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The Effects of Virtual Kayak Paddling Exercise on Postural Balance, Muscle Performance, and Cognitive Function in Older Adults with Mild Cognitive Impairment: A Randomized Controlled Trial

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Deterioration of physical and psychological health is an important issue in older adults aged 65 years or more. This study aimed to determine whether a virtual kayak paddling (VKP) exercise could improve postural balance, muscle performance, and cognitive function in older adults with mild cognitive impairment. Sixty participants were randomly assigned to the VKP ($n = 30$) or control group ($n = 30$). Participants in the VKP group performed the paddling exercise in a virtual environment for 60 min twice a week for 6 weeks, whereas those in the control group performed home exercises. Postural balance ($p < .05$), muscle performance ($p < .05$), and cognitive function ($p < .05$) were significantly improved in the VKP group and were superior to those in the control group ($p < .05$). Thus, the findings indicate that VKP exercise improves postural balance, muscle performance, and cognitive function in older adults with mild cognitive impairment.

Keywords: cognition, muscle strength, virtual reality

Most older adults prefer participating in sedentary activities, rather than physical activities to maintain health because of age-related physiological changes and the external environment (Kim, 1999). Deceased activity levels and social participation accelerate aging-related musculoskeletal, neurological, sensory, and cognitive system changes (Faulkner, Larkin, Claflin, & Brooks, 2007; Zawadka-Kunikowska et al., 2014). In older adults, regular physical exercise training is important because exercise or leisure activities are recommended to delay or reverse age-related changes (Levin, Netz, & Ziv, 2017).

Kayaking has been recently introduced among older adults as a leisure activity as it can be performed by anyone (Bjerkefors & Thorstensson, 2006). This exercise has various physical health advantages for older adults. Kayaking is an easily accessible sport used to improve postural control because the postural sway induced by the paddling movement must be compensated for, which constantly challenges the ability of participants to maintain their posture (Bjerkefors, Carpenter, & Thorstensson, 2007; Grigorenko et al., 2004). Individuals who perform kayaking have better mediolateral trunk stability in response to lateral translation (Bjerkefors et al., 2007). Hurt and Grabiner (2015) reported that age-related changes could hinder compensatory strategies that ensure stability while performing a lateral stepping and forward walking tasks in older adults. Therefore, kayak paddling movement in the sagittal planes could be emphasized to improve postural balance.

Another positive effect of kayaking is that it increases upper extremity muscle strength and endurance at the same time without any upper extremity problems or overload (Bjerkefors, Jansson, & Thorstensson, 2006; Bjerkefors & Thorstensson, 2006). Handgrip strength is necessary for performing object-manipulating action, such as grasping, holding, and lifting. In addition, handgrip strength reflects the overall muscle strength and functional conditions (Moy, Darus, & Hairi, 2015) and is widely used as a measure of general health in older adults (Savino et al., 2013). The handgrip strength test is an inexpensive and time-efficient measurement procedure that can be easily performed. Sayer et al. (2006) found that people with low handgrip strength have decreased health-related quality of life.

Handgrip strength is useful to monitor cognitive impairment and a higher handgrip strength seems to protect against cognitive decline (Fritz, McCarthy, & Adamo, 2017). Individuals with mild cognitive impairment suffer from a reduced memory span, executive function impairments, and an inability to concentrate (Salloway & Correia, 2009). Executive function-related activities, such as multitasking and planning, have been linked to the ability of performing a series of movements (Gothe, Kramer, & McAuley, 2014). Thus, executive dysfunction contributes to the restriction of instrumental activities of daily living (Marshall et al., 2011). Impairment of instrumental activities of daily living leads to early loss of social engagement and independence. Thus, improvement of muscle strength through the kayak paddling movement might help maintain or improve cognitive function and quality of life.

Kayaking has the advantages of reducing age-related physical and cognitive deterioration, but it has a safety issue considering that it should be performed on water. Virtual reality is used to safely simulate natural motion (Bohil, Alicea, & Biocca, 2011), ensure consistent and planned application of standardized therapeutic protocols, and increase patient independence using a close simulation of the real-world environment (Cho & Lee, 2014). Virtual reality is a computer-simulated environment and interaction of computer-generated experience used to enhance physical or psychological function in another place (Banos et al., 2000). The limitation of kayaking may be overcome by performing the exercise in a virtual reality-aided environment. Virtual reality is often employed in exercise programs for older adults because of its unprecedented ability to stimulate visual and auditory sensations (Cherniack, 2011). Virtual reality allows for real-time feedback and extends the capabilities of home-bound participants (de Bruin,

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Schoene, Pichierri, & Smith, 2010). The use of virtual reality has reduced health costs and increased physical activities in a limited environment in the form of exergames. Furthermore, virtual reality has increased the motivation and participation rate of individuals compared with conventional nonvirtual reality exercise (Bryanton et al., 2006; de Bruin et al., 2010).

