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Effects of different types of physical activity on the cognitive functions and attention in older people: A randomized controlled study

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ABSTRACT

This study aimed to evaluate the effects of different types of exercise on cognition. Eighty participants, 32 males and 48 females, aged 66.96 ± 11.73, volunteered for this study. The participants were randomly divided into the four following groups: Resistance Group (RG; n = 20), involved in high intensity strength training; Cardiovascular Group (CVG; n = 20), involved in high intensity cardiovascular training; Postural Group (PG; n = 20) involved in low intensity training, based on postural and balance exercises; and Control Group (CG; n = 20). Exercises were performed over the course of 12 weeks. All participants were tested for their cognitive functions pre- and post-intervention using the following neurocognitive tests: the Attentive Matrices Test, Raven's Progressive Matrices, Stroop Color and Word Interference Test, Trail Making Test and Drawing Copy Test. Statistical analysis showed that the CVG group improved significantly in the Attentive Matrices Test and Raven's Progressive Matrices (both $p = < 0.05$), whereas the RG group improved in Drawing Copy Test time ($p = < 0.05$). These results confirm that different types of exercise interventions have unique effects on cognition. Cardiovascular training is effective in improving performance attentive and analytic tasks, whereas resistance training is effective in improving praxis. Further investigation is necessary to evaluate the combination of the two exercise types in order to ascertain if their respective effects can be summated when performed together.

1. Introduction

The worldwide occurrence of dementia in 2000 was estimated at about 25 million persons and that figure is predicted to increase to 114 million by 2050 (Wimo et al., 2003). Dementia and subsequent cognitive decline are one of the major causes of disability and dependency among older people worldwide (World Health Organization [WHO], 2012); consequently, healthcare costs for this aging population are disproportionately high (Wimo et al., 2013). For this reason, strategies to prevent or offset the effects of this pathology are indispensable. However, early diagnosis and prevention remain difficult because the etiology and pathogenesis of dementia are unclear, with important differences between case (Castellani and Perry, 2014; Mayeux and Stern, 2012).

Normal age-related cognitive decline is related to pharmacological therapies (Hanlon et al., 2001); but until recently, evidence concerning the safety of these treatments was lacking (Bhattacharya et al., 2015). Physical activity (PA) might offer hope for combating the deleterious effects of dementia while simultaneously reducing the need for pharmacological interventions. Studies demonstrate that exercise produces benefits in executive functions, attention and working memory, and catecholamine system functions (Berridge and Devilbiss, 2011; Riddle et al., 2005). Exercise has the effect of changing the activity of these neurotransmitters, reducing the serotonergic stress response (Dishman et al., 2006), and integrating executive, psychological and social functions (Knöchel et al., 2012). From an economic perspective, the relatively low-cost of PA strategies makes them extremely attractive, especially in light of the benefits of sport therapy in improving quality of life and general health (Williamson et al., 2009). Several studies suggest that PA may play an important role in reducing cognitive decline and delaying the onset of dementia (Barnes and Yaffe, 2011; Zahodne et al., 2013). PA addresses modifiable risk factors, such as diabetes mellitus, hypertension, obesity, depression, smoking, diet and cognitive inactivity (Heyward and Gibson, 2014; Sigal et al., 2013). Moreover, PA promotes brain health through other mechanisms, such as environmental enrichment (Cotman and Berchtold, 2002; Erickson et al., 2013; Mora, 2013).

Human studies have shown that some loss of attention, especially vigilance and spatial attention, may be considered a normal part of the

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aging process (McGaughy and Eichenbaum, 2002). Over time, these losses may proceed to more serious cognitive disorders, such us dementia and functional mobility impairment (Bhattacharya et al., 2015). Executive functioning and attention are important in the regulation of functional mobility (Montero-Odasso et al., 2009). Consequently, motor changes associated with senescence are more pronounced in the presence of cognitive decline (Hauer et al., 2002). Moreover, mobility in daily life requires the simultaneous performance of cognitive and motor tasks, which for older people, requires additional attentional effort (Kelly et al., 2012).

Nevertheless, literature findings are equivocal about the benefits of exercise on cognitive functioning. Differences of opinion exist in terms of the type of exercise, frequency, and intensity duration required (Bartholomew and Ciccolo, 2008). There is a need for better controlled studies comparing the different exercise programs and dosages needed (Knöchel et al., 2012).

