Acute effects of light-intensity, slow-tempo aerobic dance exercise on mood and executive function in older adults

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SUMMARY

Although a growing number of studies have reported the positive effects of acute aerobic exercise on mood and executive function in older adults, little is known about the effect of aerobic dance exercise (ADE) on executive function. In the present study, we aimed to compare the acute effects of light-intensity, slow-tempo ADE and light-intensity cycling exercise (CE) on mood and executive function in older adults. Twenty-one older adults performed each type of exercise for 10 minutes on separate days. The intensity of the CE was set at 60% of the ventilatory threshold. Before and after the exercise, mood (i.e., vitality, stability, pleasure, and arousal) and executive function were assessed by using the Two-Dimensional Mood Scale and the Stroop task, respectively. The heart rates and ratings of perceived exertion during exercise indicated that the intensities of both types of exercise were within the light-intensity range. Vitality and pleasure levels were increased following ADE, but no such changes were observed following CE. Although no differences in stability levels were observed following either type of exercise, we observed a significant interaction between time and exercise group, suggesting that there could be differences between the acute effects of ADE and CE. Unlike other psychological levels, the arousal level was increased to the same extent following both types of exercise. Stroop interference time, an indicator of executive function, was shortened to the same extent after both types of exercise. These findings suggest that ADE may represent an effective exercise modality for enhancing mood and executive function in older adults.

Key words: older adults, aerobic dance exercise, cycling exercise, Two-Dimensional Mood Scale, Stroop task.

Introduction

Research has thoroughly demonstrated that cognitive function decreases with age. Executive function—which refers to prefrontal cortex-related, higher-order cognitive processes including inhibitory control, working memory, and cognitive flexibility[22)—is particularly vulnerable to aging[2). Since executive function is associated with instrumental activities of daily living in older adults[3), attenuating age-related decreases in executive function may aid in maintaining the quality of life in older adults.

Previous studies have reported that regular physical exercise exerts beneficial effects on cognitive function, especially executive function[5,14). In addition to the well-known chronic effects of exercise, accumulating evidence suggests that an acute bout of exercise can exert instantaneous positive effects on executive function[4,8,11,12,21). Furthermore, some meta-analyses have reported an inverted U-shaped relationship

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between exercise intensity and acute effects on cognitive function: i.e., moderate-intensity exercise appears to exert greater effects on cognitive function than light- or high-intensity exercise[15,20].

While such evidence suggests that moderate-intensity exercise exerts the greatest effects on executive function, light-intensity exercise may be safer and more feasible for older adults. In our recent study, 10 minutes of light-intensity cycling exercise (CE) improved inhibitory control and memory function in young adults[1,26]. Moreover, these improvements were associated with changes in psychological arousal levels due to exercise, suggesting that light-intensity aerobic exercise can effectively improve executive function by enhancing mood.

Many previous studies have examined the effects of aerobic exercise modalities such as CE and treadmill running[15,17,21]. However, in the present study, we focused on aerobic dance exercise (ADE), a music-based group activity enjoyable for people of all ages. Previous studies have revealed that participation in an ADE class instantly improves mood by, for example, increasing vigor and decreasing anger and depression[16,18,19,24]. However, only one previous study has examined the acute effect of ADE on executive function[13], and none has examined this effect in relation to that of typical aerobic exercise modalities such as walking or cycling. Therefore, in the present study, we aimed to determine whether acute ADE enhances mood and executive function in older adults more strongly than acute CE.

Methods

A. Participants

Thirty-one older adults (ages: 65 to 74 years) were initially recruited through advertisements in local magazines. After additional screening measures, one participant was excluded due to use of beta-adrenergic blockers, one was excluded due to smoking status, and two were excluded due to possible depression (> 7 scores on the Geriatric Depression Scale). Another six participants were excluded from analysis due to technical difficulties during CE or ADE (n = 2) or for falling asleep during the cognitive tasks (n = 4). Thus, we analyzed data from a total of 21 participants. Their baseline characteristics are shown in Table 1.