In our previous study, the effects of ground kayak paddling exercise were demonstrated (Choi & Lee, 2018). Although the previous kayak paddling exercise study provided positive clinical evidence on the physical and cognitive function of older adults, it could not provide motivation and a sense of immersion such as that provided by kayaking. Recent virtual reality studies have presented new applications, such as video recording, which enable the use of different exercises in various environments. Therefore, the present study aimed to investigate the effects of a virtual kayak paddling (VKP) exercises using real-world video recording on postural control, muscle performance, and cognitive function in older adults with mild cognitive impairment. We hypothesized that participants who performed the VKP exercise would have improved postural control, muscle strength, and cognitive function.

Methods

Participants

This randomized controlled trial was registered with the International Clinical Trials Registry Platform (KCT0002453). Participants were recruited from a welfare center between January 10 and 20, 2015, and the study was conducted from March to May 2015. The inclusion criteria were as follows: community-dwelling older adults aged 65 years or older who scored <26 points on the Montreal Cognitive Assessment, able to communicate, and commit to 6 weeks of intervention in this study. The exclusion criteria were as follows: individuals who had neurological, musculoskeletal, or upper extremity impairment; severe cognitive disorders such as dementia or depression; untreated medical conditions; visual deficits; or individuals who were unable to maintain a sitting posture for at least 20 min. All participants were educated about the experimental protocol and provided written informed consent before enrollment. The study was approved by the Sahmyook University Institutional Review Board (SYUIRB2015-004).

Experimental Procedure

A physical therapist of the welfare center promoted this study within the facility both verbally and through an advertisement posted on the bulletin board. Individuals who volunteered as participants were screened for compliance with the inclusion and exclusion criteria. Selected subjects were randomly assigned to the VKP ($n = 30$) or control ($n = 30$) group in a 1:1 ratio. Randomization was conducted using Random Allocation Software 2.0 (Saghaei, 2004). The pretest evaluation of demographics, postural balance, muscle performance, and cognitive function was performed a week before study commencement. Participants in the VKP group exercised for 6 weeks. Exercise sessions were conducted by an instructor and assistants twice a week for 60 min. The VKP exercise included warm-up, main exercise, and cooldown periods and was implemented using a recorded video. Participants assigned to the control group did not participate in the exercise program; instead, they performed only home exercises. The posttest evaluation was conducted a week after the end of the exercise program in the same manner as the pretest evaluation. The data were then analyzed (Figure 1).

VKP Exercise

This exercise program was modified for kayaking and conducted as a group exercise. Each session consisted of a 10-min warm-up, 40-min VKP exercise, and 10-min cooldown. The warm-up included massage with a sensory ball, gentle whole body stretching, and deep breathing exercises with light music. The shoulders and trunk were stretched to increase muscle flexibility and safety.

During the VKP exercise, participants were seated on a chair while practicing the exercise, observing a video projected on a screen. One instructor demonstrated the exercise, and two assistants corrected the postures and movements of the participants. The exercise was introduced and practiced in the first session. The participants were informed that the direction of the kayak boat movement displayed on the screen was opposite to the rowing direction. The recorded kayak boat movements included forward and backward motion, right and left turns, and a stationary position. An arrow was marked on the screen prior to the change of direction of the boat, and the participants rowed toward the direction in which the boat was moving. The weight of the paddle used in this exercise was 1 kg, and the length was 180 cm. A soft balance foam (TheraBand Exercise Station, Hadamar, Germany) was placed under the chairs to simulate the feeling of floating in the water. The video was filmed on a lake in South Korea, edited using a video editing software (Vegas Pro version 13; Sony, Tokyo, Japan), and projected onto a 100-in. screen (Model BX327; LG, Seoul, South Korea). To maximize the effect of the exercise, the assistants asked the participants to row with increased effort (Figure 2). In the middle of this exercise program, a 3-min walking break was included to prevent muscle fatigue.

The cooldown after the main exercise was performed in the same manner as the warm-up to prevent muscle fatigue and sudden hypoglycemia, facilitate muscle relaxation, and normalize the heart and respiratory rates (Brouwer, Walker, Rydahl, & Culham, 2003).

Home Exercise Education

The physical therapist who had been working in the welfare center instructed home exercise to the control group during the first, third, and fifth week. The warm-up and cooldown exercises for the control group were the same as those for the VKP group. The home exercise program consisted of William flexion exercises, curl-ups, sideways leg lifts, prone leg lifts, supine leg lifts, and prone trunk hyperextensions (Lee, Kim, & Lim, 2006). The participants were instructed to perform three sets of 10 repetitions for each home exercise during the first week, adding 10 repetitions per set every 2 weeks. In the final week, the participants performed three sets of 30 repetitions for each exercise. The home exercises were performed twice a week for 6 weeks, and the instructor confirmed the performance of exercises weekly by phone.

