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Ground Kayak Paddling Exercise Improves Postural Balance, Muscle Performance, and Cognitive Function in Older Adults with Mild Cognitive Impairment: A Randomized Controlled Trial

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Statistical Analysis C
Data Interpretation D
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Background: Kayaking is an interesting and posturally challenging activity; however, kayaking may be limited by safety issues in older adults. The aim of this study was to determine whether ground kayak paddling (GKP) exercise can improve postural balance, muscle performance, and cognitive function in older adults with mild cognitive impairment.

Material/Methods: Sixty participants were randomly allocated to a GKP group (n=30; mean age, 74 years) or a control group (n=30; mean age, 74 years). GKP exercise consisted 5 types of exercise protocols, including paddling and multi-directional reaching with repetitive trunk and upper-extremities movements, which was performed for 60 min twice a week for 6 weeks. The outcome measures included the Timed Up and Go Test, the Functional Reach Test, the Berg Balance Scale, the Arm Curl Test, handgrip strength, and the Montreal Cognitive Assessment.

Results: In this study, adherence to the regimen was 96% in the GKP group. Postural balance, muscle performance, and cognitive function were significantly improved after intervention ($p<0.05$), and all the values in the GKP group, except for the Berg Balance Scale scores, were significantly decreased or increased compared to the control group. Differences between the 2 groups were Timed Up and Go Test –0.74 s; Functional Reach Test +7.20 cm; Arm Curl Test +5.56 repetitions; right handgrip strength +3.57 kg; left handgrip strength +3.08 kg; and Montreal Cognitive Assessment, +3.46 score ($p<0.05$).

Conclusions: GKP exercise improves the physical and psychological ability of older adults with mild cognitive impairment.

MeSH Keywords: **Cognition • Exercise • Frail Elderly • Muscle Strength • Postural Balance**

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Background

Older adults undergo numerous age-related changes, including decreased muscle strength [1] and cognitive impairment [2]. Muscle strength can decrease by as much as 30% by the age of 80 years [3]. Several adverse events have been associated with decreased muscle strength and mass in older adults. This decrease has been shown to be related to reduced physical activity and total energy expenditure [4], difficulties in activities of daily living with a consequent loss of independence, falls, and poor quality of life [5]. Also, mild cognitive impairment (MCI) is clinically often observed in older adults [2]. Patients diagnosed with mild cognitive impairment are at an increased risk for dementia and Alzheimer's disease [6]. Older adults with mild cognitive impairment have worse performance, from fine motor function to complex motor function, than healthy older adults [7]. Movement control, including tracking in 2 or more planes of space and rapid body movements, are closely related to balance, which is vulnerable in older adults with mild cognitive impairment [7,8].

Various exercises, such as aerobic, resistive, and flexibility exercises, have been recommended for maintaining health and conditioning in older adults [9]. The advantages of aerobic exercise include decreased body fat, increased relative muscle mass, and improved bone mineral density [9]. In addition, aerobic exercise reduces the loss of brain tissue in older adults [10]. A recent meta-analysis has shown that exercise training has a significant beneficial effect on cognitive function and physical function of older adults with cognitive impairment [11].

Kayaking is an outdoor activity that increases muscle strength and postural balance, and can be performed by physically able and disabled individuals [12]. In addition, kayaking has a high metabolic demand and challenges the postural control system [12]. The ability to maintain continuous postural balance is required to control the motion of the paddle and kayak in the water with the upper extremities and manipulate the paddle in the air [12]. In a previous study, kayak training was used to enhance balance in patients with spinal cord injury [13–15]. Kayaking is an effective workout that simultaneously requires enhanced endurance and strength to optimize performance [16]. Increased shoulder muscle strength is another positive effect of kayak training that can be achieved without any shoulder problems or overload [14]. The trunk plays an important role in maintaining balance [17]. Because of this, we expect that kayak training would improve postural stability. However, despite these numerous advantages, kayaking is not readily accessible. Older adults may also be afraid of water and worry about safety issues. A ground kayak paddling (GKP) exercise was developed to overcome these limitations while conferring the benefits of kayaking. Therefore, the aim of the present study was to examine the effects of GKP exercise on postural balance, muscle performance, and cognitive function in older adults with mild cognitive impairment.