The inclusion criteria were as follows: (a) right-handedness, (b) normal or corrected-to-normal vision based on verbal reports, (c) no neuropsychiatric conditions, neurological diseases, or infarcts (e.g., multiple sclerosis, Alzheimer's disease, or stroke), and (d) no physical disabilities that could have been exacerbated by exercise.

Written informed consent was obtained from all participants prior to the experiment. This study was approved by the Ethics Committee of Meiji Yasuda Life Foundation of Health and Welfare (Approval number: 28003).

Table 1. Participant characteristics.

	Male (n = 10)		Female (n = 11)	
	Mean	SD	Mean	SD
Age (y)	70	2.4	69	3
Height (cm)	166	5.8	155	5.8
Weight (kg)	63	8.1	52	5.7
Education (y)	14	2.1	13	1.6
GDS (score)	0.9	0.99	1.5	1.2
VT (ml/kg/min)	13	3	13	2.6
Workload at 60% VT (W)	36	10	27	12

GDS; Geriatric Depression Scale, SD; standard deviation, VT; ventilatory threshold.

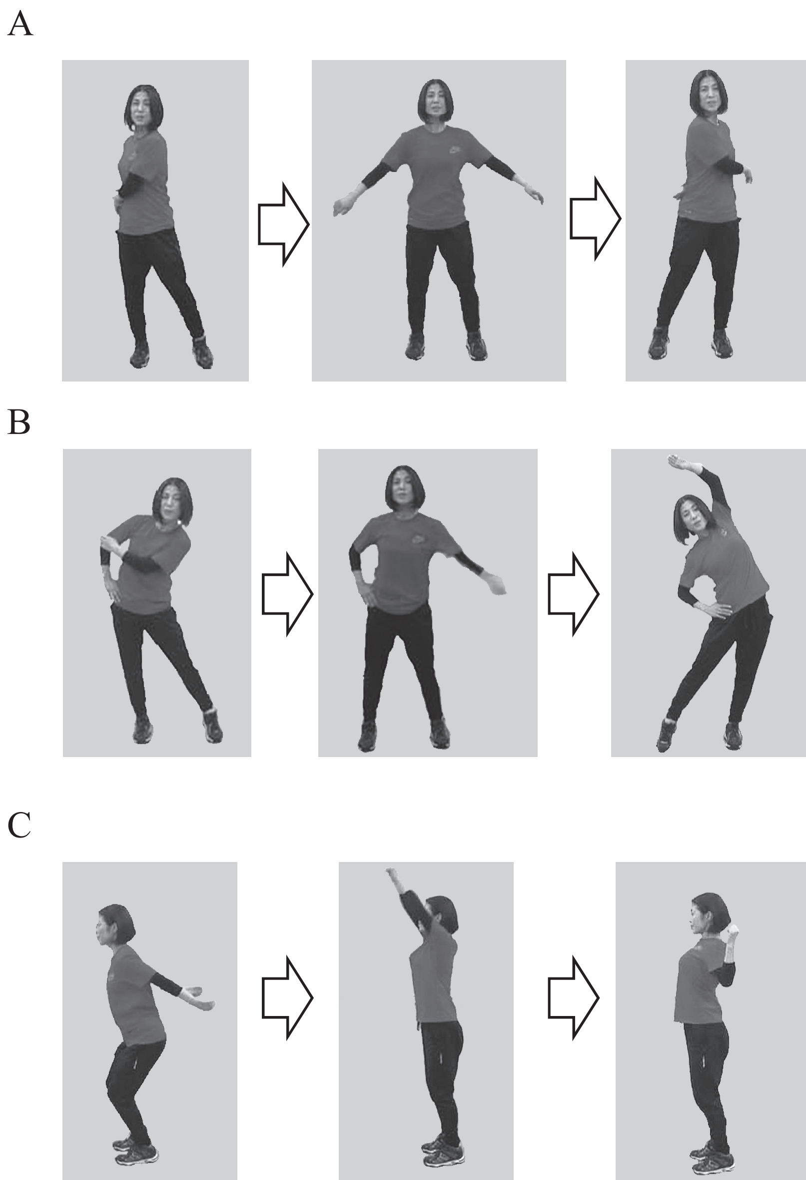

Figure 1. Illustration of the three basic components of the slow aerobic dance exercise routine.
(A) twisting the upper body, (B) swinging the arms from side to side while bending the body to each side, and (C) swinging the arms back and forth while pulling the elbows back.

B. Experimental procedure

Participants were asked to visit the laboratory used for this study three times on separate days. At the first visit, participants performed a graded exercise test on an upright cycle ergometer (Corival cpet, Lode, Netherlands) to assess their ventilatory threshold (VT). To familiarize themselves with the Stroop task, which was later used to assess executive function, the participants performed it twice. They also practiced the Slow Aerobic Dance once.

At the second and third visits, participants performed either 10 minutes of CE using an upright cycle ergometer or light-intensity, slow-tempo ADE. The participants performed the Stroop task before and 5 minutes after the CE or ADE. Mood was assessed using the Two-Dimensional Mood Scale (TDMS)[25] before the pre-exercise Stroop task session and immediately after the exercise. Heart rate (HR) was measured during both exercise sessions, and ratings of perceived exertion (RPE) were obtained at the end of each session. The order of exercise testing was counter-balanced across participants.