Outcome Measurements

Demographics, static and dynamic postural balance, muscle performance, and cognitive function were assessed by six blinded examiners.

Primary outcome measure. Static postural balance was assessed using the one-leg stance test (Jonsson, Seiger, & Hirschfeld, 2004) and the Good Balance System (Metitur Ltd., Jyväskylä, Finland; Choi, Lee, & Lee, 2015). The system consisted of a safety bar and an equilateral triangular force platform. It was connected to a laptop via Bluetooth technology at a sampling frequency of 50 Hz.

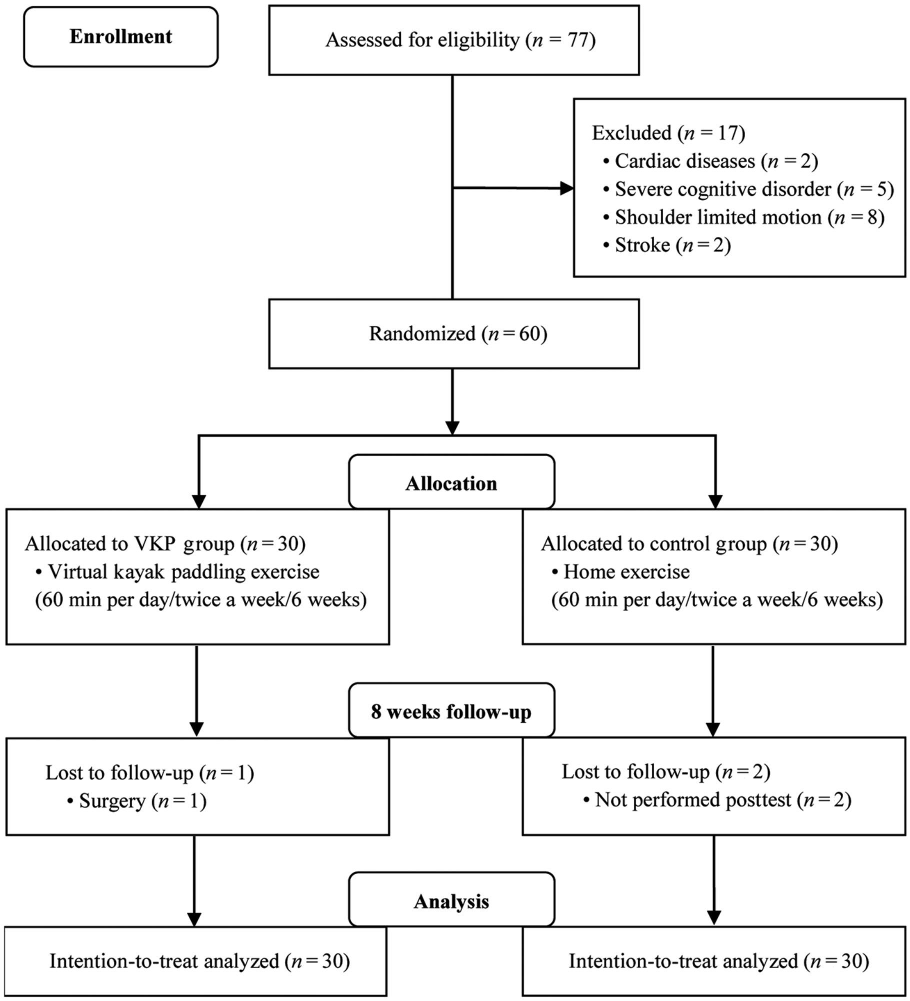

Figure 1 — Flowchart of total experimental procedure.

The static postural balance using the Good Balance System was measured under two visual conditions, eyes open and eyes closed, for 30 s each while participants were seated on a chair on the platform. The participants were instructed to sit maintaining a forward gaze, feet not touching the floor, and arms folded across the chest. Static postural balance was assessed three times and averaged for data analysis. The test–retest reliability was .46 and .53 with the eyes open and closed, respectively, in mean medial–lateral postural sway, and .69 with the eyes open or closed in anterior–posterior postural sway (Ceria-Ulep et al., 2010). Dynamic postural balance was assessed using the timed up and go test (intraclass correlation coefficient [ICC] = .97; Steffen, Hacker, & Mollinger, 2002); functional reach test (ICC = .92; Duncan, Weiner, Chandler, & Studenski, 1990; Granacher, Lacroix, Muehlbauer, Roettger, & Gollhofer, 2013); Berg Balance Scale (ICC = .98; Berg, Wood-Dauphinee, Williams, & Maki, 1992); and Four Square Step Test (ICC = .98; Dite & Temple, 2002).