Material and Methods

Participants and procedure

This study was a randomized controlled trial and was registered with the International Clinical Trials Registry Platform (KCT0002269). Participants were voluntarily recruited through a wall-poster at the Senior Welfare Center and screened based on inclusion and exclusion criteria. The sample size was estimated using G-power software version 3.1. The effect size (0.80) was selected using Cohen's d table. We used 80% power, as it is typically used in clinical trials. The level of significance was set to 0.05 (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. Randomization was conducted using Random Allocation Software 2.0 [18]. The following inclusion criteria were used: older adults with mild cognitive impairment <26 points on the Montreal Cognitive Assessment, ability to communicate, and willingness and ability to commit to 6 weeks of intervention. Participants were excluded if they had musculoskeletal impairment of the upper extremities such as frozen shoulder, tennis elbow, and pain resulting from other diseases, neurological impairment, significant cognitive disorder, untreated medical condition, or condition which made them unable to maintain a sitting posture for a long time.

All of the experimental protocols were explained to each participant, and verbal and written consents were obtained before testing and training. This study was approved by the Sahmyook University Institutional Review Board (SYUIRB2014-090).

The participants meeting eligibility criteria were randomly allocated to the GKP group or control group and completed the pretesting, including muscle performance, cognitive function, and postural balance, performed by 6 different examiners who were blinded to group assignments. Posttests were conducted 1 week after the end of the exercise program, in which participants performed the same tasks as in the pretests (Figure 1).

Intervention

A GKP exercise was developed by modifying kayaking actions as performed for moving across water. This exercise is a safe exercise method that can be performed by people who are afraid of water, while maintaining the benefits of kayaking. The GKP exercise was conducted twice a week for 6 weeks on the ground, and each session consisted of 10 min of warm-up activities, 40 min of GKP exercise, and 10 min of cool-down

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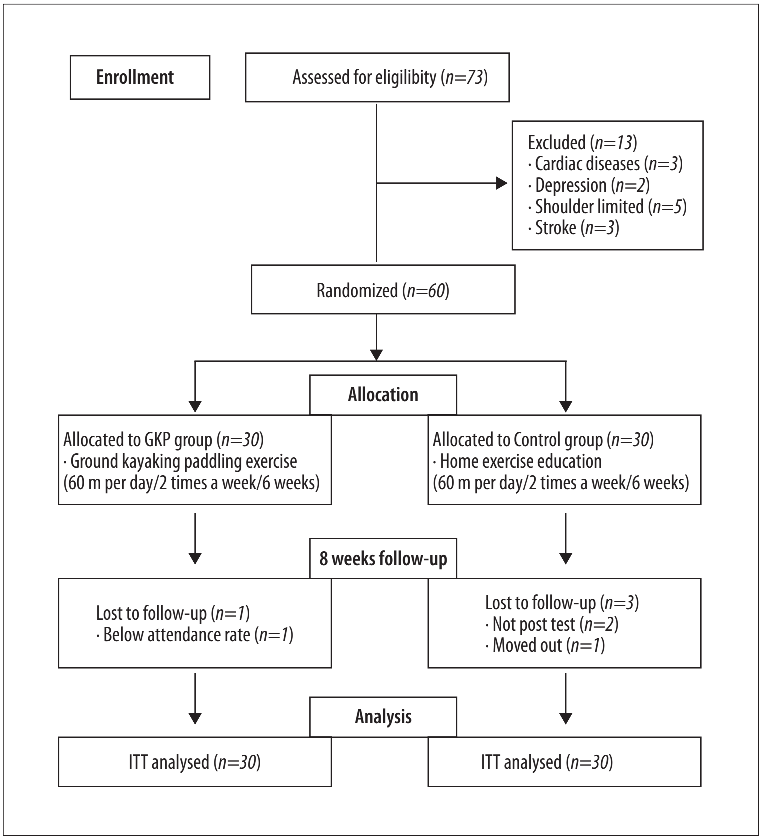

Figure 1. Flow diagram of the progression through the phases of a randomized trial of 2 groups. A total of 73 participants were enrolled and 60 participants who met the eligibility criteria were included. They were randomly allocated to 2 groups: the GKP (n=30) group and the control (n=30) group. A total of 4 participants dropped out and were analyzed based on intention to treat principles.

activities. The warm-up and cool-down activities were massage with a sensory ball, gentle stretching, and deep breathing exercises. The GKP exercise was a group exercise performed while sitting on chairs with and without a balance foam (soft blue, Thera-Band, USA), which increases the challenge by providing an unstable surface. A 2-min break was included in the exercise program to avoid muscle fatigue. The break was placed between the first and second parts of the training session, and each participant walked around the room while making a light paddling motion. One instructor led the program and 2 assistants supervised and corrected the posture of the subjects. The participants learned each motion during the first week of training. When the instructor demonstrated the 5 types of exercise to participants, they followed the motions. The 5 types of exercises are described in Table 1. Each type of exercise was conducted 4 times with 2 sets each time, with rhythmic music for interest.