C. Graded exercise test

The participants exercised at 5 W for 3 min to warm up. After the warm-up, the exercise load was gradually increased by 1 W every 6 s. HR and RPE data were recorded every 1 and 2 min, respectively. The exercise test was stopped when the participant reached an RPE of 17 (very hard). The pedaling rate was kept at 55 rpm. Ventilation parameters including oxygen intake and carbon dioxide output were measured breath-by-breath using a respiratory gas analyzer (Aeromonitor AE300S, Minato Medical Science, Japan). VT was determined via the V-slope method using the same respiratory gas analyzer, as described by Itoh et al.[10]

D. Exercise intervention

The ADE intervention used in the present study ("Slow Aerobic Dance Exercise") consisted mainly of dynamic upper-body stretching (e.g., trunk rotation) performed to slow-tempo music. In our preliminary study, we observed that complex movements were difficult for older adults to perform, because most of them had no experience with ADE[9]. Therefore, in the present study, participants were required to perform three simple movements repeatedly: (a) twisting the upper body, (b) swinging the arms from side to side while bending the body to each side, and (c) swinging the arms back and forth while pulling the elbows back (Figure 1). They routinely executed each movement for approximately 3 min and 20 s while watching a tutorial video. Original music with a tempo of 90 bpm was used for the intervention[28].

In the CE condition, the participants performed CE at an intensity of 60% of the VT on an upright cycle ergometer (Corival cpet). Pedaling rates were displayed to the participants on a screen, and the participants were asked to maintain their pedaling rates at 55-60 rpm. During CE, participants listened to the same music used in the ADE condition.

E. Mood

The TDMS consists of eight mood-expressing words related to both pleasure and arousal states (i.e., energetic, lively, lethargic, listless, relaxed, calm, irritated, and nervous). Participants reported how they were feeling at the time by responding to each item using a six-point rating scale ranging from 0 (not at all) to 5 (extremely). Vitality, stability, pleasure, and arousal levels were determined by calculating scores for each item.