Secondary outcome measure. Arm curl test (Singh et al., 2014) and handgrip strength (Abizanda et al., 2012) were used to assess muscle performance. The arm curl test measured the maximum number of biceps curl repetitions performed with a 2-kg or 3-kg dumbbell in 30 s using the dominant arm of women or men, respectively. Participants sat upright maintaining the initial posture without bending the trunk forward. This test has shown good test–retest reliability, and the ICC was .96 (Miotto, Chodzko-Zajko, Reich, & Supleer, 1999). Handgrip strength was measured using a hand-held dynamometer (Medical Handgrip Dynamometer model DHS-88; DETECTO, Webb City, MO). While sitting, the participants were instructed to apply their maximum grip strength with the elbow joint at 90° flexion. The peak value from three trials was used for data analysis. The ICC was .97, indicating the high accuracy of the measurement (Wang & Chen, 2010).

Cognitive function was assessed using Montreal Cognitive Assessment (Freitas, Simoes, Alves, & Santana, 2013) and General Practitioner Assessment of Cognition (Brodaty, Kemp, & Low, 2004). Montreal Cognitive Assessment assesses various cognitive domains, such as attention and concentration, executive function, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation. The test–retest reliability for this assessment was .75, and a good specificity of 84% and great sensitivity of 89% was shown for screening mild cognitive impairment (Lee et al., 2008). The General Practitioner Assessment of Cognition is a reliable and efficient screening instrument for detecting dementia and is useful in the primary care setting. The General Practitioner Assessment of Cognition score is not

Figure 2 — Virtual kayak paddling exercise.

influenced by the linguistic and cultural background of a subject, making it a useful screening tool in a multicultural patient setting. The test–retest reliability for this test was .87, and sensitivity and specificity were determined to be .85 and .86, respectively (Brodaty et al., 2002).

Statistical Analyses

SPSS statistical software (version 19.0; IBM, Chicago, IL) was used to perform the statistical analyses. All data were analyzed according to the intention-to-treat principle, and the results are presented as mean ± *SD*. Missing data were defined as missing completely at random by missing data analysis and were substituted by multiple imputation methods. The missing data were imputed by using Fully Conditional Specification algorithm which is an iterative Markov chain Monte Carlo method. Five imputed datasets were generated and then pooled outcomes were used for the intention-to-treat analysis. Prior to training, the normality of the data was assessed using the Shapiro–Wilk test. Chi-square analysis and independent samples *t* test were used to evaluate intergroup homogeneity. As all dependent variables were normally distributed, separate 2 (Group) × 2 (Time) repeated-measures analysis of variance (ANOVA) was conducted to assess VKP exercise over two-time points (pretest and 6 weeks posttest). The effect size (partial eta squared) was calculated as the ratio of the between-group sum of squares to the sum of the between-groups sum of squares and the error sum of squares. Eta squared of .02, .13, and .26 were interpreted as small, moderate, and large, respectively. Pearson correlations analysis was used to examine the associations between descriptive statistics.

The sample size was estimated using the G*power software (version 3.1; HHU, Düsseldorf , Germany) based on the results of a previous study that reported a large effect size (.80; Karahan et al., 2015). In clinical trials, 80% power is typically required. The level of significance was set to .05 (two-tailed). The minimum sample size was 26 individuals per group. Based on an anticipated dropout rate of 10%, 30 individuals were assigned to each group. The statistical significance was set to .05 for all tests.

Results

Sample Description

A total of 77 older adults (age range, 69–85 years) volunteered for this study; 17 did not meet the inclusion criteria as they had cardiac diseases ($n = 2$), severe cognitive disorder ($n = 5$), shoulder limited range of motion ($n = 8$), or stroke ($n = 2$). Thus, 60 subjects were randomly assigned to the VKP or control group. Three participants dropped out: one from the VKP group underwent operation because of an accident, and two from the control group did not participate in the posttest evaluation because of moving to other city. A total of 57 participants completed >80% of the exercises, but 60 subjects were analyzed according to the intention-to-treat principle. There were no significant intergroup differences at baseline for any parameter ($p > .05$) (Table 1). The attendance was 92% for the VKP group and 88% for the control group.

