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The Effect of a Single Session of Balance and Coordination Training on Cognitive Function in Older Adults

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Abstract: The cognitive decline that is characteristic of older adults has led researchers to seek methods for improving cognitive functions in this population in the short and long term. One broadly studied aspect relates to physical activity interventions and their impact on cognitive functions in older adults. This study examines the effect of a single session of balance and coordination exercises on the cognitive functions in older adults compared to that of a single session of aerobic exercises or a single control session of reading. The study included 30 physically active participants (23 females), with an average age of 73 (±5) years. The participants completed computerized cognitive tests to assess attention and executive functions in five separate sessions: two without interventions and three with interventions (aerobic exercise; balance and coordination and reading while sitting). The interval between each session was at least two weeks. The order of interventions between participants was random. While no differences were seen between the three types of intervention in executive function scores, our findings indicate that a single session of aerobic exercises and a single session of balance and coordination exercises led to higher scores on the attention test than in the control condition. This suggests that older adults may benefit from a single 30-min session of aerobic exercises or balance and coordination exercises prior to performing attention-demanding tasks.

Keywords: balance and coordination; attention; older adults

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1. Introduction

The population of people aged 60 and older is steadily on the rise and is expected to account for 22% of the world's population by 2050. As such, aging-related health problems and their prevention or treatment have become critical global issues [1]. Such health problems include cognitive declines, which are characteristic of aging and are well documented in the literature, especially in relation to older adults' lower performance in various cognitive measures and functions compared to younger adults [2].

The normal aging process is accompanied by the restructuring of functional brain networks, which are related to changes in cognitive performance [3], that may be expressed through the impairment of speed processing, executive functions, attention, or memory [4,5]. Despite a lack of consensus as to the causes of these changes, increased efforts to establish the efficacy of lifestyle strategies can be seen for promoting cognitive health in older adults [6,7].

The beneficial effect of physical activity on general health among older adults is well recognized and thus recommended by the World Health Organization [8]. The most known aspect of this benefit is the positive effect of fitness training programs for older adults and exercise for weight loss [9]. However, over the past few decades, studies have provided compelling evidence as to the benefits of chronic or even a single session of physical activity on the cognitive functioning of older adults [10,11]. Indeed, exercise has been found to improve several cognitive functions in older adults, by encouraging the release

of the brain-derived neurotrophic factor (BDNF) [12] and the insulin-like growth factor-1 (IGF-1) [13,14], which in turn, could accelerate specific structural changes in the brain. Such changes may improve executive functions, attention, processing speed, and memory [14]. Moderate intensity of aerobic activity, for example, has been shown to improve multiple cognitive domains, as well as the performance of tasks that involve attention and memory. Such improvements are associated with thickness in several prefrontal cortex areas [10]. At the same time, resistance exercises (i.e., lifting free weights or using bodybuilding machines, thereby strengthening muscles) both chronic (i.e., several times per week for several months) and acute (i.e., one session of 25–30 min) may improve memory, selective attention, and executive functions among older adults in general, and in older adults with minimal cognitive impairment in particular [13–15].

The positive effect of acute exercise on cognition may depend on the intensity of the exercise. Moderate-intensity exercise, for example, irritates the afferent interoceptive system and the proprioceptive somatosensory system, leading to the increased tonic release of catecholamines. This process results in a phasic release of dopamine and norepinephrine, and the facilitation of cognitive tasks. However, during severe exercise, the interoceptive system initiates the further tonic release of catecholamines, which attenuates phasic release and might lead to the undesirable inhibition of cognition [16].

