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Original Article

Effects of a multicomponent exercise on dual-task performance and executive function among older adults

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S U M M A R Y

Background: Previous studies showed that multicomponent exercise enhanced physical and cognitive functions. This study aimed to investigate the effects of a multicomponent exercise on dual-task performance and executive function and to demonstrate the relationship between improvement in dual-task performance and enhancement in executive function among the elderly.

Methods: A total of 27 people completed the intervention, with 16 in the experimental group and 11 in the control group. The 12-week multicomponent exercise lasted 1 h per day and 3 days per week. Participants' gait performance was assessed in dual-task conditions and executive function was examined at both pre- and post-intervention.

Results: Results showed significant interaction effects of time x group on all selected gait parameters in both dual-task conditions and the Executive Interview. Compared with the control group, the experimental group showed greater improvements in most measures following intervention. Improved dual-task performance was correlated with enhanced executive function ($r = 0.46–0.75$).

Conclusion: Our results suggested that a multicomponent exercise positively affects dual-task performance and executive function in the elderly.

1. Introduction

The ability to perform multiple tasks simultaneously is a common requirement for carrying out activities of daily living. Performing dual-tasks while walking has been shown to affect older adults' gait performance.[1] Hollman et al. reported that healthy older adults decreased gait velocity and increased gait variability when spelling words backwards or when counting backwards.[2] Dual-task decrements in gait indicated an increasing need for directing attentional resources to walking.[3]

Dual-task ability relies on executive function.[4] In turn, executive function is particularly affected by aging.[5] Executive function is defined as a set of cognitive skills necessary for planning, monitoring, and executing a sequence of goal-directed complex actions. Executive function plays a key role in dual-task coordination and is sensitive to dual-task interference in older adults.[6] Age-related declines in executive function may contribute to increased dual-task deficits in older adults.

Exercise is an evidence-based strategy for improving motor functions in older adults.[7] Previous meta-analytic and systematic reviews also reported that exercise is associated with improvements in executive function and attention in older adults.[8,9] Conversely, a moderate-dose physical activity program was found to not result in improved executive function among sedentary older adults; however, the authors suggested that physical activity may benefit executive function.[10] This inference was derived from their results of subgroup analyses showing that a physical activity program improved executive function in participants with lower baseline physical performance and those aged ≥80 years. Older adults have also been recommended to regularly engage in multicomponent physical activity programs that target endurance,

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strength, flexibility, and balance in accordance with advice from the American College of Sports Medicine and other documents.[11,12] Improved motor and cognitive functioning have been shown to be facilitated by multicomponent exercise training.[7,9,13–15]

Some studies have measured the effects of multicomponent exercise on dual-task performance. One such study showed that multicomponent exercise might improve dual-task performance,[16] while another study failed to prove a positive effect of multicomponent exercise on dual-task performance.[17] Both studies did not include a control group. Moreover, investigations into the effect of multicomponent exercise on both dual-task performance and executive function within the same study are scarce. Therefore, the aim of the present study was to evaluate the effects of a multicomponent exercise on dual-task performance during gait and on executive function, and to clarify the relationship between improved dual-task performance and enhanced executive function among older adults.

2. Methods

2.1. Participants

Participants were recruited from local public health centers in Taiwan. All 30 participants met the following inclusion criteria: (1) ≥65 years old; and (2) ability to walk outdoors independently without assistive devices. The exclusion criteria were as follows: (1) presence of a neurological disease known to impair mobility (e.g., stroke and Parkinson's disease); (2) presence of musculoskeletal problems limiting safe participation in an exercise program; and (3) a diagnosis of cardiovascular diseases, dementia, psychosis, or depression. Information on age, gender, and medical history were obtained through participant interviews.

2.2. Procedure

The study protocol was approved by the Taipei City Hospital Institutional Review Board and registered in a clinical trial registry (ClinicalTrials.gov NCT02102308). The purpose, nature, and potential risks of the experiments were fully explained to the participants. All participants gave written, informed consent before study participation. To increase attendance and compliance, participants were placed into either an experimental or control group depending on their preference. The experimental group received a multicomponent exercise three times a week for 12 weeks, while the control group attended six health education classes during the 12-week period. Outcome measures were obtained pre and post-intervention. Measures included gait performance in dual-tasks and interviews on executive function.