Changes in Static and Dynamic Postural Balance

Table 2 compares the pretest and posttest static and dynamic postural balance in the two groups. Two-way repeated-measures ANOVA revealed a significant decrease in medial–lateral postural sway with eyes open, $F(1, 58) = 11.346$, $p = .001$, $\eta^2 = .163$; anterior–posterior postural sway with eyes open, $F(1, 58) = 8.635$, $p = .005$, $\eta^2 = .129$; velocity moment with eyes open, $F(1, 58) = 4.155$, $p = .046$, $\eta^2 = .066$; medial–lateral postural sway with eyes closed, $F(1, 58) = 7.683$, $p = .007$, $\eta^2 = .117$; anterior–posterior postural sway with eyes closed, $F(1, 58) = 7.659$, $p = .008$, $\eta^2 = .116$; and velocity moment with eyes closed, $F(1, 58) = 9.903$, $p = .003$, $\eta^2 = .145$, in the VKP group compared with those in the control group. Two-way repeated-measures ANOVA showed that the one-leg stance test results for the right, $F(1, 58) = 9.099$, $p = .004$, $\eta^2 = .135$, and left one-leg stance, $F(1, 58) = 4.432$, $p = .040$, $\eta^2 = .071$, were significantly higher in the VKP group.

In dynamic postural balance, two-way repeated-measures ANOVA showed significantly faster timed up and go test, $F(1, 58) = 26.662$, $p < .001$, $\eta^2 = .314$; greater functional reach test, $F(1, 58) = 9.344$, $p = .003$, $\eta^2 = .138$; higher Berg Balance Scale, $F(1, 58) = 23.190$, $p < .001$, $\eta^2 = .285$; and faster four square step test, $F(1, 58) = 16.187$, $p < .001$, $\eta^2 = .218$, in the VKP group than in the control group.

Change in Muscle Performance

The effects of the VKP exercise on muscle performance are presented in Table 3. The arm curl test, right handgrip strength, and left handgrip strength scores in the VKP group were higher by 29.70%, 14.69%, and 15.36%, respectively, than those in the control group. Group-by-time interaction effect was significantly different for arm curl test, $F(1, 58) = 40.771$, $p < .001$, $\eta^2 = .412$; right handgrip strength, $F(1, 58) = 14.439$, $p < .001$, $\eta^2 = .199$; and left handgrip strength scores, $F(1, 58) = 4.016$, $p = .050$, $\eta^2 = .064$, between the two groups.

Change in Cognitive Function

Table 3 shows the change in cognitive function as assessed by the Montreal Cognitive Assessment and General Practitioner Assessment of Cognition. Cognitive function significantly improved by 10.04% and 13.44%, respectively. There were significant differences in the group-by-time interaction effect in the Montreal Cognitive Assessment, $F(1, 58) = 13.363$, $p = .001$, $\eta^2 = .187$, and General Practitioner Assessment of Cognition, $F(1, 58) = 7.833$, $p = .007$, $\eta^2 = .119$, between the two groups.

Relationship Among the Variables

Pearson correlations analysis between the static and dynamic postural balance showed that velocity moment with eye open correlated significantly with the timed up and go test ($r = .257$,

Table 1 Baseline Demographics of the Participants

	Virtual kayak paddling group ($n = 30$)	Control group ($n = 30$)
Sex (male/female)	5/25	4/26
Age (years)	77.27 ± 4.37	75.37 ± 3.97
Body weight (kg)	55.27 ± 5.95	58.00 ± 8.38
Height (cm)	153.37 ± 7.92	154.43 ± 7.14
Body mass index (kg/m^2)	23.56 ± 2.71	24.31 ± 3.19

Note. Values are presented as mean ± *SD*.

Table 2 Comparison of Static and Dynamic Postural Balance in the Virtual Kayak Paddling Group and Control Group

	Virtual kayak paddling group ($n = 30$)		Control group ($n = 30$)			
Variables	Pretest	Posttest	Pretest	Posttest	Group × Time, *F*(*p* value)	η^2 (95% CI)
Static balance						
Eyes open						
MLS (mm/s)	4.00 ± 1.59	3.37 ± 0.91	3.52 ± 1.03	3.74 ± 1.10	11.346 (.001)	.163 (.027, .327)
APS (mm/s)	5.87 ± 1.80	5.12 ± 1.27	5.20 ± 1.27	5.39 ± 1.06	8.635 (.005)	.129 (.013, .290)
VM (mm^2/s)	5.10 ± 3.70	3.65 ± 1.91	5.41 ± 3.89	5.43 ± 3.21	4.155 (.046)	.066 (.000, .212)
Eyes closed						
MLS (mm/s)	2.97 ± 1.28	2.62 ± 0.98	2.71 ± 0.77	2.90 ± 0.71	7.683 (.007)	.117 (.008, .276)
APS (mm/s)	4.68 ± 1.23	4.36 ± 0.86	4.34 ± 1.09	4.62 ± 1.07	7.659 (.008)	.116 (.008, .275)
VM (mm^2/s)	2.98 ± 4.22	2.34 ± 3.59	2.63 ± 0.97	3.16 ± 1.37	9.903 (.003)	.145 (.019, .308)
Right OLS (s)	10.41 ± 13.08	21.76 ± 30.25	11.30 ± 8.52	11.32 ± 7.63	9.099 (.004)	.135 (.015, .297)
Left OLS (s)	11.12 ± 14.71	22.99 ± 31.05	10.46 ± 9.01	12.93 ± 10.70	4.432 (.040)	.071 (.000, .218)
Dynamic balance						
TUG (s)	10.21 ± 1.93	8.86 ± 1.85	10.27 ± 1.76	9.97 ± 1.32	26.662 (.000)	.314 (.128, .471)
FRT (cm)	26.14 ± 6.67	30.46 ± 5.86	28.32 ± 6.28	29.82 ± 6.39	9.344 (.003)	.138 (.016, .300)
BBS (point)	50.13 ± 4.75	54.24 ± 1.99	50.50 ± 2.64	50.78 ± 2.41	23.190 (.000)	.285 (.104, .445)
FSST (s)	9.55 ± 2.04	8.02 ± 1.57	9.29 ± 2.17	9.08 ± 2.15	16.187 (.000)	.218 (.057, .382)