The control group was instructed to perform a home exercise program. The warm-up and cool-down exercises were performed identically to those in the GKP group. The home exercise program was based on previous studies [19] and consisted of the William exercise and curl-ups, sideways leg lifts, prone leg lifts, supine leg lifts, and prone trunk hyperextensions. The participants were educated on how to perform the home exercises during the first, third, and fifth weeks. In the beginning, each exercise was repeated 10 times with 3 sets each time, and gradually increased by 10 additional times every 2 weeks. In the last week, participants performed each exercise with 3 sets 30 times. They conducted the exercises twice a week for 6 weeks and received a weekly confirmation call from the instructor.

Outcome measures

The Timed Up and Go Test [20], Functional Reach Test [21], and Berg Balance Scale were used to assess postural balance [22]. Muscle performance was measured using the Arm Curl Test and handgrip strength. The Arm Curl Test measures the upper body strength of older adults [23]. The participants were asked to sit upright with their backs against the backrest of an armless chair. They performed elbow flexion curls for 30 s using 2.3 kg and 3.6 kg dumbbells for women and men, respectively, while maintaining the initial posture without bending their trunk forward. The handgrip strength was measured using a hand-held dynamometer (Medical Handgrip Dynamometer model DHS-88, DETECTO, Webb City, USA). The left and right hands were tested alternatively and the subjects were allowed to rest for 2 min between the trials. The Montreal Cognitive Assessment was designed as an instrument for rapidly screening mild cognitive dysfunction [24]. The total possible score is 30 points. A score of ≥26 is considered normal. This brief clinical cognitive

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Table 1. Five types of ground kayak paddling exercise.

Type	Starting position	Contents
I	Holding a divided paddle with both hands	Raising both hands Rotating the trunk while holding the paddle vertically Lateral flexion of trunk while holding the paddle vertically Paddling to the left and right
II	Holding a divided paddle in each hand	Alternately hiding the face with the paddles Forward paddling Backward paddling Alternately lifting the hands upward
III	Holding a divided paddle in each hand	Raising the paddles by reaching diagonally with the arms Moving the paddles forward by reaching straight Raising both hands diagonally at the same time Spreading both arms out with the elbows flexed 90°
IV	Holding a combined paddle with both hands	Paddling in the right direction only Padding in the left direction only Reaching forward Lateral flexion of trunk while holding the paddle horizontally
V	Holding a combined paddle with both hands	Lateral flexion of trunk while raising both hands with the paddle held horizontally Rotating the paddle clockwise and counterclockwise in the horizontal plane Rotating the trunk while holding the paddle horizontally behind the head Rotating the trunk while holding the paddle vertically with one hand

Table 2. General characteristics of participants.

Variables	Ground kayak paddling group (n=30)	Control group (n=30)
Sex (male/female)	6/24	5/25
Age (year)	74.90 (5.10)	74.23 (4.38)
Body weight (kg)	58.97 (6.82)	58.47 (8.33)
Height (cm)	157.57 (6.30)	157.30 (6.67)

Values are presented as mean (standard deviation).

screening tool was developed for the detection of mild cognitive impairment and mild Alzheimer disease.

Statistical analysis

SPSS statistical software (version 19.0, IBM, Chicago, IL, USA) was used for all of the statistical analyses. An intention to treat analysis was conducted. The normality of the data was assessed using the Shapiro-Wilk test. The chi-square analysis and independent samples *t* test were used to examine intergroup homogeneity. All data are presented as means (standard deviation) unless stated otherwise. Repeated-measures analysis of variance (ANOVA) was performed to evaluate the effects of time, group, and interaction effect (time × group) for the Arm Curl Test, handgrip strength, Montreal Cognitive Assessment, Timed Up and Go Test, Functional Reach Test, and Berg Balance Scale. For all the tests, the statistical significance level was set at 0.05.

