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Original Article

Effects of acute exercise in the sitting position on executive function evaluated by the Stroop task in healthy older adults

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Abstract. [Purpose] Exercise effects on executive functioning depend on exercise mode. We tested the effects of three acute exercises in the sitting position—stepping, stretching, and finger movement—on older adults' executive functioning in comparison to a resting state (i.e., control condition). [Subjects and Methods] Participants were 26 healthy older adults (mean age, 71.8 ± 4.7 years). All participants performed the three sitting exercises for 10 minutes; resting for an equal amount of time was used as a control condition. These four conditions were presented in random order. The color-word matching Stroop task was used to evaluate executive function before and after the sitting exercises and control condition. [Results] All three sitting exercises significantly reduced Stroop interference scores, while the control condition did not. There was a significant difference between the finger movement exercise and the control condition in pre-to-post-intervention changes in Stroop interference scores. [Conclusion] The acute finger movement exercise was especially beneficial for executive function as evaluated by the color-word matching Stroop task.

Key words: Chair exercise, Executive function, Motor function

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INTRODUCTION

Previous reviews on the relationship between acute exercise and cognitive function concluded that executive function is temporarily enhanced after acute exercises[1, 2)]. Furthermore, the exercise mode is a determining factor of this cognitive enhancement[2)]. For example, cycling exercises appear to lead to greater enhancement than does running[1)]. Additionally, both aerobic exercise and resistance training improved executive function on the Stroop task[3)], whereas only aerobic exercise enhanced working memory[4)].

However, one systematic review revealed that the participants of most previous studies in this area utilized young adult participants[2)], while few targeted older adults. Because cognitive decline is a serious problem among older adults, this population should be studied in greater detail. Typically, interventions for older adults rely on exercises in sitting and standing positions[5, 6)]. Sitting exercises can be used with both healthy and frail older adults, because they are relatively safe to perform[7)]. Accordingly, we targeted 3 sitting exercises (stepping as aerobic exercise, stretching, and finger movements) to determine the effects of acute exercises on executive function. In Japan, these exercises have been frequently used in com-

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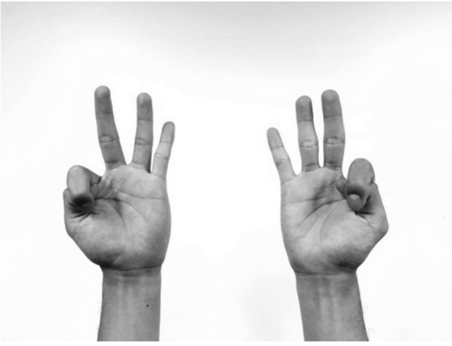

Fig. 1. An example of symmetrical movement of the fingers.

Fig. 2. An example of the wiggling finger exercise.

munity settings for older adults and in facilities that cater to this age group, such as day care centers. Identifying effective intervention methods that employ sitting exercises might help in developing beneficial programs for older adults. This study aimed to examine the effects of these 3 acute exercises in the sitting position on executive function by comparing it with a control condition in healthy older adults.

SUBJECTS AND METHODS

Community flyers were used to recruit study participants. The inclusion criteria were: (1) ≥65 years old and (2) no medical history of stroke, heart disease, or neurological disease (as these conditions would have disrupted participants' ability to exercise). Forty participants met both criteria and were then screened for dementia and depressive disorder as additional exclusion criteria. One participant dropped out before undergoing this screening process. The Mini-Mental State Examination (MMSE)[8], administered by occupational therapists, was used to screen for dementia (applying a cut-off of <23/24 as too low to continue). Depressive disorder was evaluated by the Geriatric Depression Scale (GDS)[9], with a cut-off point of ≥11. No participants had dementia or depressive disorder. During the experimental period, two further participants dropped out. Moreover, according to a previous study[10], we excluded 11 participants who had a Stroop task correct answer rate of less than 80% on at least one trial. Thus, we ultimately analyzed data from 26 community-dwelling older adults (eight men and 18 women, age: 71.8 ± 4.7 years, MMSE: 28.7 ± 1.2; GDS: 3.0 ± 2.5). This study was approved by the Ethical Committee of University of Tsukuba (Ref No., Tai 27-132). All participants were provided with an explanation of the study and obtained their written informed consent prior to their enrollment in the study.