Note. Values are presented as mean ± *SD*. CI, confidence interval; MLS = medial–lateral sway; APS = anterior–posterior sway; VM = velocity moment; OLS = one-leg stance; TUG = timed up and go test; FRT = functional reach test; BBS = Berg Balance Scale; FSST = Four Square Step Test.

$p < .05$), functional reach test ($r = -.274$, $p < .05$), Berg Balance Scale ($r = -.391$, $p < .05$), and Four Square Step Test ($r = .270$, $p < .05$). Right one-leg stance test correlated significantly with timed up and go test ($r = -.512$, $p < .05$), functional reach test ($r = .280$, $p < .05$), Berg Balance Scale ($r = .362$, $p < .05$), and Four Square Step Test ($r = -.369$, $p < .05$). Left one-leg stance test correlated significantly with timed up and go test ($r = -.484$, $p < .05$), functional reach test ($r = .317$, $p < .05$), Berg Balance Scale ($r = .416$, $p < .05$), and Four Square Step Test ($r = -.273$, $p < .05$) (Table 4).

Pearson correlations analysis revealed that muscle performance correlated significantly with cognitive function. Arm curl test score was moderately associated with the Montreal Cognitive Assessment ($r = .393$, $p < .05$) and General Practitioner Assessment of Cognition scores ($r = .349$, $p < .05$) (Table 5).

Discussion

This study proved that a virtual reality-based kayak paddling exercise effectively improves the physical and cognitive functions of community-dwelling older adults with mild cognitive impairment. The findings of the present study show that VKP exercise induces significant increases in both postural control and muscular strength and are consistent with previously published results on kayak ergometer training (Bjerkefors et al., 2007; Bjerkefors et al., 2006; Bjerkefors & Thorstensson, 2006). Previous studies used higher kayak ergometer training intensities because participants were patients with spinal cord injury or elite kayakers and it may be inappropriate for older adults (Bjerkefors et al., 2007; Gomes et al., 2012). In addition, ergometer machines are expensive and require individual monitoring during training (Bjerkefors et al., 2007; Bjerkefors et al., 2006). On the contrary, this study used a VKP exercise protocol suitable for older adults and performed as a group exercise in a well-controlled virtual reality environment. The advantage of a group exercise is that it can be performed at a specific location and time in accordance with a schedule set in advance (King, 1994). The group setting also affects the compliance of subjects (Barnett, Smith, Lord, Williams, & Baumand, 2003). For example, it is likely that competition among the subjects could have contributed to the high participation rate seen in the present study. The unique advantages of VKP exercise are that it is a good balance exercise and makes participants think about the paddling direction during exercise because paddling direction is opposite to the kayak boat movement displayed to

Table 3 Comparison of Muscle Performance and Cognitive Function in the Virtual Kayak Paddling Group and Control Group

	Virtual kayak paddling group ($n = 30$)		Control group ($n = 30$)			
Variables	**Pretest**	**Posttest**	**Pretest**	**Posttest**	**Group × Time, *F*(*p* value)**	**η^2 (95% CI)**
Muscle performance						
ACT (rep.)	21.38 ± 4.64	27.73 ± 5.75	22.63 ± 6.77	23.27 ± 5.74	40.771 (.000)	.412 (.217, .554)
Right HGS (kg)	18.64 ± 2.69	21.38 ± 2.97	18.18 ± 4.79	18.90 ± 4.04	14.439 (.000)	.199 (.046, .364)
Left HGS (kg)	16.47 ± 2.70	19.00 ± 2.51	16.76 ± 4.60	17.75 ± 5.16	4.016 (.050)	.064 (.000, .209)
Cognitive function						
MoCA (point)	21.10 ± 4.93	23.22 ± 4.48	20.03 ± 3.80	20.12 ± 3.53	13.363 (.001)	.187 (.039, .352)
GPCOG (point)	10.56 ± 3.08	11.98 ± 2.26	10.86 ± 2.17	10.97 ± 2.22	7.833 (.007)	.119 (.009, .278)

Note. Values are presented as mean ± *SD*. CI = confidence interval; ACT = arm curl test; rep. = repetition; HGS = handgrip strength; MoCA = Montreal Cognitive Assessment; GPCOG = General Practitioner Assessment of Cognition.

