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Changes in Cognitive Function after a 14-Week Recreational Resistance Training Program in Older Adults: A Pilot Study

Abstract. This pilot randomized controlled trial examined cognitive changes after 14 weeks of supervised resistance training in recreationally active adults aged over 60 years. Twenty participants were randomly assigned to intervention or control groups (n=10 each). The intervention included two supervised 45-min weekly sessions, with increasing intensity using the Borg CR10 scale. Before and after the intervention cognitive functions were assessed using the Trail Making Test, Stroop Test, and Digit Span Test. Favourable changes occurred across all tests in the intervention group, while no significant within-group changes occurred in the control group. Between-group changes indicated the effectiveness of resistance training for Trail Making Test B, Digit Span, and Stroop A and B, with the TMT and Stroop outcomes considered secondary and exploratory. After baseline adjustment, only the Digit Span effect remained significant. Supervised resistance training may improve selected cognitive outcomes, particularly working memory, in older adults. Larger randomized controlled trials are needed to confirm these preliminary findings.

Keywords: resistance training, cognition, working memory, muscle strength, older adults

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1. Introduction

Population aging is one of the most important public health challenges of the 21st century. As life expectancy increases, the number of older adults is rising, accompanied by a greater prevalence of age-related changes in both physical and cognitive

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functioning. Even in individuals without diagnosed neurodegenerative disease, aging is associated with a gradual decline in processing speed, attention, working memory, and executive function (Salthouse, 2019). These changes can limit functional independence, make activities of daily living more difficult, and reduce quality of life in older adults. Because pharmacological approaches have limited effectiveness, increasing attention has been directed toward nonpharmacological strategies that support healthy aging.

Regular physical activity (PA) is considered one of the most important modifiable factors for maintaining physical and mental health. Observational studies indicate that physically active individuals perform better on cognitive tests and have a lower risk of cognitive impairment than individuals with sedentary lifestyles (Blondell et al., 2014). Higher levels of PA and less sedentary time are also associated with better global cognitive function in older adults, while regular PA may be associated with a lower risk of dementia and Alzheimer's disease (Iso-Markku et al., 2022; Rojer et al., 2021). The importance of PA for healthy aging is also emphasized in current World Health Organization (WHO) guidelines, which recommend that older adults regularly engage in both aerobic activity and muscle-strengthening exercises involving the major muscle groups (WHO, 2020).

Within this healthy-aging context, resistance training is particularly relevant because it is recommended for older adults, yet research on exercise and cognition has predominantly focused on aerobic interventions (Silva et al., 2025). Despite the growing literature, studies on the effects of resistance training on cognitive function in older adults remain highly heterogeneous. They differ in intervention duration, exercise intensity, participant characteristics, and assessment tools. Moreover, recent evidence suggests that the relationship between PA and cognitive functioning may be more complex than previously assumed (Coelho-Junior et al., 2022; Iso-Markku et al., 2024). Well-designed intervention studies using standardized cognitive assessment tools are still needed. In particular, evidence remains limited for randomized studies in older adults without self-reported or diagnosed neurological or psychiatric conditions affecting cognition that simultaneously assess executive function, attention, and working memory. Within the Polish context, intervention studies have used different exercise modalities and participant populations. Kujawski et al. (2022) compared a 3-month resistance training program with sitting callisthenic balance exercises in healthy older participants and reported favourable effects of resistance training on several cognitive outcomes. Górniak et al. (2021) examined Nordic walking in patients with Alzheimer's disease and found no significant improvement in cognitive performance. Thus, directly comparable evidence on supervised recreational resistance training in Polish older adults without diagnosed neurodegenerative disease remains limited. This gap provides the rationale for the present study. The research question was therefore: Would adults older than 60 years completing a 14-week supervised recreational resistance training programme show more favourable changes in executive function, attention, and working memory than those maintaining their usual activity?

To address this question, 20 adults older than 60 years were randomly assigned to an intervention group or a control group (n = 10 each). The intervention group completed supervised resistance training twice weekly for 14 weeks, while the control group maintained its usual lifestyle. Cognitive function was assessed before and after the intervention using the Trail Making Test, Digit Span Test, and Stroop Test.