F. Executive function

Executive function was assessed using a computer-based color-word matching Stroop task[30]. Two rows of letters were presented on a computer screen. The participants were required to determine whether the color of the letters in the top row corresponded to the color name printed in the bottom row and to press the appropriate buttons with their forefingers to provide "yes" or "no" responses as quickly and accurately as possible. The task consisted of 30 neutral and 30 incongruent trials presented in a random order. For neutral trials, the letter sequence "XXXX" was displayed in the top row in red, green, blue, or yellow, and the word "RED", "GREEN", "BLUE", or "YELLOW" was displayed in the bottom row in black. For incongruent trials, the top row contained the word "RED", "GREEN", "BLUE", or "YELLOW" displayed in an incongruent color (e.g., "RED" in green). All word stimuli were displayed in Japanese. To achieve sequential visual attention, the top row appeared 350 ms earlier than the bottom row. The protocol contained equal numbers of trials in which "yes" was the correct answer and trials in which "no" was the correct answer. The trials were separated by inter-stimulus intervals during which a fixation cross was presented for 9-12 s to avoid prediction of the timing of the subsequent trial. Each stimulus remained on the screen for 3 s. The accuracy rate and correct reaction time were measured. Stroop interference time (i.e., the difference in correct reaction time between incongruent and neutral trials) was used as an index of executive function, as in previous studies[1,8,23,29].

G. Statistical analyses

TDMS scores and Stroop interference times were analyzed using two-way, repeated-measures analysis of variance (ANOVA) with condition (CE/ADE) and time (pre/post) as factors. When significant main effects or interactions were observed, we performed *post hoc* analyses with Bonferroni corrections. All statistical analyses were conducted using R version 3.5.1 (R Core Team 2018). Statistical significance was defined as $P < 0.05$ for all analyses.

Results

A. Exercise intensity

The average HR values during CE and ADE were 90.1 ± 12.0 bpm and 88.5 ± 13.1 bpm, respectively. The RPE values after CE and ADE were 11.3 ± 1.2 points and 11.0 ± 1.3 points, respectively. There were no significant differences in HR or RPE between the two exercise conditions.

B. Mood

Figure 2 shows the effects of exercise on TDMS scores. We observed significant interaction effects between time and condition for vitality ($F(1, 20) = 4.69$, $P = 0.043$), stability ($F(1, 20) = 7.32$, $P = 0.014$), and pleasure ($F(1, 20) = 9.74$, $P = 0.005$) levels. *Post hoc* analyses revealed that ADE significantly increased vitality ($t(20) = 3.69$, $P < 0.001$) and pleasure ($t(20) = 2.89$, $P = 0.007$) levels relative to pre-exercise levels. However, no such changes were observed following CE. Thus, vitality and pleasure levels were significantly higher following the ADE condition than following the CE condition (vitality: $t(20) = 2.24$, $P = 0.030$; pleasure: $t(20) = 2.30$, $P = 0.027$). We observed a significant main effect of time ($F(1, 20) = 8.44$, $P = 0.009$) on arousal levels. However, there were no

