulate cognition (Schultheis and Rizzo 2001). According to previous studies, general exercise focused only on a specific task improves performance in activities of daily living to limited extent. Hsieh et al. (2014) showed that when compared to general exercise, training with virtual reality resulted in a 30% reduction in falls (Hsieh et al. 2014). It can be applied with various preventive exercises against falling in the elderly. To the best of knowledge, this is the first study to apply kayak program for fall prevention in elderly persons.

Kayak ergometers provide an opportunity to perform kayak training independent of outdoor conditions and to better control training progression (Bjerkefors and Thorstensson 2006). Kayaking appears to fulfill the criteria for such an activity, as it involves most of the upper body musculature and puts severe demands on balance control in sitting (Bjerkefors et al. 2007). Kayaking is an outdoor activity that can be enjoyed with easy motions and with minimal skill, and can be performed on equal terms by both people who are physically able and those with disabilities. In addition, kayaking presents high metabolic demands and challenges to the balance control system. Maintaining the sitting posture requires continuous compensation for perturbations to the upper body by motion of the kayak and paddle in the water, as well as of the arms and paddle in the air (Grigorenko et al. 2004).

Kayaking combined with virtual reality would be expected to improve the cognitive function, muscle strength, and balance of elderly persons. Therefore, the purpose of this study was to determine the effects of 3-D virtual reality kayak program on the cognitive function, muscle strength, and balance of community-dwelling elderly.

Methods

Participants

Seventy-two elderly people participated in the study. The participants were recruited from G Senior Center in Seoul, South Korea. The following inclusion criteria were utilized: registered in the senior center, able to communicate, and able to attend a 6-week intervention. The following exclusion criteria were utilized: musculoskeletal impairment of the upper extremities, neurological impairment, significant cognitive disorders, psychological problems such as depression, untreated medical conditions, or unable to maintain the sitting position for less than 30 seconds a long time. No significant difference in general characteristics was observed between the two groups at baseline (Table 1).

The sample size was calculated by using the G-power software (Ver. 3.1). Based on the results, we set the effect size at 0.7. When a 2-tailed test with a test power of $\beta = 0.8$ and significance level of $\alpha = 0.05$ was applied (Machin et al. 2011), the calculated sample size was 80.

All protocols and procedures were approved by the institutional review board of Sahmyook University (Seoul, South Korea), and all of the participants signed a statement of informed consent.

Procedures

This study used randomized controlled trial design. Seventy-two participants were randomly allocated to either the virtual kayak program group or the control group. All of the participants had an equal probability of assignment to the groups. External randomization was achieved by using the Random Allocation Software (Ver. 2.0) (Saghaei 2004).

The participants in the control group performed 30 min of the conventional exercise, including 5-min warm-up and 5-min cool-down exercises. The warm-up, consisted of using a massage sensory ball while listening to relaxing music, stretching, and breathing exercise. The conventional exercise, consisted of side stepping, tandem walking, backwards walking, braiding, one-leg standing, cup tapping, and external perturbation while standing with the head up and back straight were conducted (Cho and An 2014). Finally, in the cool-down, muscle relaxation exercises for stretching, and breathing exercises were used.

The kayak program was performed two times per week for 6 weeks by the experimental group. The participants in the experimental group also performed 30 min of conventional exercise similar to the control group, and then performed 20 min of the virtual reality kayak program. For kayak program, water training was simulated with installing a stool and a footrest on a springboard. By using a 3-D beam projector, 3-D images of moving kayaks that were directly filmed in a river and a lake were displayed. The subjects exercised by paddling according to watch the actions performed by the 3-D images on the screen (Fig. 1).

Outcome measurements

Cognitive function: The Montreal Cognitive Assessment (MoCA) test was designed as a rapid screening instrument for mild cognitive dysfunction (Freitas et al. 2013). It assesses the following cognitive domains: attention and concentration, executive functions, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation. It takes approximately 10 min to administer the MoCA. The total possible score is 30 points. A score

Table 1. General characteristics of the participants (N = 72).