The aim of this study was to evaluate the effects of three different exercise types on attention and other executive functions in older adults. The authors' hypothesis was that each of the three training types would have differential effects on cognitive functions.

2. Materials and methods

2.1. 1. Participants

Eighty participants, 32 males and 48 females, aged 66.96 ± 11.73, volunteered for this study. The following inclusion criteria were applied: aged 55 years or above, sedentary or lightly active lifestyle in accordance with the definition of Pate et al. (2008), absence of dementia, absence of moderate or severe functional impairment, and not currently taking any medications affecting cognitive functioning. The exclusion criteria were: presence of chronic disease; moderate or severe dyslipidemia, that was total cholesterol >200 mg/dL, low-density lipoprotein (LDL) >130 mg/dL, high-density lipoprotein (HDL) <60 mg/dL, or triglycerides >150 mg/dL (Lichtenstein et al., 2006); history of ictus, stroke or other cardiopulmonary disease; and moderate or severe obesity that was body mass index <30 kg/m^2 (Shah and Braverman, 2012). The characteristics of the sample are shown in Table 1. The study was designed in conformity with the Declaration of Helsinki and was approved by the local ethical committee. All participants gave their informed written consent.

2.2. Procedures

2.2.1. Experimental intervention

At baseline, all participants had their cognitive functions assessed using a neurocognitive battery of tests. The neurocognitive battery was designed in order to evaluate the attention and other cognitive domains that are frequently affected in older persons (Bossers et al., 2012). Participants were carefully examined for the presence of any medical conditions that might prevent them from completing the proposed physical activities.

Subsequently, participants were randomly divided into four groups, three experimental and a control group. The three experimental groups performed a different training protocol each for 12 weeks, while the CG did not perform any type of training.

The first group, Resistance Group (RG; $n = 20$), performed high intensity strength training involving six muscle groups: shoulders, arms, chest, abdomen, back and legs. All the exercises were performed on isotonic machines, for monitoring exercise intensity and to ensure correct execution of the exercises. The RG protocol is described in Table 2 — Panel A.

The second group, Cardiovascular Group (CVG; $n = 20$), performed high intensity cardiovascular training on ergometer machines, including treadmills, cyclo-ergometers and step-ergometers. Participants' heart rate reserve (HRR) was used to indicate training intensity and was monitored in real time, during the training sessions, using heart rate monitors (Table 2 — Panel B).

The third group, Postural Group (PG; $n = 20$), performed low intensity training based on postural and balance exercises. PG exercise protocols are described in Table 2 — Panel C.

The last group, Control Group (CG; $n = 20$), did not perform any type of training during the 12 weeks.

At the commencement and end of the 12 weeks of training, participants underwent a physical assessment to evaluate the efficacy of each type of training in improving their physical health parameters.

2.2.2. Environmental context description

The present study was designed to reduce external environmental stimuli during the training sessions, with each experimental group being trained separately. The training sessions were performed on Monday, Wednesday and Friday morning, from February to April. The gymnasium was reserved especially for this experiment so that no other people or activities were performed during the participants' training sessions. The temperature in the training rooms was controlled at 22 °C. No music was used during the training sessions. In order to ensure participants safety and the correct execution of the exercises, each group performed their respective training under the strict supervision of four professional trainers. After randomization, participants performed three preliminary sessions of their respective training in order to familiarize them with the protocol, the training machines and the correct execution of the exercises. At the beginning of each training session, participants in the RG were provided with a personal and daily training schedule detailing the exercise order, number of sets, series, overweighs and rest periods. CVG participants were provided with a schedule indicating the exercise order, duration, rest periods and %HRR target. PG participants received a schedule reporting the exercise order and duration of each exercise.

The trainers' role was limited only to proposing the training protocols at the beginning of the intervention. Successively, during all the time of the intervention, personal interactions between the trainers and the participants were avoided and the trainers only supervised the safe and correct execution of the exercises, and the participants' adherence to the trainings.

2.2.3. Neurocognitive assessment

To assess participants' cognitive functions a sensitive and validated neuropsychological test battery was used. This cognitive test battery included cognitive domain measures that frequently affected older persons (Bossers et al., 2012).

Attentive Matrices Test (Attentive Test) is a valid instrument to measure selective and sustained attention (Spinnler and Tognoni, 1987). It consists of 3 numeric matrices (10 columns of 13 numbers from 0 to 9). The participants are required to check specific target numbers in 45 s for each matrix. There are 1 target in the first matrix, 2 in the second one, and 3 in the third one. The score is assigned giving 1 point for each

Table 1
Sample characteristics.