While aerobic and resistance modalities are well-studied exercise modalities, the literature lacks studies on the effect of balance and coordination (bal&coor) exercises on cognitive functions among the elderly [17–19]. As aerobic and strength exercises require higher mobility, people with limited locomotive ability might have difficulty experiencing the beneficial effect of such exercise on their cognitive functioning. Additionally, studies on motor exercises demonstrate that movement task complexity and the related involvement of executive function strongly impact neuroplasticity and cognitive function [17]. As such, exercises with reduced locomotion requirements that are based on cognitive involvement, such as bal&coor exercises, may provide cognitive benefits for elderly people with restricted mobility. Indeed, Kwok et al. [18] studied the effect of eight weeks of a coordination exercise program, that was based on a simplified version of Tai Chi, which is considered a mind–body exercise that is characterized by slow motion and emphasizes conscious control of body movements, on the cognitive performance of older adults. These researchers found significant improvements in the participants' global cognition following the eight-week program. They suggested that this improvement might be the outcome of mind-body characteristics that are typical of the coordination exercises that were included in the program.

As mentioned earlier, a positive effect of aerobic and resistance exercises on cognitive functioning among the elderly has been seen following both long-term programs and single session ones. However, the effect of bal&coor exercises on cognition among older adults has been studied to a lesser extent, particularly the effect of a single session of such a modality. Accordingly, the purpose of the current study was to compare the effectiveness of a single session of three different conditions: (1) aerobic exercises; (2) bal&coor exercises and (3) journal-reading (control condition) on two domains of cognitive function: (1) attention and (2) executive functions among older adults. The hypothesis was that a single session of aerobic exercises or bal&coor exercises would show significantly higher cognitive functioning than a single session of journal reading.

2. Materials and Methods

2.1. Participants

A simulation-based power analysis was used to find a sample size that would reach 80% statistical power. Using G-POWER 3.1 program, the following data were entered: effect size = 0.25; power $(1 - \beta) = 0.8$; $\alpha = 0.05$; r = 0.5. Accordingly, a sample size of 26 participants was required. However, 30 participants were recruited to the study to come over cases of dropping out. Accordingly, the study included 30 physically active older adults (23 females; aged = 73 $\pm$ 5 years) who were recruited from the community

through ads that were distributed at sports clubs. Inclusion criteria were non-smoking, no prescribed medications that might alter cognitive function, no neurological or psychiatric disease, and no long-term hospitalization or head injury in the previous three months. Additionally, participants had to be able to perform 'spinning'—aerobic exercise—for at least 30 min and had to be involved in habitual physical activity at least twice a week for at least six months before the beginning of the study. Exclusion criteria included a score of <24 on the Mini-Mental State Examination (MMSE) [20] and an inability to use a computer (due to difficulties in vision or motor function). The participants' descriptive variables are presented in Table 1.

Table 1. Descriptive variables of the participants (mean ± SD).

	Mean ± SD All, N = 30	**Mean ± SD Female, N = 23**	**Mean ± SD Male, N = 7**	**t (df)**	***p***
Age (years)	73.00 ± 5.43	72.57 ± 5.65	74.43 ± 4.72	0.79 (28)	0.44
Education (year)	15.53 ± 3.42	15.00 ± 3.55	17.29 ± 2.36	1.59 (28)	0.12
MMSE (score out of 30)	29.30 ± 0.65	29.35 ± 0.65	29.14 ± 0.69	0.72 (28)	0.48

All participants provided written informed consent for the study, which was approved by the Ethics Committee of the Hillel Yaffe Medical Center (Hadera, Israel, no. 0136-17-HYMC).

2.2. Cognitive Assessments: Attention and Executive Functions

Participants performed three tests: The go-NoGo test—a timed continuous performance test where responses are made to colored stimuli that are any color but red; the Stroop test—a timed test of response inhibition. In the first phase (no interference [color]), participants choose the letter color of a general word. In the second phase (no interference [meaning]), participants choose the color named by a word presented in letters colored white. In the third phase (interference), the task is to choose the letter color of a word that names a different color; The Catch Game—a test of motor planning that involves hand-eye coordination and rapid responses that requires participants to catch a falling object on the computer screen by moving a paddle horizontally so that it can be positioned directly in the path of the falling object.