	Experimental group (n = 36)	Control (n = 36)	χ^2/t (p)
Sex (male/female)	36 (3/33)	36 (1/35)	0.303 (0.311)
Age (year)	72.97 ± 2.98	74.11 ± 2.88	0.860 (0.104)
Height (cm)	155.16 ± 5.57	153.64 ± 4.68	0.821 (0.217)
Weight (kg)	54.21 ± 5.01	53.15 ± 3.97	0.872 (0.326)

Values are presented as mean ± standard deviations.

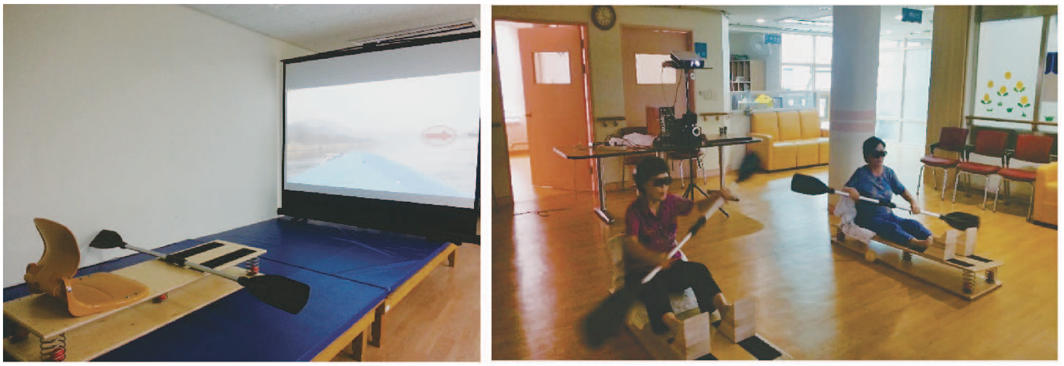

Fig. 1. 3-D virtual reality kayak program.

of 26 or higher is considered to be in the normal (Freitas et al. 2013).

The internal consistency of the MoCA is high (Cronbach's alpha: 0.86), and its test-retest reliability was found to be 0.75. It had good specificity of 84% and high sensitivity of 89% for screening mild cognitive impairment (Lee et al. 2008).

Muscle strength: Handgrip strength, a measure of strength of the hand and forearm muscles, is a useful index of overall musculoskeletal condition (Sin et al. 2009). Handgrip strength was measured by using a handheld dynamometer (Medical Handgrip Dynamometer model DHS-88, Detecto, Webb City, USA). While seated, the participants were instructed to maximally grip squeeze the dynamometer (Abizanda et al. 2012). The mean of three trials was used in this study. The left and right hands were tested alternatively, and the subjects were allowed to rest for 1 min between the trials. The results were expressed in kilograms. The handgrip strength test has an excellent reliability when used in the elderly. The test-retest reliability was ICC = 0.97, which indicates the high accuracy of the measurements (Wang and Chen 2010).

The arm curl test (ACT) measures the strength of the upper body in older adults (Singh et al. 2014). It has shown good test-retest reliability in the sitting position. With an intraclass correlation coefficient was 0.96 (Miotto et al. 1999). The participants were asked to sit upright with their back against the backrest of an armless chair. They performed biceps curls without bending the trunk forward for 30 seconds with 2.3- and 3.6-kg dumbbells for women and men, respectively. The score was the total number of arm curls.

Standing and sitting balance: Postural sway was measured by using the Good Balance system (Good Balance, Metitur Ltd, Finland). The system was composed of a safety bar and an equilateral triangular force platform. It was connected to a laptop by using the Bluetooth technology. The sampling frequency was 50 Hz.

The following 3 different variables were calculated for the trajectory of the center of pressure: anterior-posterior sway velocity, medial-lateral sway velocity, and velocity moment, which refers to the first moment of velocity estimated as the mean area covered by the movement of the center of pressure during each second of the test, taking into account both the distance from the geometrical midpoint of the test and the speed of the movement during the same period (Salminen et al. 2009).

Standing balance measurements were performed with the subject standing on a force platform for 30 seconds with the eyes open, hands hanging down loosely, feet comfortably apart, and gaze fixed forward, followed by quiet standing for another 30 seconds but with the eyes closed. The tests were performed 3 times in the same order for each subject. Sitting balance was measured in the same manner. The subject sat on a high chair with the feet not contacting the floor.