2.3. Intervention

Participants in the experimental group received multicomponent exercise for 1 h per day and 3 days every week over 12 weeks. The exercise program was based on the recommendations for the elderly population from the American College of Sports Medicine, including 20-min resistance training, 20-min endurance training, and 20-min balance training. The sequence of intervention was endurance, resistance, and then balance training. During the exercise period, a physical therapist provided guidance and assistance for each participant. Resistance training focused on major muscles of the hip, knee, and ankle joints. Training dose started from 50% maximal voluntary contraction for 10 repetitions, and then increased to 75%–80% maximal voluntary contraction progressively. A 5-min stretching exercise was conducted before and after resistance training to prevent muscle soreness and injury. The endurance training program was a sequence of whole body activity including 5-min warm-up, 20-min endurance training and a 5-min cool-down exercise. Stepping, brisk walking and hula hoop with upper limb movement were protocols for endurance exercise. The training dose was set at 70–75% maximal heart rate (220−age). The rate of perceived exertion between 12 and 14 was also considered during the training period. The balance exercise program involved static and dynamic balance training. Static balance training included the participant standing on the floor or a foam mat and changing their base of support by both forward reaching and from a single stance with their eyes opened or closed. Dynamic balance training included straight walking, sideway walking, backward walking and figure-8 walking.

Participants in the control group attended six education classes regarding health for 1 h per day and 1 day every 2 weeks over 12 weeks. The class provided information regarding common exercises for the elderly, with an individualized exercise program and teaching on prevention of injury during exercise.

2.4. Measures

2.4.1. Gait performance

The GAITRite system (GAITRite, CIR Systems Inc., USA) was used to evaluate gait performance. The validity and reliability of gait parameters as measured by the GAITRite system in the elderly is well established.[18,19]

Gait was evaluated while walking under two dual-task conditions, serial seven subtractions and naming animals. Serial sevens, counting down from a random three-digit number, is a clinical test that evaluates one's ability to maintain attention with distraction. Naming animals, i.e., generating as many examples of animals as possible, is a clinical test used to assess abstract thinking and word generation. Participants were asked to walk three trials under each condition. Trial interval lasted 1 min. Data were averaged from the three trials. No instruction was provided for prioritization of one of the tasks (walking or cognitive task) during the dual-task trials. To minimize the learning effect and fatigue, the order of the dual-tasks was randomized. Gait parameters of interest were velocity (cm/s), stride time (ms), stride length (cm), stride time variability (%) and stride length variability (%). The coefficient of variation (CV) was used to assess the variability of gait. Lower values reflect a more consistent gait pattern. The formula of CV given as a percentage is as follows: standard deviation/mean × 100%.

2.4.2. Executive function

The 25-item Executive Interview (EXIT 25) is a quick screening tool for assessing of executive function.[20] The Chinese version (C-EXIT 25) was uses in this study.[21] The C-EXIT 25 had high internal consistency and good reliability.[21] The test consisted of a 25-item rating for executive function on tasks. Scores ranged from 0 to 2 for each item, and higher scores indicated worse performance.[20]

2.5. Sample size

The primary outcome was gait velocity. The sample size was determined using G*power based on an effect size f of 0.25, an alpha level of 5%, 80% power, and an ANOVA model.[22] A minimum sample size of 28 participants was indicated.

2.6. Statistical analysis

All analyses were performed using the SPSS 20.0 statistical package (SPSS Inc., Chicago, IL, USA). Descriptive statistics were generated for all variables, and distributions of variables were expressed as mean ± standard deviation. Intergroup differences among baseline characteristics were evaluated using an independent t-test or chi-square analysis. A two-way analysis of variance (group × time) was used to determine differences of each dependent variable. When the interaction effect was significant, the main factor's group and time were tested again using independent and paired t-tests, respectively. Change scores were calculated by subtracting pre-intervention data from post-intervention data. Pearson's test was used to analyze the correlation between change in each dual-task parameter and change in executive function. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Participant recruitment and attendance

Fig. 1 shows the flow of participants from time of screening to study completion at 12 weeks. Of 30 participants, 14 self-allocated themselves to the control group, and the other 16 self-allocated to the experimental group. Three control group participants did not complete intervention. The 27 participants who completed the intervention attended all intervention sessions. None of the participants reported any adverse events.