These tests are part of the NeuroTrax (NeuroTrax Corp., Israel) computerized battery of traditional neuropsychological tests [21]. Outcome parameters include four scores: accuracy (number of correct responses); reaction time (RT); standard deviation (SD) of RT and a performance index (computed as [accuracy/RT] × 100) that assesses performance in terms of both accuracy and response time. The scores of the outcome parameters are averaged to produce two summary scores, for two different cognitive domains:

Attention: Mean RTs for the Go-NoGo test and the no-interference (meaning) phase of the Stroop test, and mean SD of RT for the Go-NoGo test. These variables are related to attention as fast responses are an indication that the participant is properly attending to the stimuli [21].

Executive function: Performance indices for the Go-NoGo test and the Stroop test, and mean accuracy for the Catch Game. This performance index reflects executive function—a broad construct related to the participant's overall ability to perform the task successfully [21].

2.3. Procedure

Each participant participated in five sessions, which took place at least two weeks apart. Participants were asked not to conduct any structured exercise on the day of the testing session and not to consume caffeine for two hours before the session. The sessions were performed as follows:

Pre 1—first baseline testing. On the first laboratory visit, participants signed an informed consent form and health declaration, then filled out a self-demographic questionnaire, followed by the MMSE. After a 10-min break, each participant performed the NeuroTrax cognitive test (first time), which lasted 15 min.

Pre 2—second baseline testing. On the second laboratory visit, participants performed the NeuroTrax cognitive test for the second time (in order to overcome the learning effect).

Visits 3, 4, and 5—experimental sessions. The order of the different experimental sessions (i.e., bal&coor, aerobic, and control) was randomized and counterbalanced across participants to minimize possible order or learning effects. During these sessions, participants performed the cognitive test immediately after the experimental condition, which consisted of 30 min of either aerobic exercise or bal&coor, or reading a journal in a seated position (the control condition).

All sessions were performed at the same hour of the day, with no eating, drinking coffee/tea, or performing physical activity at least two hours before the session.

The aerobic exercise session was performed on a spinning bike. It began with a warm-up period of 5 min of 60–80 RPM, gradually reaching the target heart rate—70% of maximal heart rate (males: 208—70% of their age; females: 209—80% of their age) [22]. In the main part of this session, the participant kept their target heart rate while performing different drills on the spinning bike (i.e., asymmetric exercise by focusing on one leg for several cycles, changes in cycling rate, changes in resistance, based upon changes in heart rate) for 20 min. At the end of this session, participants walked slowly to the room where the post-cognitive test would take place, which was considered as a 5-min cool-down. During this session, participants wore heart rate monitors.

The bal&coor session began with a 5-min warm-up that included light movements of different parts and joints of the body, walking in place, and static and dynamic stretching. In the central part of this session, participants performed weight transfer exercises on different surfaces (stable/unstable), standing on a single leg, and controlling their balance with stabilizer muscles while performing coordinative movements such as basketball dribbling, bouncing, or throwing the ball toward the trainer. Additionally, exercises that were based on height changes in the center of mass were included, as well as changes in the base of support. At the end of this session, participants walked slowly to the room where the post-cognitive test would take place, which was considered a 5-min cool-down.

During the control session participants read journal articles about healthy lifestyles, in a seated position, for 30 min.

2.4. Statistical Analysis

Two pair *t*-tests were conducted in order to examine possible statistically significant differences between the two pre-intervention measurements (Pre1 and Pre2), one for each category—Attention (ATT) and Executive Function (EF) of the cognitive test. A repeated measures ANOVA model, separately for each category (ATT and EF), was employed in order to analyze possible statistically significant differences between the measurements: pre-intervention, aerobic exercise, bal&coor exercise, and reading a journal (control condition).