Table 4 Relationship Between the Static and Dynamic Postural Balance

Variables	ROLS	LOLS	MLSEO	APSEO	VMEO	MLSEC	APSEC	VMEC
TUG	−.512*	−.484*	.176	.055	.257*	−.092	−.054	.038
FRT	.280*	.317*	−.115	−.219	−.274*	−.080	−.001	−.055
BBS	.362*	.416*	−.131	−.213	−.391*	−.098	−.276*	−.151
FSST	−.369*	−.273*	.137	.054	.270*	.001	.122	.094

Note. ROLS = right one-leg stance; LOLS = left one-leg stance; MLSEO = medial–lateral sway with eyes open; APSEO = anterior–posterior sway with eyes open; VMEO = velocity moment with eyes open; MLSEC = medial–lateral sway with eyes closed; APSEC = anterior–posterior sway with eyes closed; VMEC = velocity moment with eyes closed; TUG = timed up and go test; FRT = functional reach test; BBS = Berg Balance Scale; FSST = Four Square Step Test.
*Statistically significant at $p < .05$.

Table 5 Relationship Between the Muscle Performance and Cognitive Function

Variables	ACT	Right HGS	Left HGS
MoCA	.393*	.214	.188
GPCOG	.349*	.228	.064

Note. ACT = arm curl test; HGS = handgrip strength; MoCA = Montreal Cognitive Assessment; GPCOG = General Practitioner Assessment of Cognition.
*Statistically significant at $p < .05$.

the screen. This can stimulate more cognitive processing than simple repetitive movements. Another advantage is that VKP exercise has made it possible to make an outdoor activity like kayaking be exercised indoors using real-world video recording.

VKP exercise significantly increased the dynamic and static balance because it involved a consistent rotatory movement of the trunk. The movements during kayak paddling are performed in a diagonal direction, which stimulates the core muscles. From a functional viewpoint, core muscles support the connections of upper and lower limbs to the trunk through the pelvic and shoulder girdle muscles. Moreover, these muscles function to transmit angular momentum and torque while performing physical activities required for sports, leisure, fitness, and daily life through kinetic chains (Behm, Drinkwater, Willardson, & Cowley, 2010). Poor core muscle recruitment makes it more difficult to perform daily activities or movements (Ferreira et al., 2010). Hwang et al. (2008) reported that older adults show a delay in the paraspinal reflex latencies compared with younger adults and that the aging process is associated with decreased spinal motor control (Hwang, Lee, Park, & Kwon, 2008). Older adults experience gradual muscle degeneration and a decrease in recruitment speed. Trunk stability is closely related to balance and co-activated prior to or upon the occurrence of external forces by anticipatory postural adjustments. Such feedforward activation is based on experience, and trunk inactivity leads to poor motor control and loss of postural balance (Frank & Patla, 2003). Suri et al. (2009) demonstrated the influence of the trunk muscles in mobility-limited older adults on balance and mobility performance. They reported that trunk endurance is related to Berg Balance Scale score and that trunk muscle strength is associated with the performance in the one-leg stance test (Suri, Kiely, Leveille, Frontera, & Bean, 2009). In this study, Berg Balance Scale score and one-leg stance time were significantly increased in the VKP group, and this supports the fact that VKP exercise contributed to the improvement of trunk muscle strength and endurance.

The VKP exercise was performed while sitting on a chair, which decreased the risk of falling. The use of the soft balance foam gave participants the feeling of actually being on the water and facilitated the external sway, exposing the participants to constant instability combined with the internal sway achieved by paddling (Srivastava, Taly, Gupta, Kumar, & Murali, 2009). This exercise was a modified form of kayaking, and the participants benefitted from its significant effect on postural balance and from the safety solution provided by the modification for the problems associated with kayaking. Reduced proprioception is one of the causes of poor postural balance in older adults (Borel & Alescio-Lautier, 2014). Proprioception may have been stimulated in the participants because of the various trunk muscle length changes occurring owing to the postural sway experienced during paddling movements.