Participants took part in 4 sessions: the 3 types of sitting exercises (stepping, stretching, and finger movements) and a control condition, administered in a randomized order (randomization was performed using a random number table). For each sitting exercise session, participants were first asked to perform the Stroop Color Word Test task (approximately 6 minutes long), after which they engaged in one of the three types of sitting exercise for 10 minutes. Participants then rested for 3 minutes before and 5 minutes after each sitting exercise. After completing each exercise, the participants performed the Stroop task again. In the control session, participants engaged in a 10-minute rest instead of one of the sitting exercises. To avoid any residual effects, participants were not allowed to participate in the experiment for 2 days consecutively. Additionally, we asked participants to avoid exercising before the measurements.

In the stepping exercise, participants were asked to step at their usual pace while sitting on a 41-cm chair for 10 minutes. For stretching, we used the sitting version of the stretching program. The program involves static and dynamic stretching such as flexion and extension of the neck and lateral bending of the trunk. Participants performed the program for 10 minutes while watching a video that demonstrated the exercise movements. For the finger movement exercise, participants performed symmetrical or asymmetrical movements of bending and extending each finger for 5 minutes (Fig. 1), and then wiggled their fingers for another 5 minutes (Fig. 2).

The Japanese version of the color-word matching Stroop task[10–12] which is commonly used to evaluate executive function, was adopted in this study, because previous studies have used it to evaluate the effects of acute exercise[10, 13]. The task was displayed on a computer screen placed in front of the participants. The task display comprised upper and lower rows: the upper row depicted a figure or word colored red, blue, yellow, or green, and the lower row depicted one of the following words: "RED," "BLUE," "YELLOW," or "GREEN." If the color of the character displayed in the upper row was the same as the meaning of the word in the lower row, the trial is considered correct. Otherwise, the trial was considered incorrect. For neutral trials, the upper row displayed a figure, while for incongruent trials, the upper row displayed a word.

A total of 60 trials were included in each session, 30 neutral and 30 incongruent. These 60 trials were broken into four sets of 15 trials, each containing a random assortment of neutral and incongruent trials. Each trial was separated by an interval of 3 seconds, while each set was separated by 30 seconds. Although the trials were randomly presented, we programed it such

Table 1. Characteristics of the participants

Age (years)	71.7 ± 4.7
Women, n (%)	18 (69.2)
Education (years)	14.4 ± 2.2
MMSE (points)	28.7 ± 1.2
GDS (points)	3.0 ± 2.5

SD: standard deviation; MMSE: Mini-Mental State Examination; GDS: Geriatric Depression Scale.

Table 2. Results of the reaction time data for the Stroop task in each session

	Neutral			
	Before session	After session	Interaction	Main effect of time
			p value	p value
Neutral				
Control (s)	798.2 ± 109.4	755.1 ± 75.4	0.865	<0.001
Stepping ex (s)	802.7 ± 112.6	769.3 ± 108.6		
Stretching ex (s)	815.9 ± 100.6	767.5 ± 93.9		
Finger movement ex (s)	828.8 ± 140.4	789.7 ± 108.9		
Incongruent				
Control (s)	966.8 ± 144.9	920.4 ± 131.9	0.680	<0.001
Stepping ex (s)	1,003.6 ± 157.8	944.4 ± 123.2		
Stretching ex (s)	996.2 ± 143.9	933.4 ± 125.0		
Finger movement ex (s)	1,026.6 ± 166.0	956.9 ± 129.7		

ex: exercise.

that there would be a correct answer rate of 50% for all sessions. The upper row was presented for 350 ms before the word in the lower row was displayed, and each trial was displayed for 2 seconds. Participants answered using buttons labeled “yes” (i.e., correct) or “no” (i.e., incorrect), and were asked to answer as quickly as possible. The response time and error rate were measured in each trial. Before the start of the experiment, participants performed two sessions as practice (for a total of 120 trials). Moreover, participants were required to carry out 20 trials as practice on each experimental day.

To determine the effects of each exercise, we compared the reaction times in the neutral and incongruent trials with the Stroop interference (yielded by subtracting the reaction time of neutral trials from that of incongruent trials) before and after each session using a two-way repeated measures analysis of variance (ANOVA) (intervention × time). As an ancillary analysis, we analyzed the number of incorrect answers in the same manner. A decrease in the Stroop interference from before to after the session indicated improvement. Simple main effect analyses with Bonferroni corrections were performed for significant interactions. Post hoc multiple comparisons using Dunnett’s test, with the control condition as a reference, were also performed because the purpose of this study was to determine which exercises were effective in comparison to the control condition. All analyses were conducted using SPSS Statistics 21.0 for Windows (IBM Corp., Armonk, NY, USA). A $p<0.05$ was regarded as significant.