		Means	SD
RG n = 20	Age (years)	65.80	6.32
9 men–11 women	Scholarization (years)	12.40	3.45
CVG n = 20	Age (years)	68.44	6.40
8 men–12 women	Scholarization (years)	11.08	4.18
PG n = 20	Age (years)	66.67	5.83
7 men–13 women	Scholarization (years)	11.33	3.88
CG n = 20	Age (years)	66.47	6.32
8 men–12 women	Scholarization (years)	12.29	4.30

The groups resulted homogeneous and no significant differences were found in term of age and scholarization.
RG = Resistance Group; CVG = Cardiovascular Group; PG = Postural Group; CG = Control Group.

Table 2
Training protocol description.

Panel A — resistance training for RG

Exercise	Muscle group involved	Weeks 1–4	Weeks 5–8	Weeks 9–12
Lateral raise	Shoulders	60–70% 1-RM	70–80% 1-RM	80–85% 1-RM
Arm curl	Arms	3 series × 12 repetitions	3 series × 8 repetitions	3 series × 6 repetitions
Leg press	Legs	3 minute rest between series; duration	3 minute rest between series; duration	3 minute rest between series; duration
Lat machine	Back	of the session was ≈30 min.	of the session was ≈30 min.	of the session was ≈30 min.
Frontal chest press	Chest			
Abdominal crunch	Abdominal			

Panel B — cardiovascular training for CVG

Exercise	Weeks 1–2	Weeks 3–4	Weeks 5–6	Weeks 7–8	Weeks 9–10	Weeks 11–12
Treadmill	50–60% HRR	55–65% HRR	60–70% HRR	65–75% HRR	70–80% HRR	70–80% HRR
Bike-ergometer	30 min	30 min	30 min	30 min	30 min	30 min
Ergometer for arms						

Panel C — postural training for PG

Exercises	
Flexibility (5 min)	Exercises for balance (15 min)
Core stability (10 min)	Muscle relaxing (5 min)
Respiratory exercises (5 min)	

In all the 3 experimental intervention the interaction between the participant and trainers was <4 min per session.
RG = Resistance Group; CVG = Cardiovascular Group; PG = Postural Group; 1-RM = One Repetition Maximum; HRR = Heart Rate Reserve.

target correctly found in the 3 matrices (max 60 for all the 3 matrices). The time to complete the 3 matrices is considered as scores too.

Raven's Progressive Matrices Tests (Raven Test) are multiple choice intelligence tests of abstract reasoning, listed in order of progressive difficulty (Raven, 2000). In each test item, the subject is asked to analyze a geometric pattern and identify the missing piece. The test is composed of 3 series of 12 figures for a total of 36 figures. One point is assigned for each missing piece that the subject correctly points out, so that the total score ranges from 0 (worst) to 36 (best). The time to complete the test is considered as score too.

Stroop Color Word Interference Test (Stroop test) provides an evaluation of the selective attention, visual attention and inhibitory control (Stroop, 1935). This test includes 3 time-limited (45-s) subtests. First, subjects are asked to read a list of words printed in black ink that name colors ("red", "green" and "blue"). Successively, subjects are presented with a list of circle that differs in ink color, and are asked to name the color of the ink for each circle. In the third subtest, a list of the words "red", "green" and "blue", written with an ink color different from the presented word (i.e., the word "red" printed in blue ink), are presented and the subjects are asked to say the color of the ink and ignore the word's semantic meaning (i.e., respond "blue" instead of "red" in the previous example). The score was calculated as: (1) "interference in the time of the execution" ($\text{Stroop}_{\text{time}}$), calculated with the formula $\{\text{Stroop}_{\text{time}} = (T_3 - (T_1 + T_2)) / 2\}$, where T_1, T_2 and T_3 are respectively the execution time of the 1st, 2nd, and 3rd subtest; and (2) "interference in the error" ($\text{Stroop}_{\text{error}}$), calculated with the formula $\{\text{Stroop}_{\text{error}} = (E_3 - (E_1 + E_2)) / 2\}$, where E_1, E_2 and E_3 are respectively the number of errors occurred during the 1st, 2nd, and 3rd subtests.