The test-retest reliabilities were 0.83 with the eyes open and closed, respectively, when assessed using the log mean medial-lateral speed, and 0.69 with the eyes open or closed when evaluated using the log mean anterior-posterior speed (Ceria-Ulep et al. 2011).

Statistical analyses

For data analysis, SPSS ver. 19.0 was used for averages and standard deviations. Data normality was tested using the Shapiro-Wilk test, and all variables showed normal distribution. Independent t tests and chi-squared tests were used for homogeneity testing. A paired t test was used for within-group comparison. An independent t test was used for comparison of exercise differences between the groups. The significance level was set at 0.05 for all the analyses.

Results

Comparison of cognitive function

The results of MoCA for cognitive function are shown in Table 2. In the comparison between the MoCA score before and that after the kayak program, a significant increase was observed in the experimental group. However, there was a significant decrease in the control group ($p < 0.05$). The difference in MoCA scores from pre-test to post-test showed that the experimental group improved significantly compared to the control group ($p < 0.05$), the increase was significantly higher in the experimental group than in the control group ($p < 0.05$).

Comparison of muscle strength

The results of the ACT for muscle strength are shown in Table 3. In the comparison between the ACT scores before and those after the kayak program, a significant increase was observed in the experimental group. However, there was a significant decrease in the control group ($p < 0.05$). In the comparison of the difference in ACT scores from before to after the program, we found that there was a significant difference between the two groups. Significantly higher in the experimental group than in the control group ($p < 0.05$).

In the comparison of grip strengths for muscle strength, a significant difference was observed in both

Table 2. Changes in the cognitive function at pre- and post-program (N = 72).

		Experimental group (n = 36)	Control group (n = 36)	Difference (post-pre)		t (p)
				Experimental group	Control group	
MoCA (point)	Pre	22.63 ± 4.91	22.88 ± 4.18	2.05 ± 2.60	−1.11 ± 2.29	5.475 (0.000)
	Post	24.69 ± 4.65	21.77 ± 5.19			
	t (p)	−4.731 (0.000)	2.911 (0.006)			

Values are presented as mean ± standard deviations.
MoCA, Montreal Cognitive Assessment.

Table 3. Changes in the muscle strength at pre- and post-program (N = 72).

		Experimental group (n = 36)	Control group (n = 36)	Difference (post-pre)		t (p)
				Experimental group	Control group	
Arm curl (rep)	Pre	25.41 ± 6.60	26.41 ± 9.00	7.05 ± 8.87	−4.56 ± 4.85	6.896 (0.000)
	Post	32.47 ± 10.06	21.84 ± 6.71			
	t (p)	−4.771 (0.000)	5.646 (0.000)			
Grip strength (Right) (kg)	Pre	21.38 ± 5.64	20.39 ± 5.52	1.96 ± 4.22	−2.66 ± 4.73	4.367 (0.000)
	Post	23.35 ± 4.86	17.73 ± 5.19			
	t (p)	−2.784 (0.009)	3.369 (0.002)			
Grip strength (Left) (kg)	Pre	20.06 ± 6.82	18.36 ± 5.18	3.03 ± 4.36	−3.09 ± 4.73	5.836 (0.000)
	Post	23.10 ± 5.18	15.27 ± 4.51			
	t (p)	−4.174 (0.000)	4.084 (0.000)			

Values are presented as mean ± standard deviations.

groups ($p < 0.05$). The difference in grip strength from before to after the program, we found a significant difference between the groups ($p < 0.05$).

Comparison of static balance ability in standing

For all standing balance tests (Table 4), significant increases were shown in experimental group after the program ($p < 0.05$). However, there was a significant decrease in control group. In the comparison of the difference all standing balance test. We found significant difference between the groups ($p < 0.05$).

Comparison of static balance ability in sitting

For all sitting balance tests (Table 5), significant increases were shown in experimental group after the program ($p < 0.05$). However, there was a significant decrease in control group. In the comparison of the difference all sitting balance test. We found significant difference between the groups ($p < 0.05$).