The VKP exercise is considered a resistance exercise as the combined effect of air and paddle weight provides resistance. Low resistance and a number of repetitive paddling motions may have contributed to the increase in muscle strength, as shown in the results of the present study. Moreover, kayak paddling requires fast and intensive movements of the upper limbs, which may have accelerated the improvement of upper limb strength. Van Roie, Delecluse, Coudyzer, Boonen, and Bautmans (2013) reported that low resistance training, such as 80 to 100 repetitions at 20% of one repetition maximum for a total of 36 sessions, resulted in muscle hypertrophy (Van Roie et al., 2013). Watanabe, Madarame, Ogasawara, Nakazato, and Ishii (2014) reported that low-intensity exercise (30% of one repetition maximum) increased the muscle size and strength in older adults aged 60–77 years (Watanabe et al., 2014). The exercise protocol comprised three sets of eight repetitions of an eccentric contraction for 3 s, a concentric contraction for 3 s, and an isometric contraction for 1 s, performed twice a week for 12 weeks. After 12 weeks, cross-sectional magnetic resonance imaging revealed an increase in muscle size ($p < .01$) and strength ($p < .05$). This demonstrates that the total muscle contraction time and number of repetitions are related to muscle size and strength gain.

In the present study, handgrip strength was significantly increased after VKP exercise, and improvements in handgrip strength might contribute to improvements in functions such as postural balance and cognition. Handgrip strength represents the overall physical condition, and an increase in handgrip strength could be interpreted as a protective factor against multimorbidity of chronic diseases (Chen et al., 2012; Cheung, Nguyen, Au, Tan, & Kung, 2012). Garcia-Pena et al. (2013) reported that a 1 kg decrease in handgrip strength of 20.65 kg in a male corresponds to a functional decline by 14.9% (Garcia-Pena et al., 2013). Alfaro-Acha et al. (2006) observed that people with low handgrip strength displayed lower mini-mental state examination scores after 7 years of follow-up and that a low handgrip strength was significantly related to decreased cognition (Alfaro-Acha et al., 2006). Based on the findings of previous studies, it is reasonable to assume that an increase in handgrip strength is involved in cognitive improvement. Furthermore, the fact that the participants were required to constantly coordinate paddling direction with the direction of the kayak boat could facilitate cognitive improvement. The correlation between physical and cognitive functions is noteworthy. The human frontal lobe gives commands for movement control, and the prefrontal areas perform executive function and mental processing, which are deteriorated by aging (Berchicci, Lucci, & Di Russo, 2013). Fast and efficient information processing increases cognitive function, which is affected by the integrity of the white brain matter (Penke et al., 2010). The VKP exercise required quick movement decisions such as changes in paddling direction and bimanual coordinated movement based on the situation. Neural processing through the cerebellum and basal ganglia is required to coordinate and perform the desired movements, and integration in the association area of the brain is required for changing the direction of rowing based on the arrows on the screen (Kandel et al., 2013). Bimanual coordinated movement generates stronger brain activation than unimanual movement (Swinnen, 2002). Cognitive decline is linked with cerebral blood flow in older adults (Stoquart-ElSankari et al., 2007). Regular exercise can improve age-related cerebral perfusion by microvascular changes, resulting in an increase in cerebral blood oxygenation and brain activity (Villringer & Dirnagl, 1995). Therefore, VKP exercise might influence the integration of white brain matter and contribute to cognitive improvement by maintaining or increasing the brain volume of the participants. In older adults with mild cognitive impairment, improved executive function might be useful for performing high-level functional tasks of daily living.

This study has some limitations. It is difficult to generalize the effects of VKP exercise because this exercise was implemented for a short term in mostly older women with mild cognitive impairment. The supervision provided during the VKP exercise might have allowed the VKP group to focus more on intervention than the control group because the instructor may contribute to participant's exercise enjoyment and the development of self-efficacy during supervised exercise (Carrasco, Martinez-Rodriguez, Ortiz, & Fernandez-De-Larrinoa, 2012). The supervised exercise provides a limitation of the current study is that multiple tests within similar constructs (e.g., static balance eyes open, eyes closed) were applied. This increases the alpha-error probability and consequently the risk for Type I errors. Another limitation is the lack of brain activity scans. Thus, it is difficult to directly determine how brain activity in older adults with mild cognitive impairment was facilitated. This study was implemented in a virtual environment to increase the sense of immersion of the participants, but it was not perfect because of the absence of screen movement and the fact that it was performed on a chair, which cannot completely mimic the actual kayak paddling posture. Finally, we did not assess exercise satisfaction in our participants. However, the participants showed interest in the exercise and maintained a high participation rate.

Conclusion

This study investigated the effects of VKP exercise on postural balance, handgrip strength, and cognitive function in older adults with mild cognitive impairment. We found that VKP exercise was well designed to improve the physical and cognitive health of older adults with mild cognitive impairment. The virtual environment allowed the subjects to focus better on the exercise, which could be performed easily at home. Future research should employ immersive virtual reality that provides auditory cues according to the direction in which the kayak boat is moving and allows the subject to maintain a similar posture to that during actual kayak paddling.

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