Trail Making Test (TMT) provides information on visual search, speed of processing, mental flexibility, selective visual attention and ability to shifting (Reitan, 1958). It consists of two parts (A and B), both consisting of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1–25, and the subject should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1–13) and letters (A–L) and the subject should draw lines to connect alternatively numbers and letters in ascending order (i.e., 1–A–2–B–3–C). The subject should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Errors should be pointed out immediately and subjects should be allowed to correct it. Time required to complete each of the two parts is recorded, considered as scores of the test.

Drawing Copy Test is used to evaluate praxis abilities (Caltagirone et al., 1979). In the first part of the test (Drawing Test I), the subject must copy 3 geometric drawings. The score is calculated on the basis of the adherence to the original model. The range of the assigned score is from 0 (worst — no adherence at all) to 4 (best — perfect adherence) for each drawing (total test score ranges from 0 — the worst, to 12 — the best). In the second part of the test (Drawing Test II), subject must complete a series of 12 uncompleted geometric drawings to obtain one of the 3 geometric models used in the first part of the test. The score is calculated assigning 1 point for each correct line drawn (max 70), so the total score is from 0 (*worst*) to 70 (*best*). Also in this case, the time to complete the entire test was considered as scores.

2.2.4. Physical assessment

In order to assess the effectiveness of the training in improving participants' physical condition, the participants were evaluated pre- and post- the 12-week training period. This physical assessment was performed the day after the neurocognitive assessment to avoid influences on cognitive outcomes. The test sequence was the following: neurocognitive pre-tests (performed in 2 days), physical pre-tests (performed during the following day), 1 day of rest, 12 week training, 1 day of rest after the last session of training, neurocognitive post-tests (performed again in 2 days), and physical post-tests (performed in the following day).

Strength performance was evaluated using the maximum repetition (1-RM) of the six muscle groups trained during the experimental period. In this study, 1-RM was indirectly evaluated via the Brzycki submaximal method (Brzycki, 1993) to ensure the safety of participants.

Cardiovascular performance was tested using a one-mile walking test (1MWT) (Kline et al., 1987). The 1MWT is a simple and safe test for the indirect measurement of the VO_2max, which is the best indicator of cardiovascular improvement. This test is particularly indicated for elderly and sedentary subjects.

Balance performance was assessed using the Stork Balance Stand Test (SBST) (Johnson and Nelson, 1979). This test consists of maintaining a one-legged balance position for as long as possible, with the nonsupporting foot positioned against the supporting leg knee. Participants did not wear shoes and kept the hands on their hips.

2.3. Statistical analysis

Participants' randomization into the four groups was performed using a random number list, generated using online software (https://www.random.org/sequences/, Dublin, Ireland). The procedure for randomization is described thus: a progressive number was assigned to each of the participants in alphabetical order according to their surname; a random number list was subsequently generated and, in accordance with this random number list order, the participants were allocated in blocks of four participants per group in the order CVG, RG, PG and CG. After randomization, analysis of variance (ANOVA) was performed to verify that the four groups were homogenous at baseline in terms of participants' age, instruction level, gender, physical fitness and cognitive scores.

Repeated measures multivariate analysis of variance (RM-MANOVA) was performed to evaluate the significance of differences in the cognitive scores pre- and post-intervention (within factor: time) and among the four groups (between factor: groups). The 11 scores obtained in the neurocognitive tests were used as dependent variables of analysis. Bonferroni post-hoc test was used to assess mean differences where a significant *F* was observed.

Analysis of variance for repeated measures (one-way RM-ANOVA) was instead performed to evaluate significant differences between pre- vs post-intervention physical fitness scores. The analysis was performed independently for each group and for each physical score, in order to evaluate significant improvements obtained by each group in the nine physical fitness scores.

The alpha test level for statistical significance was set at 0.05 and the Bonferroni correction for multiple testing was applied during the analysis. SPSS was used for all statistical analyses (IBM, v.20.0, Chicago, IL, USA).

3. Results

The results of the study are reported as means ± SD in Table 3. The four groups were homogeneous at baseline in terms of their cognitive scores, age, instruction level and gender.