Following the general analysis, we performed additional analysis to find individual behavioral patterns. First, for each category (ATT and EF), we divided the participants into three groups: (1) those who achieved the highest scores (relative to themselves) after aerobic exercise, (2) those who achieved the highest scores after bal&coor exercise (3) those how achieved the highest scores after reading a journal (control condition). Then, repeated measures ANOVA models were conducted for each group separately (for both categories: ATT and EF). For additional analysis, we explored the association of demographic variables and scores in each category (ATT and EF) in each group. Repeated measures ANOVA models and crosstabs were used to analyze the parametrical demographics and non-parametric variables, respectively.

3. Results

3.1. Pre-Intervention Tests

Pair *t*-tests revealed significant improvement (that was considered a learning effect) in the EF category of the cognitive test: Pre1—99.39 ± 13.26, Pre2—104.50 ± 13.46, (t(29) = 2.59, $p < 0.05$) and improvement (however, not significant) in the ATT category: Pre1—98.63 ± 12.03, Pre2—102.54 ± 11.88, (t(29) = 1.75, $p = 0.09$). Therefore, scores from the Pre2 session were used as a baseline in the coming analysis.

3.1.1. Attention

Mean scores of the ATT category of the cognitive function test were significantly dependent on the condition of exercise ($F(3,87) = 2.73$, $p < 0.05$, $\eta^2_p = 0.09$) (Figure 1). Pairwise comparisons analysis revealed that the performance after the aerobic exercise (106.5 ± 7.67) and after the bal&coor exercise (106.34 ± 7.61) were significantly ($p < 0.05$) better than the performance in the baseline condition (102.54 ± 11.88). However, mean scores after the control condition were not significantly different from performance in all other conditions (baseline, aerobic, and bal&coor) (Figure 1).

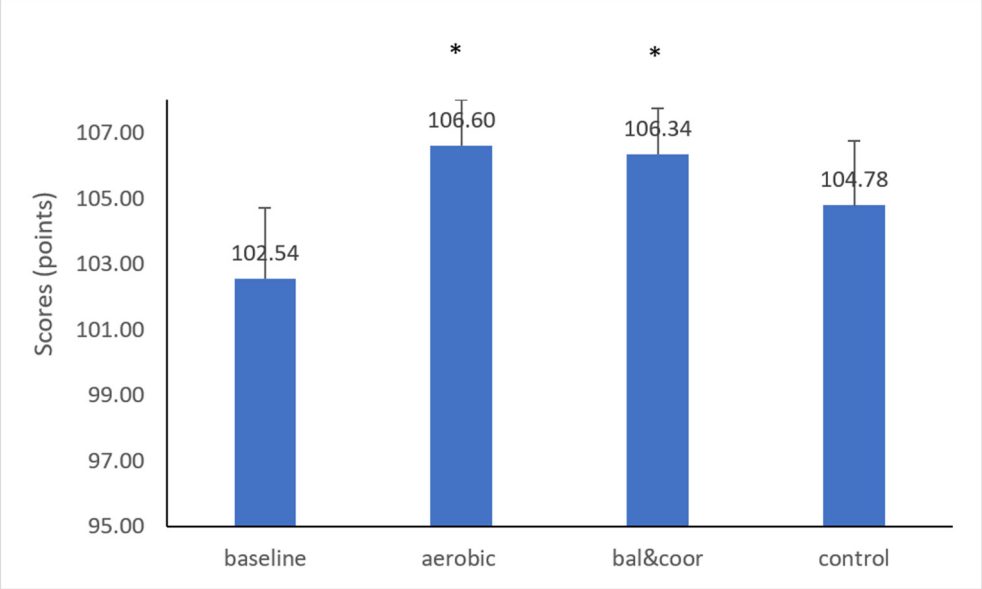


Figure 1. Means and SEs for the attention scores at the different sessions. * Significantly higher than baseline ($p < 0.05$).

3.1.2. Executive Functions

Mean scores of the EF category in the cognitive function test were found to be significantly dependent on the condition of exercise ($F(3,87) = 3.86$, $p < 0.05$, $\eta^2_p = 0.12$) (Figure 2). Pairwise comparisons analysis revealed that the performance following all three intervention conditions (including the control condition) (Table 2) was significantly ($p < 0.05$) better than the baseline performance (Figure 2).