3.2. Participants' characteristics at baseline

Demographic characteristics of participants are presented in Table 1. The differences in the demographics and pre-intervention-selected measures of the two groups were insignificant.

3.3. Effects of exercise on gait in dual-task conditions

These results of intervention effects are presented in Table 2. Analysis of variance showed a significant two-way interaction effect of time × group on all selected gait parameters in both dual-task conditions. The analysis also showed a significant main effect of time on all selected gait parameters in both dual-task conditions. In the experimental group only, significant improvements were observed on all selected gait parameters in both dual-task conditions. Compared with the control group, the experimental group demonstrated better performance in each outcome except stride length at post-intervention.

3.4. Effects of exercise on executive function

Analysis of variance with group and time interval as between-subjects factor and within-subject factor, respectively, showed a significant two-way interaction effect of time × group on the C-EXIT25 score ($p < 0.001$). The analysis also showed a significant time effect on C-EXIT25 ($p < 0.001$). Post hoc analysis revealed that only the experimental group showed a decrease in C-EXIT25 score after intervention ($p < 0.001$) (Table 2). Post hoc analysis also showed a significant difference between the groups at post-intervention ($p < 0.001$) (Table 2).

3.5. Correlation between dual-task performance and executive function

Table 3 shows that improved each dual-task outcome correlated significantly with improved executive function ($r = 0.46–0.75$).

4. Discussion

This study's main finding was that a multicomponent exercise significantly improved gait during a dual-task activity in older adults relative to the control group. The present results also support the hypothesis that improved executive function following multicomponent exercise may contribute to improved dual-task performance.

Our results demonstrated that multicomponent exercise led to improved dual-task performance in gait compared with the control group. These improvements may be attributed to beneficial effects of the training intervention on both physical and cognitive functions. Multicomponent exercise is an effective tool for improving postural stability and gait performance.[7,13] Improved postural stability and gait, especially gait speed, may contribute to enhanced dual-task ability while walking.[23] Additionally, executive function plays an essential role in the ability to walk and perform another task simultaneously.[24] Dual-task decrements in gait were thought to be closely related to executive function.[23] Our results showed moderate-to-high correlations between improved dual-task performance and improved executive function. These results implied that dual-task improvement may be partially due to enhanced executive function. Furthermore, review studies reported mechanisms underlying the exercise effect. These mechanisms include neurotrophins, synaptic plasticity, neurogenesis, angiogenesis, and cerebral blood flow.[25,26] These mechanisms may contribute to the positive effects of exercise on dual-task performance and executive function.

Executive function is known to decline with age. Previous studies have demonstrated that multicomponent exercise benefits cognitive functions in elderly people.[9,14,15] However, some studies have failed to demonstrate that multicomponent exercise has a positive effect on cognitive performance.[27,28] These studies showed considerable variation in exercise dose and cognitive measures. A positive relationship between higher exercise dose and cognitive health has been reported in aging adults.[29,30] Among cognitive measures, a consistent result was obtained regarding how exercise improved executive function. The present findings support recently emerging indications that multicomponent exercise positively influences executive function with a medium-to-large effect.[31] Our results showed that a multicomponent intervention improved executive function with a large effect compared with that of education control. The positive results may be due to the design of the exercise program, which was based on effective doses and patterns from previous studies. For example, our intervention included resistance training that was of moderate-to-high dose [32]; aerobic stepping exercise that emphasized movement agility[9] and balance training focused on postural control and coordination.[31] We thus suggest the positive effects of exercise intervention on executive function were possible because the dose response and the additive effect of intervention programs.

The main limitations of the present study were lack of randomization of the sample. Non-randomized studies with inadequate control of biases may threaten the results. Also, non-randomized clinical trials may overestimate the effect of an intervention and the self-allocation strategy poses a threat to the study's internal validity. However, these limitations were hard to avoid because it was difficult to maintain participation in the programs for 12 consecutive weeks. Despite the existing evidence of positive effects of exercise on cognitive or motor function in participants with neurological diseases or cardiovascular diseases,[33,34] participants with these diseases were excluded in this study. The homogeneity of our sample limits the ability to generalize the findings to mixed populations of healthily diverse older adults. Additionally, a lack of adequate data in demographic characteristics and medical conditions of the participants might cause selection bias. The results must be interpreted carefully. Other limitations included small sample size, greater contact for the experimental group compared with the control group and without recording participants' cognitive performance in dual-task conditions. In addition,