Discussion

Exercise is an important factor that is closely related with the improvement of quality of life (Montuclard et al. 2000). Generally, there is a decline in muscle power decreased joint working ranges, and deterioration of various sense organs affect balance and physical functions due to aging. Besides these physical problems, mental problems, such as a decline in cognitive functions or depression are incurred (Kim et al. 2009). These result in decreased quality of life, and social and economic problems in the elderly. To prevent these problems and to maintain and develop physical and psychological functions, proper and consecutive interventions are necessary. Kayak exercise requires high-level physical ability and enhances functions of the upper limbs, cardiopulmonary capacity, and ability of posture control (Bjerkefors and Thorstensson 2006; Bjerkefors et al. 2007). In previous research studies, kayaking was mostly used only for the purpose of training athletes. Recently, by using stable and interesting elements of kayaking, kayak exercise can be applied for health improvement of the general population.

In this study, through with application of the 3-D virtual reality technique, we found that these kayak training programs were highly effective in improving the muscle strength of community-dwelling elderly people. In addition, this study demonstrates that the programs substantially heightened balance in both the sitting and standing postures. In the experimental group particular, the fact that

Table 4. Changes in the standing balance with eyes opened and eyes closed at pre- and post-program (N = 72).

		Experimental group (n = 36)	Control group (n = 36)	Difference (post-pre)		t (p)
				Experimental group	Control group	
Eye opened						
X sway (mm/s)	Pre	6.78 ± 2.54	7.20 ± 3.64			
	Post	5.07 ± 2.31	7.84 ± 4.34	−1.70 ± 1.29	0.63 ± 1.98	−5.922 (0.000)
	t (p)	7.918 (0.000)	−1.917 (0.063)			
Y sway (mm/s)	Pre	9.40 ± 3.18	8.91 ± 3.36			
	Post	7.56 ± 2.97	9.88 ± 4.18	−1.83 ± 2.37	0.97 ± 1.86	−5.595 (0.000)
	t (p)	4.635 (0.000)	−3.56 (0.003)			
VM (mm^2/s)	Pre	22.73 ± 15.23	17.82 ± 14.01			
	Post	12.53 ± 6.97	17.95 ± 12.17	−10.20 ± 10.28	0.13 ± 8.78	−4.583 (0.000)
	t (p)	5.950 (0.000)	−0.089 (0.929)			
Eye closed						
X sway (mm/s)	Pre	6.79 ± 3.01	8.01 ± 3.85			
	Post	5.95 ± 2.94	9.63 ± 6.30	−0.84 ± 1.91	1.61 ± 3.92	−3.384 (0.001)
	t (p)	2.635 (0.012)	−2.479 (0.018)			
Y sway (mm/s)	Pre	11.87 ± 4.72	11.19 ± 4.67			
	Post	9.76 ± 3.80	11.95 ± 5.23	−2.10 ± 2.19	0.76 ± 1.90	−5.942 (0.000)
	t (p)	5.765 (0.000)	−2.423 (0.021)			
VM (mm^2/s)	Pre	25.94 ± 18.72	19.63 ± 11.89			
	Post	17.13 ± 11.74	23.19 ± 12.17	−8.80 ± 9.49	3.55 ± 2.76	−7.498 (0.000)
	t (p)	5.563 (0.000)	−7.716 (0.000)			

Values are presented as mean ± standard deviations.
X sway: anterior-posterior sway; Y sway: medial-lateral sway; VM: velocity moment.

Table 5. Changes in the sitting balance with eyes opened and eyes closed at pre- and post-program (N = 72).