RM-MANOVA showed significant differences among the four groups ($F = 2.231$, $df = 33$, $p = 0.022$) and between pre- and post-intervention cognitive scores ($F = 2.401$, $df = 11$, $p = 0.014$). The results for the interaction Time × Groups was not significant ($F = 1.128$, $df = 33$, $p = 0.354$). Univariate analysis showed significant pre- and post-differences in: Attentive Test target ($F_{1,76} = 4.554$, $p = 0.036$), Raven Test score ($F_{1,76} = 5.256$, $p = 0.025$), Raven Test time ($F_{1,76} = 10.659$, $p = 0.002$) and Copy Drawing Test time ($F_{1,76} = 3.957$, $p = 0.046$). Significant differences were found among the four groups in the same cognitive scores: Attentive Test target ($F_{3,76} = 2.661$, $p = 0.048$), Raven Test score ($F_{3,76} = 3.576$, $p = 0.018$), Raven Test time ($F_{3,76} = 2.772$, $p = 0.045$) and Copy Drawing Test time ($F_{3,76} = 2.971$, $p = 0.037$). No significant differences in the scores of the other cognitive variables or in the interaction Time × Groups were found. Table 3 details the results of the analysis, post-hoc results and average scores.

The results of one-way RM-ANOVA performed on physical scores showed that CVG significantly improved VO_2max ($F_{1,19} = 4.627$, $p = 0.038$) and reduced the time to perform 1MWT ($F_{1,19} = 37.225$, $p < 0.001$), RG improved 1-RM in all the six strength tests (p between 0.45 and <0.001), PG improved the SBST score ($F_{1,19} = 15.225$, $p < 0.001$). The detailed results are reported in Table 4.

4. Discussion

Cardiovascular training significantly improved attention and abstract reasoning performances, whereas resistance training significantly improved praxis. In fact, each of the three types of PA interventions produced different effects on cognition, over the course of the 12 weeks, according to Voelcker-Rehage et al. (2011). Evidence strongly indicates that regular physical exercise produces positive effects on human biology and psychology, and that it may offer some protection against the loss of cognitive functioning (Blumenthal et al., 2007). The research literature indicates that exercise prevents cognitive decline (Podewils et al., 2005) and positively influences self-efficacy in daily life (Alfermann and Stoll, 2010).

The Attentive Test score improved significantly in the CVG, based on the number of targets found (Colcombe et al., 2004; Smith et al., 2010), as well as the Raven Test scores, both in terms of time and number of correct answers. Several studies have shown that cardiovascular training, with long period of training, may be effective in increasing the volume of the hippocampus and grey matter (Ahlskog et al., 2011), and reducing white matter degradation and cerebral ischemia (Knopman et al., 2001). Nevertheless, there is a paucity of evidence attesting to the causal relationship between improvements in cognition and cardiovascular fitness (Angevaren et al., 2008). No significant improvements were found in executive function, thus contradicting the findings of Smith et al. (2010).

Resistance training significantly reduced the time needed to complete the Copy Drawing Test. Two explanations of this result are offered: (a) RG improved participants' information processing speed; (b) participants' may develop manual dexterity inline in increased strength. While aging may drastically reduce PA levels, accelerate sarcopenia, muscle strength and power losses (Rodríguez-Mañas et al., 2013), resistance training may improve the functional capacity of the

Table 3
Neurocognitive test scores in pre- and post-training assessments.

Test		PRE				POST			
		CVG	RG	PG	CG	CVG	RG	PG	CG
Attentive Matrices	Time (s)	95.4 ± 36.7	93.1 ± 41.9	92.7 ± 26.9	103.4 ± 31.5	94.7 ± 20.7	85.2 ± 9.8	92.5 ± 18.2	100.5 ± 25.8
	Targets	48.5 ± 5.1	49.6 ± 6.8	49.3 ± 6.0	48.2 ± 5.4	56.8 ± 4.9*#	51.2 ± 5.1	52.6 ± 7.7	50.6 ± 5.0
Raven Test	Correct answers	26.2 ± 4.7	26.9 ± 4.1	27.7 ± 6.0	28.1 ± 8.4	28.8 ± 4.6*#	26.4 ± 4.5	27.3 ± 4.2	26.7 ± 4.6
	Time (s)	315.6 ± 71.9	327.3 ± 71.0	299.1 ± 99.6	346.6 ± 133.1	249.7 ± 50.4*#	295.0 ± 47.8	281.0 ± 68.7	320.9 ± 96.6
Stroop test	Error	0.8 ± 3.2	0.7 ± 1.3	1.1 ± 3.4	0.2 ± 0.7	0.3 ± 0.9	0.2 ± 0.5	0.8 ± 1.2	0.1 ± 0.6
	Time (s)	21.6 ± 11.7	23.5 ± 11.6	25.4 ± 11.4	22.5 ± 11.1	22.7 ± 7.3	23.1 ± 9.7	24.9 ± 11.4	24.6 ± 11.8
TMT	Part A	42.8 ± 17.0	41.5 ± 12.6	44.0 ± 15.6	41,3 ± 12.5	40.0 ± 13.2	35.1 ± 8.1	42.7 ± 11.8	39.2 ± 14.3
	Part B	77.0 ± 44.3	92.6 ± 36.9	77.6 ± 24.7	78,1 ± 29.0	66.7 ± 22.3	69.9 ± 21.9	82.1 ± 18.1	79.6 ± 35.2
Drawing Copy Test	Simple copy	10.0 ± 2.7	10.4 ± 1.5	9.8 ± 2.4	10.6 ± 1.8	10.0 ± 2.0	10.8 ± 1.3	10.2 ± 1.6	9.8 ± 1.9
	Copy with elements	68.7 ± 2.0	68.3 ± 3.5	68.3 ± 4.1	69.3 ± 0,9	69.0 ± 1.5	69.3 ± 1.9	68.8 ± 2.4	68.9 ± 2.0
	Time (s)	293.6 ± 121.4	260.7 ± 84.3	246.6 ± 67.8	284.9 ± 102,6	253.7 ± 83.5	212.5 ± 66.9*†	227.5 ± 67.9	266.8 ± 74.2