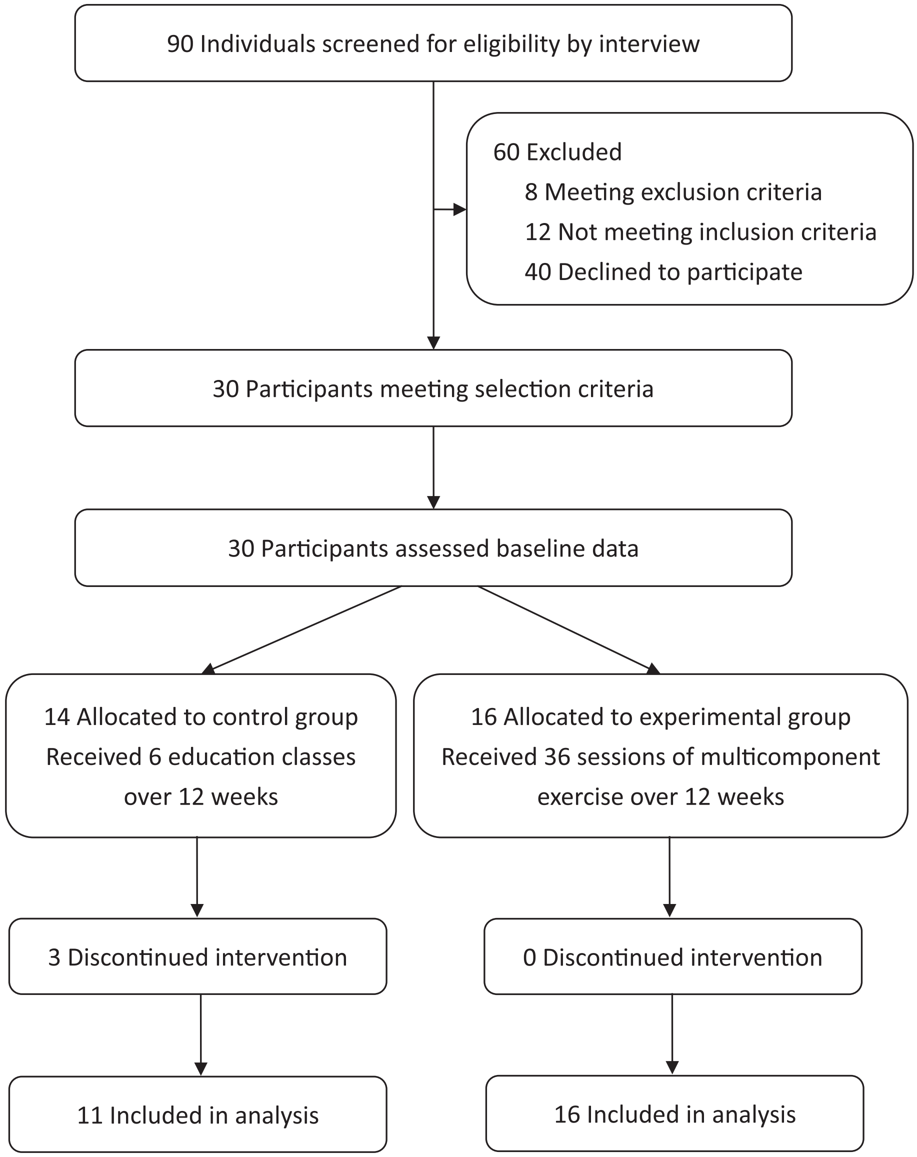

Fig. 1. Flow chart of the participant recruitment process.

Table 1
Baseline characteristics of the participants.

Variables	Control group (n = 11)	Experimental group (n = 16)	*p*
Gender (male/female)	3/8	4/12	1.00
Age (years)	71.00 ± 5.48	70.25 ± 4.71	0.71
C-EXIT25 (score)	10.27 ± 2.24	11.13 ± 3.38	0.47
Gait performance			
Velocity (cm/s)	106.33 ± 10.41	103.65 ± 16.20	0.63
Stride time (s)	1.03 ± 0.03	1.06 ± 0.06	0.21
Stride length (cm)	108.97 ± 13.88	109.97 ± 16.54	0.87
Stride time variability (%CV)	10.13 ± 5.00	12.14 ± 7.11	0.43
Stride length variability (%CV)	5.00 ± 2.90	6.19 ± 5.78	0.54

Abbreviations: C-EXIT25 = Chinese version of 25-item Executive Interview; CV = coefficient of variation.
Data are presented as the mean ± SD or number.

our data were collected by an investigator who was not blinded to group assignment. Nonetheless, bias in study results was minimized by the use of standardized instructions during testing. Future studies should be randomized with a large sample size to investigate cognitive and dual-task ability after exercise.