		Experimental group (n = 36)	Control group (n = 36)	Difference (post-pre)		t (p)
				Experimental group	Control group	
Eye opened						
X sway (mm/s)	Pre	4.10 ± 1.76	4.48 ± 2.45			
	Post	3.14 ± 1.07	4.97 ± 2.57	−0.96 ± 1.62	0.49 ± 1.28	−4.205 (0.000)
	t (p)	3.548 (0.001)	−2.292 (0.028)			
Y sway (mm/s)	Pre	6.03 ± 2.40	6.12 ± 5.73			
	Post	4.66 ± 1.25	6.89 ± 6.04	−1.36 ± 2.09	0.77 ± 1.49	−4.979 (0.000)
	t (p)	3.916 (0.000)	−3.083 (0.004)			
VM (mm^2/s)	Pre	4.39 ± 1.25	6.80 ± 8.48			
	Post	2.15 ± 1.25	6.70 ± 9.49	−2.24 ± 4.14	−0.09 ± 3.29	−2.426 (0.018)
	t (p)	3.242 (0.003)	0.180 (0.858)			
Eye closed						
X sway (mm/s)	Pre	3.31 ± 1.78	3.04 ± 1.22			
	Post	2.65 ± 1.00	3.76 ± 1.88	−0.66 ± 1.70	0.72 ± 1.03	−4.162 (0.000)
	t (p)	2.333 (0.026)	−4.171 (0.000)			
Y sway (mm/s)	Pre	4.98 ± 1.54	4.88 ± 1.68			
	Post	4.36 ± 1.43	5.59 ± 1.80	−0.61 ± 1.81	0.70 ± 0.86	−3.958 (0.000)
	t (p)	2.037 (0.049)	−4.921 (0.000)			
VM (mm^2/s)	Pre	2.63 ± 3.32	3.06 ± 3.51			
	Post	1.44 ± 0.62	4.18 ± 4.59	−1.18 ± 3.39	1.12 ± 2.03	−3.503 (0.001)
	t (p)	2.096 (0.043)	−3.317 (0.002)			

Values are presented as mean ± standard deviations.
X sway: anterior-posterior sway; Y sway: medial-lateral sway; VM: velocity moment.

physical activity via kayak program decreased risked cognitive impairment can be useful.

The upper limbs are heavily utilized in daily life activities, and have a major impact on the quality of life of elderly individuals (Pendleton and Schultz-Krohn 2013). Gripping power as an important factor of upper extremity function has been used as a criterion to predict health of the elderly. In particular, grip strength can predict early mortality, early detection of disorders such as dementia, complications after operations, hospitalization period after bone fractures, and life span (Sugiura et al. 2013). In this study, via 6 weeks of kayak program, the ACT results showed that the muscle strength of the upper limbs increased significantly as well as significant changes in grip strength. In the kayak programs, several forms of exercise are generated according to situations depicted in virtual reality through the 3-D screen. The subjects hold real paddles, and rows consecutively and repeatedly in order to move the kayak on the screen. Because the muscle power of the upper limbs and grip strength increases, the upper extremity functions appeared to be increased overall.

In this study, an important result is reduced risk of cognitive impairment by the kayaking. Most psychological problems are treated with medication and counseling. However, solutions to psychological problems via physical exercise are rarely used. Hence, reduced risk of cognitive impairment through kayak program is thought to be a significant result. According to research studies, decline in cognitive function is closely connected with restriction of physical activities and decline in functions (Gazzola et al. 2006).

In this study, the first reason of the decreased risk of cognitive impairment after kayak program can be considered the increase in gripping power. Alfaro-Acha et al. (2006) investigated the relationship between grip strength and cognitive functions (Alfaro-Acha et al. 2006). They reported that as grip strength weakened, Mini Mental State Examination scores and cognitive ability decreased (Sugiura et al. 2013). Moreover, in a previous research that targeted 76 elderly people, the analysis of test-retest reliability between cognitive functions and gripping strength revealed that grip strength showed significant reliability. The authors reported that grip strength could be used as an evaluation standard for dementia, mild dementia, and severe dementia at baseline (Alencar et al. 2012). As a basis to support this, a recent study reported that a substance called apolipoprotein $\varepsilon 2$ is a genetic factor to prevent decline of cognitive functions and that this factor appeared decreased in elderly people. In addition, people with several factors showed less decline in gripping power (Batterham et al. 2013). Thus, based on changes in cognitive capacity in the test, increased grip power through kayak program is presumed to be one cause.