The goal of this pilot study was to obtain preliminary estimates of between-group differences in changes in cognitive function following a 14-week resistance training program in recreationally active adults older than 60 years. Additional pilot objectives were to assess the safety, feasibility, and acceptability of the program and to obtain information useful for planning a future definitive trial. We hypothesized that after completing the resistance training programme participants would show favourable changes in executive function, attention, and working memory compared to participants in the control group.

2. Literature Review

2.1. Cognitive Aging in Older Adults

Normal aging is accompanied by gradual and domain-specific changes in cognitive functioning, even in people without mild cognitive impairment or dementia. Processing speed, aspects of episodic and working memory, and executive abilities are among the domains that tend to decline, whereas vocabulary and accumulated knowledge are comparatively preserved (Harada et al., 2013; Salthouse, 2019). These changes are generally subtle, but they are important because efficient attention, memory, and executive control support everyday decision-making and complex activities required for independent living.

Age-related cognitive trajectories are not uniform. Considerable interindividual variability exists, and the magnitude of change differs across cognitive domains and across individuals (Harada et al., 2013; Salthouse, 2019). This heterogeneity is relevant when studying older adults who do not have diagnosed neurodegenerative disease because the absence of a diagnosis does not imply identical cognitive status or identical rates of age-related change. Consequently, studies of interventions intended to support cognition should use domain-specific measures and interpret changes in relation to the characteristics of the population being examined.

Executive function, attention, processing speed, and working memory are particularly relevant in this context because they contribute to adapting behaviour, maintaining goal-directed activity, and managing information during complex tasks. These domains are also frequently examined in exercise studies involving older adults (Northey et al., 2018; Chen et al., 2020). Identifying modifiable behaviours that may help maintain these functions is therefore an important component of research on healthy aging.

2.2. Physical Activity and Cognitive Function

Among potentially modifiable behaviours, physical activity (PA) has received substantial attention. Observational evidence generally indicates that more physically active older adults perform better on measures of global cognition and may have a lower risk of cognitive impairment and dementia than less active peers (Blondell et al., 2014; Iso-Markku et al., 2022; Rojer et al., 2021). A review prepared for the 2018 Physical Activity Guidelines Advisory Committee also concluded that moderate evidence from randomized trials supports beneficial associations between moderate- to vigorous-intensity PA and cognitive outcomes, including processing speed, memory, and executive function (Erickson et al., 2019).

At the same time, the magnitude and consistency of this association should not be overstated. A recent systematic review and meta-analysis of longitudinal studies reported that PA was associated with better late-life cognition, but the association was small and no clear dose-response relationship was identified (Iso-Markku et al., 2024). Differences in study design, follow-up duration, PA measurement, baseline cognitive status, and cognitive tests contribute to heterogeneity. These limitations support the need for controlled intervention studies that use clearly defined exercise programs and standardized cognitive outcomes.

Evidence from exercise interventions is nonetheless encouraging. Northey et al. (2018) found that exercise interventions in adults older than 50 years improved cognitive function, with particularly favourable findings for executive function, while Chen et al. (2020) reported beneficial effects of exercise training on executive function in older adults. Current World Health Organization recommendations therefore include regular aerobic and muscle-strengthening activity as part of healthy aging (WHO, 2020). However, the cognitive literature has historically focused more strongly on aerobic exercise, and the evidence base for resistance training remains smaller and methodologically heterogeneous (Silva et al., 2025). This provides a rationale for examining resistance training as a distinct exercise modality in older adults.

2.3. Resistance Training and Cognitive Function in Older Adults

Research on the effects of PA on cognitive function has predominantly focused on aerobic interventions (Silva et al., 2025). In recent years, however, resistance training has attracted increasing interest because, in older adults, it may improve muscle strength and selected aspects of functional fitness, represent an important component of sarcopenia management, and positively affect cognitive function and neuroplastic processes (Coelho-Junior et al., 2022; Khodadad Kashi et al., 2023; Shen et al., 2023; Stillman et al., 2020). This is particularly relevant for older adults, for whom maintaining functional independence is essential for preserving a high quality of life.

A growing body of evidence suggests that resistance training may have beneficial effects on selected domains of cognitive function. This is supported by systematic reviews and meta-analyses. Northey et al. (2018), in an analysis of studies involving adults older than 50 years, found that PA-based interventions improved cognitive function, particularly executive function. Similarly, Chen et al. (2020) reported beneficial effects of PA on executive function, one of the cognitive domains most susceptible to aging.