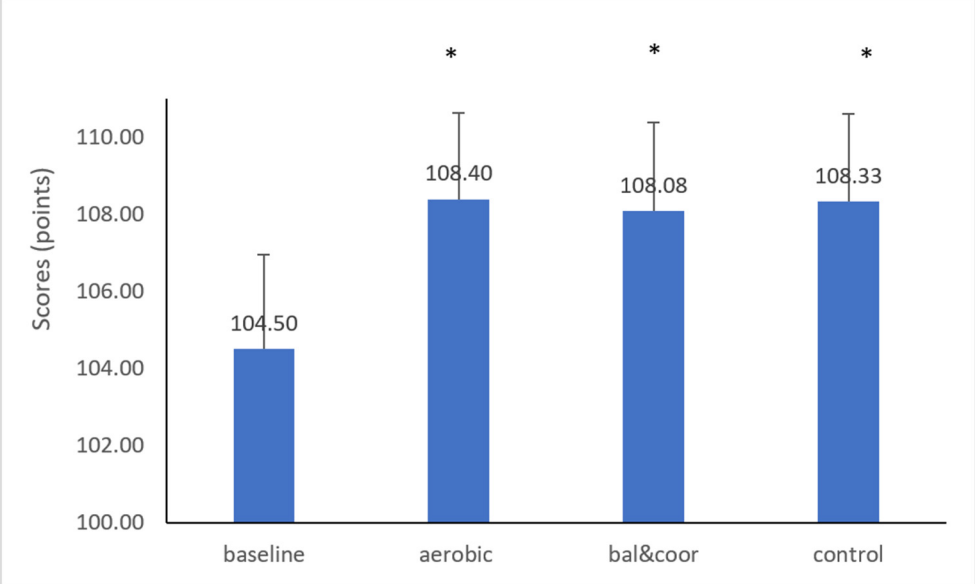


Figure 2. Means and SEs for the executive function scores at the different sessions. * Significantly higher than baseline ($p < 0.05$).

Table 2. Score of EF and ATT before and after 3 intervention conditions (mean ± SD) and 95% Confidence Interval (CI).

	Condition	Mean ± SD	95% CI	*F* (df)	*p*	η^2_p
Attention	Baseline	102.54 ± 11.88	98.11–106.98	2.73 (3,87)	<0.05	0.09
	Aerobic	**106.60 ± 7.67**	103.74–109.47			
	Bal&coor	**106.34 ± 7.61**	103.50–109.18			
	Control	104.78 ± 10.74	100.77–108.79			
Executive Function	Baseline	104.50 ± 13.46	99.48–109.53	3.86 (3,87)	<0.05	0.18
	Aerobic	**108.40 ± 12.28**	**103.81–112.98**			
	Bal&coor	**108.08 ± 12.69**	**103.34–112.82**			
	Control	**108.33 ± 12.42**	**103.70–112.97**			

Note: Scores in **bold** are statistically significant from baseline.

3.1.3. Personal Behaviors—Attention

Exploring the personal achievements in ATT revealed three behavior groups that are based on the highest score following different condions: 1. Following aerobic exercise (N = 11); 2. Following bal&coor exercise (N = 12); 3. Following reading a journal (control condition) (N = 7) (see Figure 3).

For group 1, those who scored the highest scores after the aerobic exercise, mean scores after the aerobic exercise (109.90 ± 5.69) were significantly higher than the scores following other conditions [105.57 ± 8.44 follow the bal&coor exercise; 105.98 ± 6.89fol-low control condition; 105.98 ± 6.89 in baseline, F(3.30) = 4.24, $p < 0.05$, $\eta^2_p = 0.30$)].