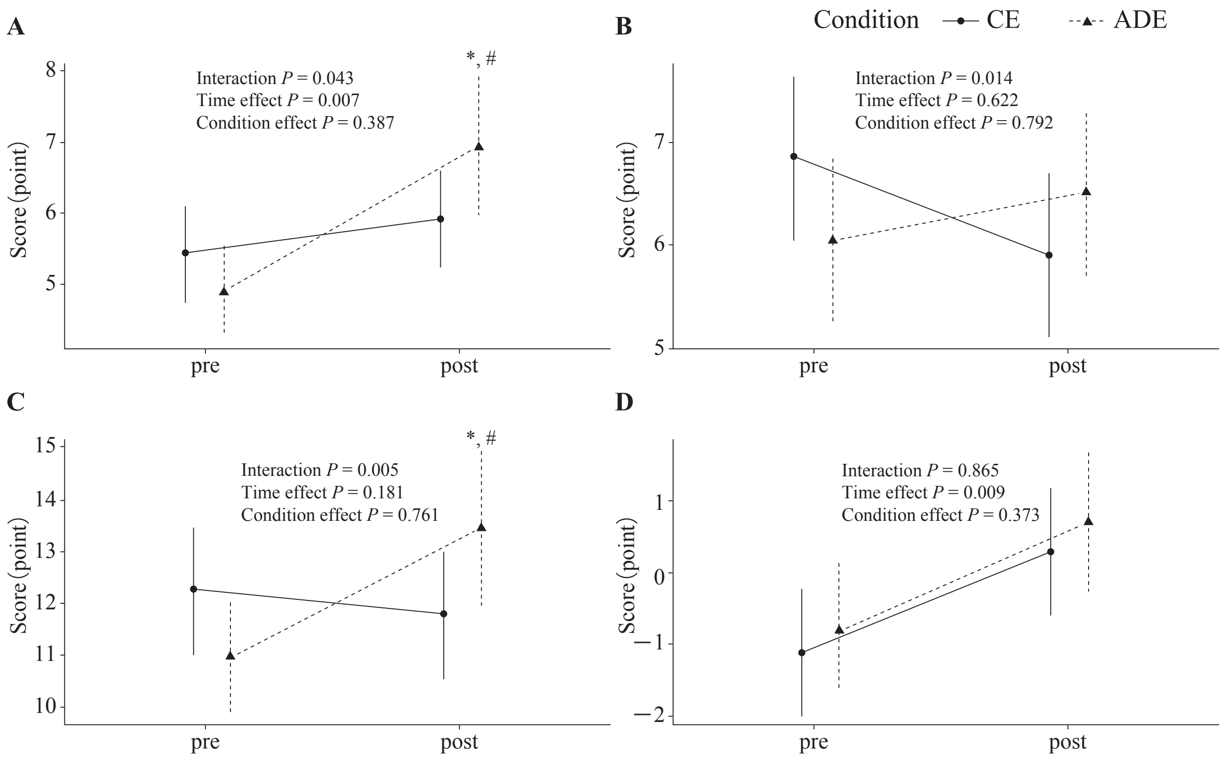

Figure 2. Changes in TDMS scores for vitality levels (A), stability levels (B), pleasure levels (C), and arousal levels (D).
Error bars indicate standard errors. The P values shown are the results of two-way ANOVA with time and condition as factors. ADE; aerobic dance exercise, ANOVA; analysis of variance, CE; cycling exercise, TDMS; Two-Dimensional Mood Scale. * $P < 0.01$ vs. pre, #: $P < 0.05$ vs. CE.

Table 2. Behavioral data for the Stroop task.

	CE				ADE			
	Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CR (%)								
Neutral	99.4	1.7	98.7	2.0	98.6	2.0	99.7	1.0
Incongruent	95.6	4.9	98.3	2.3	98.3	2.0	98.9	1.9
RT (ms)								
Neutral	816.6	138.9	781.9	135.9	803.0	152.7	774.2	150.1
Incongruent	1037.9	226.1	978.3	206.0	1039.9	233.9	973.0	205.5
SIT (ms)	221.4	116.4	196.3	92.6	236.9	113.2	198.8	97.3

ADE; aerobic dance exercise, CE; cycling exercise, CR; correct rate, RT; reaction time, SD; standard deviation, SIT; Stroop interference time.

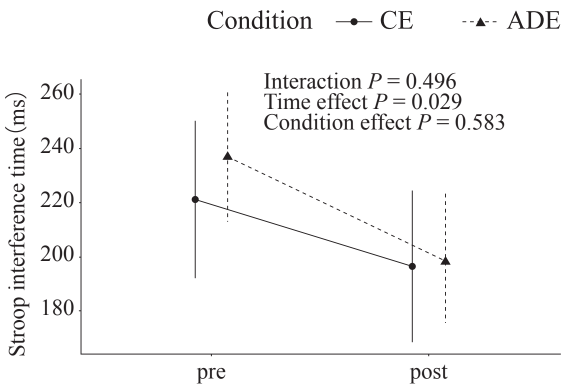

Figure 3. Changes in Stroop interference time.
Error bars indicate standard errors. The P values shown are the results of two-way ANOVA with time and condition as factors. ADE; aerobic dance exercise, ANOVA; analysis of variance, CE; cycling exercise.

significant interactions or main effects of condition. *Post hoc* analysis revealed that post-exercise arousal levels were higher than pre-exercise levels ($t(20) = 3.0$, $P < 0.007$).