Another reason of the enhanced cognitive functions in this research was the coping mechanism in diverse situations that could not be predicted in virtual reality through the 3-D video and demand for directional changes to the front, back, left, and right, where fast and correct decision is required. Via these series of brain activities, it can be said that correct physical response courses positively influence the cognitive functions of old people.

Kayak programs through 3-D virtual reality were shown to be effective in increasing the balance of elderly people. Various physical and mental changes due to aging eventually cause the decline in balance ability. They can be the most important cause of injuries from falls, which incur the most frequent and serious social and economic problems. Falls can cause diverse injuries, from minor abrasions to more serious problems such as fractures and brain damage in older people (Alencar et al. 2012). This can affect the quality of life and overall health of patients by causing an increase in dependency, decrease in autonomy, confusion, immobility, and limitation of daily activities (Rubenstein 2006).

In this study, efficient kayak program using 3-D virtual reality was designed by producing an apparatus with the size and shape similar to a real kayak (Fig. 1). In addition, programs were constructed to induce natural motions of the trunk and arms. Leading big motions of the upper limbs for paddling made the center of the subject unstable. To balance in the unstable conditions of the torso of the subject is controlled. As this leads to activation of trunk muscles, it may increase balance ability. Elderly people experience gradual loss of strength and control of trunk muscles as they age. Reaction times are slowed compared with that of young adults (Granacher et al. 2013). Core muscles to control the torso connect the upper extremity and the lower extremity, and play an important role in stability (Kloubec 2010). Hence, the enhanced balance ability in this study is considered to be caused by activation of torso muscles through the rowing motion in kayak program. For balance improvement and falling prevention in old people, kayak program is considered effective.

In this study, by using a balance disk, by giving visual biofeedback stimulus after projecting on the screen a kayaking environment on the water and images that were filmed in the river, an environment similar to a real kayak is made. Therefore, significant results of reduced risk of cognitive impairment, upper extremity strength, and balance ability were achieved.

The limitation of this study is that it did not consider underwater resistance, which is present in rowing in real kayak exercise. In addition, some subjects felt dizzy from being exposed to the 3-D environment. Lastly, even though the conventional exercise program did not show a positive effect on the results in the control group, it would have been more beneficial, compared to a control group without any sort of treatment. In future research studies, it is necessary to develop programs that can overcome this limitation.

Acknowledgments

This study was supported by Sahmyook University.

Conflict of Interest

The authors declare no conflict of interest.

References

Abizanda, P., Navarro, J.L., García-Tomás, M.I., López-Jiménez, E., Martínez-Sánchez, E. & Paterna, G. (2012) Validity and usefulness of hand-held dynamometry for measuring muscle strength in community-dwelling older persons. *Arch. Gerontol. Geriatr.*, **54**, 21-27.

Alencar, M.A., Dias, J.M., Figueiredo, L.C. & Dias, R.C. (2012) Handgrip strength in elderly with dementia: study of reliability. *Rev. Bras. Fisioter.*, **16**, 510-514.

Alfaro-Acha, A., Al Snih, S., Raji, M.A., Kuo, Y.F., Markides, K.S. & Ottenbacher, K.J. (2006) Handgrip strength and cognitive decline in older Mexican Americans. *J. Gerontol. A Biol. Sci. Med. Sci.*, **61**, 859-865.

Batterham, P.J., Bunce, D., Cherbuin, N. & Christensen, H. (2013) Apolipoprotein E ε4 and later-life decline in cognitive function and grip strength. *Am. J. Geriatr. Psychiatry*, **21**, 1010-1019.

Bjerkefors, A., Carpenter, M.G. & Thorstensson, A. (2007) Dynamic trunk stability is improved in paraplegics following kayak ergometer training. *Scand. J. Med. Sci. Sports*, **17**, 672-679.

Bjerkefors, A. & Thorstensson, A. (2006) Effects of kayak ergometer training on motor performance in paraplegics. *Int. J. Sports Med.*, **27**, 824-829.

Borah, D., Singh, U., Wadhwa, S. & Bhattacharjee, M. (2007) Postural stability: effect of age. *IJPMR*, **18**, 7-10.