For group 2, those who scored the highest following the bal&coor exercise, mean scores after the bal&coor exercise (108.00 ± 8.33) were significantly better than the scores after the two other conditions (104.75 ± 9.26 following the aerobic exercise and 100.91 ± 14.38 following control condition, (F(3.33) = 4.16, $p < 0.05$, $\eta^2_p = 0.28$) but not than baseline (105.37 ± 7.00).

For group 3, those who scored the highest scores after the control condition, mean scores after the control condition (109.52 ± 6.36) were significantly higher than the scores after the other conditions [104.59 ± 6.46 follow the aerobic exercise; 104.70 ± 4.89 after the bal&coor exercise; 102.39 ± 12.03 in baseline, (F(3.18) = 3.76, $p < 0.05$, $\eta^{2p} = 0.39$)].

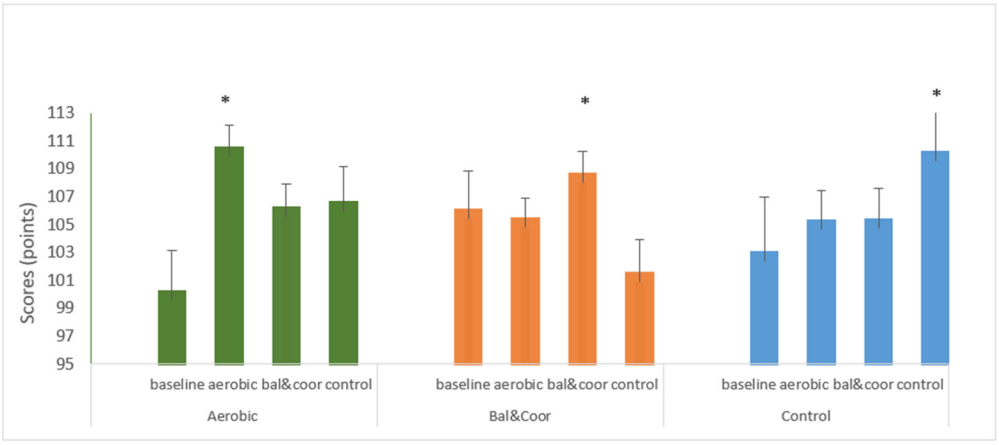


Figure 3. Means and SEs for the attention scores at the different sessions, at different groups of personal behavioral patterns. * Significantly higher than other conditions ($p < 0.05$).

3.1.4. Personal Behaviors—Executive Functions

Exploring the personal achievements in EF revealed three behavior groups that are based on the highest score following different condions: 1. Following aerobic exercise (N = 10) 2. Following bal&coor exercise (N = 13) 3. Following reading a journal (control condition) (N = 7) (see Figure 4).

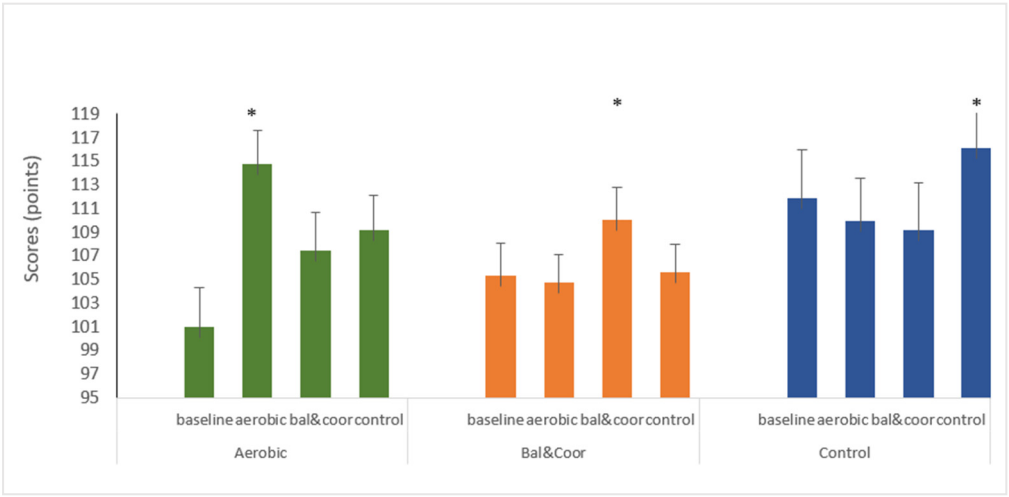


Figure 4. Means and SEs for the executive functions scores at the different sessions, at different groups of personal behavioral patterns. * Significantly higher than other conditions ($p < 0.05$).