RG = Resistance Group; CVG = Cardiovascular Group; PG = Postural Group; CG = Control Group.
* $p < 0.05$ PRE vs. POST;
\# $p < 0.05$ CVG vs. CG;
† $p < 0.05$ RG vs. CG.

Table 4
Physical test scores of the 3 experimental groups in Pre- and Post-training assessments.

Group	Test	Analyzed parameters	PRE	POST	$F_{1.19}$	Significance	Differences
CVG	1MWT	VO_2max (mL/kg/min)	19.35 ± 5.88	23.02 ± 6.34	4.627	$p = 0.038^{*}$	19%
		Time (s)	922.29 ± 89.18	768.18 ± 112.62	37.225	$p < 0.001^{**}$	−17%
	1 RM	Shoulder (kg)	7.4 ± 3.52	9.45 ± 3.56	3.357	$p = 0.075$	28%
		Arms (kg)	29.2 ± 3.62	31.1 ± 4.17	2.369	$p = 0.132$	7%
		Legs (kg)	142.05 ± 41.28	148.05 ± 41.28	0.211	$p = 0.648$	4%
		Back (kg)	46.45 ± 12.05	47.7 ± 13.8	0.093	$p = 0.762$	3%
		Chest (kg)	33.7 ± 7.47	34.7 ± 7.47	0.179	$p = 0.674$	3%
		Abdomen (kg)	31.45 ± 7.73	34.45 ± 7.73	1.507	$p = 0.227$	10%
	SBST	Time (s)	15.55 ± 5.07	16.6 ± 6.28	0.338	$p = 0.564$	7%
RG	1MWT	VO_2max (mL/kg/min)	20.6 ± 3.84	22.1 ± 3.71	1.576	$p = 0.217$	7%
		Time (s)	938.1 ± 93.87	893.6 ± 88.99	2.367	$p = 0.132$	−5%
	1 RM	Shoulder (kg)	7.96 ± 2.79	11.00 ± 2.70	5.839	$p = 0.021^{*}$	38%
		Arms (kg)	29.67 ± 4.14	43.56 ± 10.78	93.507	$p < 0.001^{**}$	47%
		Legs (kg)	135.61 ± 45.73	167.33 ± 50.36	4.297	$p = 0.045^{*}$	23%
		Back (kg)	46.48 ± 12.56	57.65 ± 14.11	9.213	$p = 0.004^{**}$	24%
		Chest (kg)	39.85 ± 17.18	57.57 ± 17.40	67.231	$p < 0.001^{**}$	44%
		Abdomen (kg)	34.08 ± 12.63	46.04 ± 19.47	6.741	$p = 0.01^{*}$	35%
	SBST	Time (s)	16.35 ± 4.49	20.8 ± 9.98	3.309	$p = 0.077$	27%
PG	1MWT	VO_2max (mL/kg/min)	21.35 ± 5.13	21.6 ± 6	0.020	$p = 0.888$	1%
		Time (s)	968.5 ± 69.28	976.8 ± 78.13	0.126	$p = 0.724$	1%
	1 RM	Shoulder (kg)	6.45 ± 2.82	7.3 ± 2.87	0.894	$p = 0.350$	13%
		Arms (kg)	28.7 ± 4.33	29.25 ± 4.78	0.146	$p = 0.705$	2%
		Legs (kg)	147.8 ± 41.99	149.15 ± 41.81	0.002	$p = 0.961$	1%
		Back (kg)	43.45 ± 10.06	44.35 ± 9.78	0.082	$p = 0.776$	2%
		Chest (kg)	37.85 ± 9.51	38.15 ± 10.95	0.047	$p = 0.830$	1%
		Abdomen (kg)	32.4 ± 7.82	33.05 ± 9.43	0.056	$p = 0.814$	2%
	SBST	Time (s)	18.88 ± 10.94	27.65 ± 10.11	15.381	$p < 0.000^{**}$	46%
CG	1MWT	VO_2max (mL/kg/min)	21.1 ± 4.63	19.95 ± 5.58	0.503	$p = 0.482$	−5%
		Time (s)	928.45 ± 91.66	927.65 ± 95.67	0.001	$p = 0.979$	0%
	1 RM	Shoulder (kg)	7.1 ± 2.69	7.75 ± 2.84	0.551	$p = 0.463$	9%
		Arms (kg)	29.6 ± 3.36	30.95 ± 4.56	1.136	$p = 0.293$	5%
		Legs (kg)	149.6 ± 40.48	151.6 ± 40.82	0.024	$p = 0.877$	1%
		Back (kg)	46 ± 11.32	46.15 ± 12.56	0.002	$p = 0.969$	0%
		Chest (kg)	38.8 ± 5.66	38.15 ± 6.11	0.122	$p = 0.729$	−2%
		Abdomen (kg)	32.35 ± 7.61	32.1 ± 9.08	0.009	$p = 0.925$	−1%
	SBST	Time (s)	14.8 ± 5.18	16.4 ± 9.61	0.430	$p = 0.516$	11%