Bryanton, C., Bosse, J., Brien, M., Mclean, J., McCormick, A. & Sveistrup, H. (2006) Feasibility, motivation, and selective motor control: virtual reality compared to conventional home exercise in children with cerebral palsy. *Cyberpsychol. Behav.*, **9**, 123-128.

Ceria-Ulep, C.D., Grove, J., Chen, R., Masaki, K.H., Rodriguez, B.L., Donlon, T.A., Guralnik, J., Willcox, B.J., Willcox, D.C. & Nigg, C. (2011) Physical aspects of healthy aging: assessments of three measures of balance for studies in middle-aged and older adults. *Curr. Gerontol. Geriatr. Res.*, **2010**, 849761.

Cho, S.I. & An, D.H. (2014) Effects of a fall prevention exercise program on muscle strength and balance of the old-old elderly. *J. Phys. Ther. Sci.*, **26**, 1771-1774.

Fitzpatrick, A.L., Buchanan, C.K., Nahin, R.L., DeKosky, S.T., Atkinson, H.H., Carlson, M.C. & Williamson, J.D.; Ginkgo Evaluation of Memory (GEM) Study Investigators (2007) Associations of gait speed and other measures of physical function with cognition in a healthy cohort of elderly persons. *J. Gerontol. A Biol. Sci. Med. Sci.*, **62**, 1244-1251.

Freitas, S., Simões, M.R., Alves, L. & Santana, I. (2013) Montreal cognitive assessment: validation study for mild cognitive impairment and Alzheimer disease. *Alzheimer Dis. Assoc. Disord.*, **27**, 37-43.

Gazzola, J.M., Perracini, M.R., Ganança, M.M. & Ganança, F.F. (2006) Functional balance associated factors in the elderly with chronic vestibular disorder. *Braz. J. Otorhinolaryngol.*, **72**, 683-690.

Granacher, U., Lacroix, A., Muehlbauer, T., Roettger, K. & Gollhofer, A. (2013) Effects of core instability strength training on trunk muscle strength, spinal mobility, dynamic balance and functional mobility in older adults. *Gerontology*, **59**, 105-113.

Grigorenko, A., Bjerkefors, A., Rosdahl, H., Hultling, C., Alm, M. & Thorstensson, A. (2004) Sitting balance and effects of kayak training in paraplegics. *J. Rehabil. Med.*, **36**, 110-116.

Holm, R. & Priglinger, M. (2008) Virtual Reality Training As A Method For Interactive And Experience-based Learning. In *Intelligent Energy Conference and Exhibition*, Society of Petroleum Engineers, **1**, 1-7.

Horak, F.B. (2006) Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age Ageing*, **35** Suppl 2, ii7-ii11.

Howe, T.E., Rochester, L., Jackson, A., Banks, P.M. & Blair, V.A. (2007) Exercise for improving balance in older people. *Cochrane Database Syst. Rev.*, **4**, 1-75.

Hsieh, W.M., Chen, C.C., Wang, S.C., Tan, S.Y., Hwang, Y.S., Chen, S.C., Lai, J.S. & Chen, Y.L. (2014) Virtual reality system based on Kinect for the elderly in fall prevention. *Technol. Health Care*, **22**, 27-36.

Kim, J.I., Choe, M.A. & Chae, Y.R. (2009) Prevalence and predictors of geriatric depression in community-dwelling elderly. *Asian Nurs. Res.* (*Korean Soc. Nurs. Sci.*), **3**, 121-129.

Kloubec, J.A. (2010) Pilates for improvement of muscle endurance, flexibility, balance, and posture. *J. Strength Cond. Res.*, **24**, 661-667.

Lee, J.Y., Lee, D.W., Cho, S.J., Na, D.L., Jeon, H.J., Kim, S.K., Lee, Y.R., Youn, J.H., Kwon, M. & Lee, J.H. (2008) Brief screening for mild cognitive impairment in elderly outpatient clinic: validation of the Korean version of the Montreal Cognitive Assessment. *J. Geriatr. Psychiatry Neurol.*, **21**, 104-110.

Machin, D., Campbell, M.J., Tan, S.B. & Tan, S.H. (2011) *Sample size tables for clinical studies*, John Wiley & Sons, UK.