The current results showed that a 12-week multicomponent exercise is effective in improving gait performance in dual-task conditions among older adults. The beneficial effect of exercise on executive function has also been observed. Improved dual-task performance may be related to enhanced executive function.

Table 2
Effects of exercise on executive function and gait performance in dual-task condition.

Measures	Control (n = 11)		Experimental (n = 16)		Time effect p	Time × Group p
	Pre	Post	Pre	Post		
C-EXIT25 (scores)	10.00 ± 2.34	10.08 ± 2.23	11.41 ± 3.48	4.94 ± 2.79***,†††	0.000	0.000
Gait performance in serial 7 subtractions task						
Velocity (cm/s)	82.65 ± 15.08	82.72 ± 15.01	82.38 ± 16.67	104.49 ± 15.25***,††	<0.001	<0.001
Stride time (s)	1.20 ± 0.12	1.20 ± 0.11	1.15 ± 0.11	1.00 ± 0.08***,†††	<0.001	<0.001
Stride length (cm)	100.39 ± 13.66	99.40 ± 13.90**	95.88 ± 18.14	107.57 ± 13.19***	0.001	<0.001
Stride time variability (%CV)	12.38 ± 3.48	12.37 ± 3.44	13.30 ± 4.62	4.87 ± 2.14***,†††	<0.001	<0.001
Stride length variability (%CV)	11.55 ± 6.25	11.64 ± 6.12	13.06 ± 9.03	2.81 ± 2.37***,†††	<0.001	<0.001
Gait performance in naming animals task						
Velocity (cm/s)	73.01 ± 18.18	73.03 ± 18.22	74.80 ± 17.27	96.91 ± 16.79***,††	<0.001	<0.001
Stride time (s)	1.31 ± 0.17	1.31 ± 0.16	1.24 ± 0.20	1.10 ± 0.13**,††	0.003	0.003
Stride length (cm)	99.91 ± 15.92	99.87 ± 16.17	94.49 ± 19.69	105.55 ± 16.32**	0.003	0.002
Stride time variability (%CV)	18.66 ± 10.16	18.62 ± 10.14	18.89 ± 9.13	5.33 ± 3.40***,†††	<0.001	<0.001
Stride length variability (%CV)	13.27 ± 8.43	13.36 ± 8.62	15.06 ± 13.99	4.00 ± 2.19**,†††	0.01	0.01

Abbreviations: C-EXIT25 = Chinese version of 25-item Executive Interview; Pre = pre-intervention; Post = post-intervention; CV = coefficient of variation.
Data are presented as the mean ± SD.
Double asterisks ($p < 0.01$) and triple asterisks ($p < 0.001$) show a significant difference versus pre-intervention.
Double symbol †† ($p < 0.01$) and triple symbol ††† ($p < 0.001$) show a significant difference versus control group.

Table 3
Correlation (r) between change in executive function and change in dual-task performance (n = 27).

Measures	Executive function	
	r	*p*
Serial 7 subtractions task		
Velocity (cm/s)	−0.71	<0.001
Stride time (s)	0.75	<0.001
Stride length (cm)	−0.62	<0.001
Stride time variability (%CV)	0.66	<0.001
Stride length variability (%CV)	0.62	0.001
Naming animals task		
Velocity (cm/s)	−0.66	<0.001
Stride time (s)	0.49	0.009
Stride length (cm)	−0.50	0.007
Stride time variability (%CV)	0.59	0.001
Stride length variability (%CV)	0.46	0.02

Practically, a short-term thrice-weekly multicomponent exercise including resistance training, endurance training and balance training induces improved gait performance in dual-task conditions as well as executive function. These improvements are important to carrying out daily activities for the elderly population.

Conflicts of interest

There are no conflicts of interest.

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