RG = Resistance Group; CVG = Cardiovascular Group; PG = Postural Group.
1MWT = One-Mile Walking Test; 1-RM = One Repetition Maximum; SBST = Stork Balance Stand Test.
* $p < 0.05$.
** $p < 0.01$.

elderly (Correa et al., 2012). No significant differences were found in other tests after resistance training, thus corroborating the findings of several other studies (Chang et al., 2012; Kelly et al., 2014; van Uffelen et al., 2008). Cassilhas et al. (2007) reported that only high intensity training was effective in improving central executive functions and attention. We planned for the resistance training to increase progressively, across the 12 weeks, from moderate to high intensity. It is possible that the null results in this intervention were due to the brief duration of the high intensity phase.

The PG did not exhibit any significant improvement in cognitive functions or attention. This finding may be due to the low-intensity of the postural activities. To the best of our knowledge, no previous studies have investigated the cognitive or attentional effects of this kind of activity despite often being recommended to older people (Son et al., 2010; Stijntjes et al., 2015).

The protocols used in this study indicated three PA sessions weekly (Heyn et al., 2004; Pajonk et al., 2010) per the American College of Sport Medicine guidelines for the elderly. We used a standard neuropsychological battery of tests in this study that were easily administrable, and allows for data reproducibility and comparability in future studies.

The combination of the two protocols, resistance and aerobic training, may have dual benefits in improving attention and executive functioning. However, the results of this study do not allow confirming this hypothesis.

The environmental contexts, in which the exercises are performed, may play an important role in promote cognitive functioning. The procedures of this study were designed to reduce the external stimuli during the execution of the training protocols. However further studies are needed to better understand if differences in physical, social and psychological variables during PA may influences cognition.

Finally, a limitation of this study could be that differences on cognition may be due to the different physiological loads of the three PA protocols, and not only to the different exercise modalities.

5. Conclusion

Cardiovascular training was shown to be effective in improving participants' attentive and analytic tasks, while resistance training was effective only in improving praxis. Moreover, by shifting from aerobic to resistance exercises, elderly people might experience potential cognitive benefits related to the different environmental enrichments. Different PA protocols combined might guarantee a variety of stimuli that may favor biological and physiological adaptations in humans (Wilson et al., 2013). Any authors have suggested that combined interventions, such as strength plus aerobic training, could be effective in reducing cognitive risk factors, as compared to singular types of training (Kelly et al., 2014). This hypothesis might be confirmed by future studies.

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