For group 1, those who scored the highest scores after the aerobic exercise, mean scores after the aerobic exercise (113.86 ± 13.72) were significantly better than the scores after the other conditions [106.54 ± 17.31 following the bal&coor exercise; 108.29 ± 14.48 following control condition; 100.09 ± 15.41 in baseline, ($F(3,27) = 10.28$, $p < 0.001$, $\eta^2_p = 0.53$)].

For group 2, those who scored the highest following the bal&coor exercise, mean scores after the bal&coor exercise (109.17 ± 8.21) were significantly better than the scores after the other conditions [103.84 ± 9.10 following the aerobic exercise, 104.65 ± 8.34 following control condition and 104.40 ± 10.22 at baseline, ($F(3,36) = 9.41$, $p < 0.01$, $\eta^2_p = 0.44$)].

For group 3, those who scored the highest scores after the control condition, mean scores after the control condition (115.23 ± 14.39) were significantly better than the scores after the two other conditions [109.05 ± 13.65 following the aerobic exercise and 108.26 ± 13.70 following the bal&coor exercise, $p < 0.01$ but not compared to baseline 110.98 ± 15.13, $p = 0.063$, ($F(3,18) = 6.62$, $p < 0.01$, $\eta^2_p = 0.53$)].

In order to find demographical explanations for the different personal behaviors, we analyzed the demographic variables (employment status, using a computer, years of education) that did not reveal differences between the groups in the ATT category. However, a significant difference was found in years of education between the personal behavior groups in the EF category ($F(2,27) = 5.63$, $p < 0.01$). Participants who scored the highest scores after the control condition and those who scored the highest scores after the bal&coor condition had significantly higher years of education (18.00 + 2.94 and 16.00 + 2.74 years, respectively) than participants who score the highest scores after the aerobic condition (13.2 + 3.29 years). No significant differences were found in years of education between bal&coor and control groups.

Comparing the three groups in the ATT category and the three groups in the EF category, we found that seven participants score the highest scores in the ATT and EF categories after aerobic exercise (63.63% out of 11); Eight participants score the highest scores in ATT and EF categories following bal&coor exercise (61.53% out of 13); and one participant score the highest score both in ATT and EF categories following control condition (13.33% out of 7).

4. Discussion

The aim of this study was to examine the effect of a single session of aerobic exercises or bal&coor exercises on higher cognitive functioning in comparison to a single session of journal reading. The main findings show a positive effect of such exercise on attention in older adults, compared to a sitting and reading control task. Attention was assessed based on the ability to inhibit a response to read a word and activate a weaker response to name the color of the ink in which the word appeared (RT for the Go-NoGo test and RT at the no-interference phase of the Stroop test). The results of the positive effect of aerobic exercise on attention are in line with previous studies. Chronic aerobic exercise was associated with potent structural and functional neuroplastic changes and improved cognitive functions [23]. Acute aerobic exercise is associated with enhancing several neurotransmitter systems afferent to the hippocampus, which are essential to hippocampal function [24] and have been found to be related to improved cognitive functions, especially prefrontal cortex-dependent cognition, such as working memory and cognitive flexibility [23].