RESULTS

The means and SDs of the participants’ characteristics are shown in Table 1. The reaction time data for the Stroop task are presented in Table 2. There was no significant interaction between intervention and time for either the neutral ($p=0.865$) or incongruent trial reaction times ($p=0.680$). However, for the neutral trial reaction times, there was a significant main effect of time ($p<0.001$). For incongruent trial reaction times, there was also a significant main effect of time ($p<0.001$).

Table 3 shows the results of the Stroop interference in each session. The Intervention × Time interaction for the Stroop interference was significant ($p=0.036$). Bonferroni-corrected simple effects analysis revealed that the three exercise interventions improved Stroop interference (stepping exercise: $p=0.027$, stretching exercise: $p=0.032$, finger movement exercise: $p=0.004$), but the control condition did not ($p=0.364$). Multiple comparisons of the changes in Stroop interference using Dunnett’s test indicated significant differences between the control condition and the finger movement exercise ($p=0.021$). However, the control condition did not significantly differ from the stepping exercise ($p=0.072$) or the stretching exercise ($p=0.081$).

Table 3. Stroop interference in each session

	Stroop interference					
	Before session	After session	Interaction	Simple main effect of time	Changes in Stroop interference	Dunnett's test
			p value	p value		p value
Control (S)	173.9 ± 73.0	186.2 ± 97.8	0.036	0.364	−12.3 ± 73.7	ref.
Stepping ex (S)	212.1 ± 87.2	181.8 ± 79.4		0.027	30.3 ± 77.5	0.072
Stretching ex (S)	186.4 ± 102.2	157.1 ± 105.0		0.032	29.3 ± 65.5	0.081
Finger movement ex (S)	211.6 ± 99.8	171.8 ± 80.8		0.009	39.8 ± 57.0	0.021

ex: exercise.

The error rate for the neutral trials did not show a significant Intervention × Time interaction (p=0.153) or a main effect of time (p=0.188). The incongruent trials also did not show a significant interaction effect (p=0.723), but we did observe a significant main effect of time (p<0.001).

DISCUSSION

This study investigated the effects of three acute exercises in the sitting position on executive function in healthy older adults. All three sitting exercises were found to moderate Stroop interference, indicating that they improved executive function. Moreover, the change in Stroop interference was significantly greater after the finger movement exercise than after the control condition.

Some previous studies have reported that acute exercise improves executive function in older adults[10, 14, 15]. In agreement with these studies, we confirmed that acute exercises enhanced executive function as assessed with a Stroop task. Although these previous studies adopted aerobic exercises such as cycling[10, 14, 15], we selected sitting exercises to identify which would be most effective. Based on the results of the multiple comparisons using Dunnett's test, the finger movement exercise was especially effective for improving executive function. While our study cannot explain why an acute finger movement exercise improved executive function, some previous findings might be able to explain the results. In particular, complex hand movement appears to have a stronger association with cognitive function than does simpler movement, such as tapping[16]. Additionally, performing a complex task using the fingers has been shown to result in greater brain activation than does performing a simple task[17].

Aerobic exercise is known to improve executive function in a variety of populations, including younger[4], middle-aged[3], and older adults[10]. One previous study reported that chair exercises that included stepping and stretching were 1.5–3.0 metabolic equivalents in participants with diabetes (age: 66 ± 3 years)[18]. Although this study did not measure exercise intensity, the stepping and stretching exercises in a sitting position were more likely to use cardiopulmonary functions than were the finger exercise, and these sitting exercises showed significant improvements in Stroop interference. Our results suggested that, similar to regular aerobic exercise, mild aerobic exercises with sitting positions are effective in maintaining executive function.

The strengths of our study are that we examined 3 types of sitting exercises simultaneously and compared their effects on executive function in healthy older adults. However, there are some limitations in this study. First, although we could expect that the intensities of the 3 sitting exercises were low, we did not provide definite measures of exercise intensity. Future studies should address exercise intensity in sitting exercises because it is possible that different results would be obtained when moderate to high intensity exercise in the sitting position were conducted. Second, none of the participants in this study had dementia, depression, or physical frailty, which means that we cannot discount the possibility that our results might differ according to participants' physical or cognitive function. Therefore, participants with frailty or mild cognitive impairment might show different results. Finally, although we found immediate effects of acute sitting exercise on executive function, the long-term effects are unclear. Future studies should perform short- or long-term interventions to reveal the continuous effects.

Based on our results and those in past studies, we can conclude that acute exercises in a sitting position are beneficial for executive function, regardless of the exercise mode. However, the finger movement exercise was found to be especially beneficial. Because the finger exercise does not require any equipment and can be widely recommended, including to frail adults, our findings might be useful for older adults.

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Conflict of interest

None.

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