Masud, T. & Morris, R.O. (2001) Epidemiology of falls. *Age Ageing*, **30** Suppl 4, 3-7.

Miotto, J.M., Chodzko-Zajko, W.J., Reich, J.L. & Supler, M.M. (1999) Reliability and validity of the Fullerton Functional Fitness Test: an independent replication study. *J. Aging Phys. Act.*, **7**, 339-353.

Montuclard, L., Garrouste-Orgeas, M., Timsit, J.F., Misset, B., De Jonghe, B. & Carlet, J. (2000) Outcome, functional autonomy, and quality of life of elderly patients with a long-term intensive care unit stay. *Crit. Care Med.*, **28**, 3389-3395.

Pendleton, H.M. & Schultz-Krohn, W. (2013) *Pedretti's occupational therapy: practice skills for physical dysfunction*, Elsevier Health Sciences, Missouri, MO.

Raji, M.A., Ostir, G.V., Markides, K.S. & Goodwin, J.S. (2002) The interaction of cognitive and emotional status on subsequent physical functioning in older Mexican Americans findings from the Hispanic established population for the epidemiologic study of the elderly. *J. Gerontol. A Biol. Sci. Med. Sci.*, **57**, M678-M682.

Rand, D., Kizony, R. & Weiss, P.T. (2008) The Sony PlayStation II EyeToy: low-cost virtual reality for use in rehabilitation. *J. Neurol. Phys. Ther.*, **32**, 155-163.

Rogers, S.D. & Jarrott, S.E. (2008) Cognitive impairment and effects on upper body strength of adults with dementia. *J. Aging Phys. Act.*, **16**, 61.

Rubenstein, L.Z. (2006) Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing*, **35** Suppl 2, ii37-ii41.

Saghaei, M. (2004) Random allocation software for parallel group randomized trials. *BMC Med. Res. Methodol.*, **4**, 26.

Salminen, M., Vahlberg, T., Sihvonen, S., Sjösten, N., Piirtola, M., Isoaho, R., Aarnio, P. & Kivelä, S.L. (2009) Effects of risk-based multifactorial fall prevention on postural balance in the community-dwelling aged: a randomized controlled trial. *Arch. Gerontol. Geriatr.*, **48**, 22-27.

Schultheis, M.T. & Rizzo, A.A. (2001) The application of virtual reality technology in rehabilitation. *Rehabil. Psychol.*, **46**, 296-311.

Shaw, F.E. (2002) Falls in cognitive impairment and dementia. *Clin. Geriatr. Med.*, **18**, 159-173.

Sin, M.K., Choe, M.A., Kim, J., Chae, Y.R., Jeon, M.Y. & Vezeau,

T. (2009) Comparison of body composition, handgrip strength, functional capacity, and physical activity in elderly Koreans and Korean immigrants. *Res. Gerontol. Nurs.*, **2**, 20-29.

Singh, D.K., Manaf, Z.A., Yusoff, N.A.M., Muhammad, N.A., Phan, M.F. & Shahar, S. (2014) Correlation between nutritional status and comprehensive physical performance measures among older adults with undernourishment in residential institutions. *Clin. Interv. Aging*, **9**, 1415-1423.

Sugiura, Y., Tanimoto, Y., Watanabe, M., Tsuda, Y., Kimura, M., Kusabiraki, T. & Kono, K. (2013) Handgrip strength as a predictor of higher-level competence decline among community-dwelling Japanese elderly in an urban area during a 4-year follow-up. *Arch. Gerontol. Geriatr.*, **57**, 319-324.

Wang, C.Y. & Chen, L.Y. (2010) Grip strength in older adults: test-retest reliability and cutoff for subjective weakness of using the hands in heavy tasks. *Arch. Phys. Med. Rehabil.*, **91**, 1747-1751.

Zhang, L., Abreu, B.C., Masel, B., Scheibel, R.S., Christiansen, C.H., Huddleston, N. & Ottenbacher, K.J. (2001) Virtual reality in the assessment of selected cognitive function after brain injury. *Am. J. Phys. Med. Rehabil.*, **80**, 597-604.