Results

In the present study, 73 older adults, aged >65 years, with cognitive impairment were enrolled, and 13 were excluded (3 had cardiac disease, 2 had depression, 5 had limited range of motion of the shoulder, and 3 had a stroke). Four subjects dropped out because 1 had an insufficient attendance rate, 2 did not complete the posttest, and 1 moved (GKP group 1 and control group 3). All of the data were analyzed by a researcher. The demographic characteristics of participants are presented in Table 2, and there was no significant difference between the 2 groups. The GKP group had a 96% attendance

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Table 3. Comparison of postural balance, muscle performance, and cognitive function between ground kayak paddling and control groups.

Variables	Ground kayak paddling group (n=30)		Control group (n=30)		Time		Group		Interaction effect (time × group)	
	Pre-test	Post-test	Pre-test	Post-test	F	p	F	p	F	P
TUG (s)	8.34 (1.42)	7.59 (1.14)	8.49 (1.13)	8.38 (1.25)	24.555	<0.001	2.289	0.136	13.361	0.001
FRT (cm)	28.46 (6.79)	35.67 (6.77)	27.91 (5.85)	28.25 (6.30)	48.197	<0.001	6.432	0.014	39.951	<0.001
BBS (score)	53.66 (3.78)	55.43 (1.33)	54.16 (2.30)	54.86 (2.02)	21.202	<0.001	0.003	0.955	3.965	0.051
ACT (rep.)	18.13 (3.86)	23.70 (6.14)	19.83 (5.49)	21.16 (6.52)	79.345	<0.001	0.089	0.766	29.867	<0.001
RHS (kg)	16.12 (3.95)	19.70 (4.45)	16.59 (4.23)	17.57 (4.54)	67.424	<0.001	0.593	0.444	22.049	<0.001
LHS (kg)	15.70 (4.65)	18.78 (5.01)	16.73 (4.51)	17.61 (5.16)	73.007	<0.001	0.003	0.956	22.397	<0.001
MoCA (score)	21.66 (3.24)	25.13 (2.78)	20.76 (3.02)	21.46 (3.11)	50.386	<0.001	9.785	0.003	22.215	<0.001

TUG – timed up and go test; FRT – functional reach test; BBS – Berg Balance Scale; ACT – arm curl test; RHS – right handgrip strength; LHS – left handgrip strength; MoCA – Montreal Cognitive Assessment. Values are presented as mean (standard deviation).

rate during GKP exercise, and the control group had an 89% attendance rate. There were no significant differences in the postural balance, muscle performance, and cognitive function between the 2 groups at baseline.

The effects of the GKP exercise on muscle performance, cognitive function, and postural balance are presented in Table 3. Repeated-measures ANOVA reveal significant differences in the postural balance, including Timed Up and Go Test (8.99%, p<0.001), Functional Reach Test (29.47%, p<0.001), and Berg Balance Scale (3.29%, p<0.001) after intervention in the GKP group. A significant main effect of group on the Functional Reach Test was observed (p=0.014), and Functional Reach Test scores were increased about 21-fold (7.20 cm *vs.* 0.33 cm) compared to the control group. Interaction effects (time × group) were found in the Timed Up and Go Test (p=0.001) and Functional Reach Test (p<0.001).

In muscle performance, the Arm Curl Test, right handgrip strength, and left handgrip strength increased by 30.66%, 22.14%, and 19.61%, respectively in the GKP group and 6.70%, 5.84%, and 5.26% in the control group (p<0.001 in all the cases). Repeated-measures ANOVA revealed significant interaction effects (time × group) in Arm Curl Test (p<0.001), right handgrip strength (p<0.001), and left handgrip strength (p<0.001).

Cognitive function showed a significant improvement in both groups compared with baseline (p<0.001). Montreal Cognitive Assessment scores were increased by 16.02% in the GKP group and 3.37% in the control group from baseline. Repeated-measures ANOVA revealed a significant main effect of group in Montreal Cognitive Assessment (p=0.003). The GKP group scores were about 5 times (3.46 score *vs.* 0.70 score) higher than in the control group in Montreal Cognitive Assessment. In addition, the interaction effect (time × group) was significant at p<0.001.

Discussion

This was the randomized trial to investigate the effects of GKP exercise for older adults with mild cognitive impairment. We found that the GKP exercises improve postural balance, muscle performance, and cognitive function. Our results clearly demonstrate that 6 weeks of well-designed training can improve the physical and psychological parameters in older adults with mild cognitive impairment. Reduced proprioception of older adults results in decreased functional activity and increased postural body sway when standing [5]. Physical activities or exercises are usually considered appropriate solutions to diminished proprioception [25]. In addition, trunk mobility should be considered because an inflexible trunk negatively affects postural balance [26]. According to Kasukawa et al.