While the positive effect on attention is already well established for aerobic exercises [10–12], the positive effect of bal&coor found in the current study is unique. In several studies, mind-body exercises (i.e., Tai Chi, Qigong, Yoga, and Pilates), which involve a variety of actions, such as the stretching and relaxation of skeletal muscles, as well as coordinated body and regular breathing movements, were found to moderately improve cognitive functions. The researchers suggested that the meditative states involved in mind-body exercise regulate attention and consciousness, thus improving functions that demand attention [6]. As such, it may be possible that the exercises that were practiced in the current study during the bal&coor session made participants focus their attention on specific targets (i.e., controlling balance while standing on one leg and focusing their eyes on a bouncing ball), thereby leading to increased attentional levels. It is also possible that the complexity of the tasks that the participants performed during this session and the related involvement of cognitive functions led to improved attention functions [25].

Regarding the effect of exercise on executive function, no differences were found in the current study between aerobic, balance, and coordination exercises or reading a journal. All those interventions led to a significant improvement compared to the baseline assessment. This result stands in opposition to results about the beneficial effect of aerobic exercise upon control intervention in healthy older adults [6,10,15,26]. It is possible that the intensity that was practiced in the current study during both aerobic as well as bal&coor exercises did not reach the optimal threshold for improvement in the domain of executive function [15]. In addition, it is possible that the bal&coor exercise, although based on cognitively challenging movements, was performed only once (as a single session) and thus did not reach the neural stimulation needed for induced cognitive changes [27]. Future

studies should assess the effect of different bal&coor exercise intensities and durations on executive function in older adults.

An exciting result that emerged in the study refers to the phenomenon of different behavior groups responding to different types of intervention. More specifically, some of the participants showed significantly higher cognitive scorers following aerobic exercise (seven participants for both ATT and EF), while others showed significantly higher cognitive scorers following bal&coor exercise (eight participants), and one participant showed significantly higher cognitive scorers following the control (reading a journal) condition. While exploring mediating factors for this phenomenon, we looked for associations with possible demographic variables and found that years of education were significantly different between the groups of scores on the EF category. More specifically, participants who scored the highest scores after the control condition and those who scored the highest after the bal&coor condition had significantly higher years of education (18.00 + 2.94 and 16.00 + 2.74 years, respectively) than participants who scored the highest scores after the aerobic condition (13.2 + 3.29 years). It is important to note that those differences were not found in the ATT category. This phenomenon may be explained by previous suggestions about the strength of the relationship between exercise and cognition, which was hypothesized to be influenced by moderators such as age, education, and genetics [28]. In addition, personal differences in the effect of bal&coor exercise on cognitive function may be the result of different stages of skill acquisition among participants [28]. It is possible that for participants who were familiar with the coordinative exercises that were included in that session, those exercises were not considered challenging, thus, did not reach the needed threshold for cognitive improvement. On the other hand, it is possible that this expertise allowed those participants to achieve greater attention on postural control, thus leading to improved achievement on the ATT category of the cognitive test. Future studies should assess participants' task acquisition differences as a mediator factor.

4.1. Strengths and Limitations of the Study

To the best of our knowledge, this is the first attempt to compare the effect between a single session of aerobic exercises and that of bal&coor exercises on attention and executive functions in healthy older adults. The results support the hypothesis whereby bal&coor exercises may improve attention in older adults. Although examining only active and healthy participants may be considered a limitation of the current study, it may provide an incentive for healthy, active older adults to perform bal&coor exercises. As these skills are an essential component of daily activities, our results show that in addition to improving basic skills, they may also enhance cognitive functioning. It is recommended that the effect of a single session of bal&coor exercise on different aspects of cognition be examined in additional populations, such as in individuals who suffer from cognitive impairments.

4.2. Conclusions

The present findings support and enhance the literature on improved attention in healthy older adults following a single aerobic exercise session, indicating the positive effect of a single bal&coor exercise on attention among healthy older adults. As such, in addition to the importance of bal&coor training in older adults, these findings could be used to encourage the development of bal&coor exercise programs for older adults. Future research should be designed to assess the effect of chronic bal&coor on cognitive function among older adults.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data supporting reported results can be found upon request from the authors.

Conflicts of Interest: The authors declare no conflict of interest.

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