C. Executive function

Table 2 shows the correct reaction times and accuracy rates for the neutral and incongruent trials in each exercise condition. Stroop interference time was calculated to examine the acute effect of exercise on executive function. Two-way ANOVA revealed a significant main effect of time for Stroop interference time ($F(1, 20) = 5.56$, $P = 0.029$). *Post hoc* analysis revealed that post-exercise Stroop interference times were significantly shorter than pre-exercise Stroop interference times ($t(20) = 2.36$, $P = 0.028$) (Figure 3). However, there were no significant interactions or main effects of condition.

Discussion

In the present study, we aimed to clarify the differences in the acute effects of light-intensity ADE and light-intensity CE on mood and executive function in older adults. Based on changes in HR and RPE, we confirmed that each condition consisted of comparable, very light- to light-intensity exercise, in accordance with the American College of Sports Medicine guidelines[7]. However, ADE significantly increased psychological vitality and pleasure levels, whereas CE did not. We observed no significant differences in arousal levels following the two exercise conditions. Stroop task performances showed similar improvements in executive function in both conditions. Indeed, our findings indicated that ADE exerted greater effects on mood than CE did and that both had comparable effects on executive function. Taken together, these findings highlight the potential of ADE as an effective exercise modality for enhancing mood and executive function in older adults.

The observed increases in vitality and pleasure levels following ADE are consistent with the findings of previous studies that have reported that ADE enhances vigor (equivalent to vitality) and decreases tension and fatigue as assessed using the Profile of Mood States in young and older adults[16,19,24]. However, participants in these previous studies performed ADE for more than 30 minutes in a group setting, and the authors did not compare the effects of ADE and other aerobic exercise modalities. In the present study, we demonstrated that 10 minutes of light-intensity ADE can enhance mood in older adults and that greater effects can be achieved by ADE than by CE at comparable intensities and durations. However, we observed no significant differences between the two exercise conditions in their effects on arousal levels. A previous study reported that exercise-induced arousal levels were associated with exercise intensity[6]. Therefore, exercise intensity may exert a greater impact on arousal levels than exercise modality.

Contrary to our expectations, we observed no significant differences in the effects of ADE and CE on Stroop interference time, a measure of executive function. The improvements in Stroop task performance after acute aerobic exercises found in this study are consistent with those of our previous studies that demonstrated that 10 minutes of light- or moderate-intensity CE reduces Stroop interference time in both young and older adults[1,8,29]. Arousal theory posits that appropriate levels of exercise-induced physiological arousal exert beneficial effects on cognitive function[27]. Thus, the lack of a difference in exercise-induced psychological arousal levels between the two conditions may explain the similarities in the Stroop task performance between them.

The present study has some notable limitations. First, because we did not include a resting control condition, decreases in reaction time might have been influenced by habituation. However, previous studies have reported no significant differences in Stroop task performance prior to and following the resting condition[1,8,29], suggesting that the decreases in Stroop interference time observed in this study reflect the acute effects of exercise. Second, participants performed ADE while watching a tutorial video in which the instructor also performed the movements, whereas no videos were utilized in the CE condition. Thus, visual stimulation might have exerted effects on mood and executive function in the ADE condition.

In summary, our experiments with older adults showed that a single session of light-intensity, slow-tempo ADE exerts positive effects on mood that are greater than those of light-intensity CE and positive effects on executive function that are similar to those of light-intensity CE. Long-term interventional studies are required to more fully elucidate the effect of ADE on executive function in this population.

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