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(2010) and Suri et al. (2009), trunk extensor strength and postural balance was decreased with age [26,27]. The GKP exercise in the present study consisted of multi-directional movements of the trunk and was designed to reproduce the natural movements of the trunk and upper extremities. Active upper-body movement activates the sensorimotor control system that provides proprioception, and the added unstable surface (balance foam) might stimulate the proprioceptors, and could lead to improved postural balance [28]. We hypothesized that participants would enhance their ability to control their center of gravity by moving it in various directions. Since multi-directional movements might induce a subsequent increase in limit of stability, this could significantly improve Functional Reach Test scores. Shujaat et al. (2014) suggested that kayaking exercise would improve trunk mobility in patients with Parkinson's disease [29]. Granacher et al. (2013) found that core instability strength training strengthened trunk muscles and improved spinal mobility, dynamic balance, and functional mobility of older adults [30]. To the best of our knowledge, there are few articles on the effects of kayak-related exercise on trunk mobility and stability. Our results suggest that GKP exercises increase flexibility and activate the muscles of the trunk, especially the core muscles, because GKP exercises including the trunk flexion, extension, and rotational movement and repetitive trunk and upper-extremities movement are accompanied by core muscles activation.

Sustaining muscle mass and muscle strength is required to support functional independence and perform activities of daily living in older adults [31]. A report indicated that lower muscle strength, physical ability, and muscle density contribute to a higher risk of hospitalization in older adults aged 70–79 years [32]. Taekema et al. (2010) reported that handgrip strength reflects the overall muscle strength and predicts the deterioration of physical, psychological, and social health in older adults. Therefore, we may assume that reduced handgrip strength is related to cognitive decline [33].

A study by Bjerkefors et al. (2006) included subjects with paraplegia and spinal cord injury, and showed significant improvements of shoulder muscle strength after exercising on a kayak ergometer [14]. McKean and Burkett (2014) also reported that kayaking exercise performance in elite athletes increased the upper body strength [34]. This finding suggests that paddling motion effectively improves muscle strength and shows that GKP exercise can improve upper-extremity muscle strength in older adults. The participants must be continuously holding a paddle and conducting repetitive movements by using the upper-extremity muscles during GKP exercise, which increases the strength of the upper-extremity muscles and handgrip strength. This repetitive motion might help increase muscle fatigue resistance and then allow the participants to continue exercising [35]. This study did not use paddling in the water, as in actual kayaking, but the resistance of the air itself might have been enough to improve participant strength.

Cognitive function was significantly improved in both the GKP and control groups. Atkinson et al. (2010) reported that cognitive impairment precedes or co-occurs with physical performance decline [36]. In particular, cognitive impairments are related to decline of cerebral blood flow in older adults [37]. Regular exercise can improve age-related cerebral hypoperfusion by microvascular changes [38,39]. The participants in the GKP group performed regular strength training exercises, which can increase cerebral blood flow and improve cognitive function. Therefore, the greater increase of muscle strength and cognitive function observed in the GKP group could have resulted from the proportional correlation between cognition and muscle strength.

As the results, the GKP exercise can be applied for older adults who are frail or have cognitive dysfunction. This exercise is also feasible for patients with severe cognitive impairment such as dementia. Since it is effective to follow the motion without memorize the exercise sequence, subjects can perform the exercise easily. In this study, GKP exercise had demonstrated effects for older adults with mild cognitive impairment; however, it can be also used for healthy older adults to prevent cognitive dysfunction and maintain fitness. Many healthy older adults have reduced capacity for exercise and have trunk stiffness due to a sedentary life style [26].

The limitations of the present study include the preponderance of female subjects (80%) and the fact that all of the subjects were residents of the same community. Mild cognitive impairment was diagnosed using the Montreal Cognitive Assessment alone. Therefore, it is difficult to generalize about older populations with mild cognitive impairment. Participants were not blinded to which group they were allocated to; however, the space in which the intervention was performed was separated by instructors to minimize exchanges of information between the 2 groups. Moreover, the study period was too short to investigate the most beneficial effects of GKP exercise, and it is difficult to demonstrate the direct relationship between the GKP exercise and the trunk proprioception because this was not measured.

Conclusions

The GKP exercise was more effective for improving postural balance, muscle performance, and cognitive function than was home exercise program in older adults with mild cognitive impairment. The GKP exercise is safer than kayaking in the water and is easier to use in the clinical setting.

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Conflicts of interest

None.

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