The meta-analysis by Coelho-Junior et al. (2022) is particularly relevant to evaluating the effects of resistance training on cognitive function. Across studies involving older adults with different levels of cognitive functioning, the authors found that resistance training significantly improved cognitive function, especially memory and executive function. These findings suggest that resistance training may be an effective strategy for supporting cognitive health during aging.

Individual randomized trials provide additional support, although findings have been obtained from diverse populations and intervention protocols. Cassilhas et al. (2007) reported cognitive benefits after 24 weeks of resistance training, whereas Liu-Ambrose et al. (2010) demonstrated improvements in executive function following a 12-month resistance training program. Studies involving older adults with mild cognitive impairment have also reported beneficial effects on cognitive outcomes (Nagamatsu et al., 2012; Fiatarone Singh et al., 2014). These differences in cognitive status, intervention duration, training dose, and outcome selection limit direct comparison across studies.

2.4. Potential Mechanisms

Further insight is provided by studies examining the potential mechanisms underlying these changes. Mavros et al. (2017) reported that improvements in cognitive function after resistance training may be partly associated with gains in muscle strength during the intervention, suggesting a relationship between neuromuscular adaptations and cognitive functioning. Stillman et al. (2020) indicated that the beneficial effects of PA on brain function may involve enhanced neuroplasticity, improved cerebral perfusion, regulation of glucose metabolism, and increased concentrations of neurotrophic factors.

3. Materials and Methods

3.1. Study Design and Participants

The study was designed as a prospective, pilot randomized controlled trial with two assessment time points: before the intervention (T1) and after the 14-week training programme (T2). Participants were randomly assigned to the intervention group (IG), which completed the resistance training program, or to the control group (CG), which did not participate in an organised exercise intervention.

Because of the exploratory nature of the study, no formal sample size calculation designed to confirm intervention efficacy was performed. Feasibility and acceptability were evaluated on the basis of attendance, the proportion of participants completing the intervention, and the occurrence of adverse events.

The Digit Span Test score, reflecting short-term memory and working memory, was designated as the primary cognitive outcome. Trail Making Test part A (TMT-A), Trail Making Test part B (TMT-B), Stroop A, and Stroop B were treated as secondary exploratory outcomes. PA level and functional fitness were also assessed.

The study was conducted from February 1 to May 31, 2026. Participants were recruited during the first week of February 2026 through local senior clubs and fitness clubs. Twenty adults older than 60 years, including nine women, were enrolled.

The training intervention was conducted at a fitness club in Poznań, Poland, equipped with resistance exercise machines, free weights, and a functional training area. Cognitive assessments were performed in a quiet room within the same facility under conditions intended to minimize distracting stimuli. After eligibility screening, participants were randomly assigned to the IG (n = 10) or CG (n = 10).

The inclusion criteria were age older than 60 years, no regular resistance training during the 3 months before study entry, no contraindications to physical exercise, and provision of written informed consent. The exclusion criteria included neurological or psychiatric conditions, either self-reported or previously diagnosed, which could affect cognition; cardiovascular or pulmonary conditions that could compromise the safety of participation in exercise; balance disorders that limited exercise performance; contraindications to physical exercise; and clinically relevant visual or hearing impairment that could interfere with the study procedures. No formal cognitive screening test, such as the Mini-Mental State Examination or Montreal Cognitive Assessment, was administered.

All participants received detailed information about the purpose and procedures of the study and provided written informed consent. Randomization was stratified by sex to achieve a comparable distribution of women and men between groups and to reduce the potential confounding effect of sex. Participants were first divided into two strata according to sex, and an independent random allocation procedure was then conducted within each stratum. Each participant was assigned an identification number. Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes containing the designation „IG" or „CG". The envelopes were opened sequentially after eligibility had been confirmed and the baseline assessment had been completed. The randomization procedure was performed by a person who was not directly involved in delivering the training program.

The IG included five women and five men, whereas the CG included four women and six men. Sex distribution did not differ significantly between groups. No statistically significant between-group differences were observed in age category, education, living arrangement, or marital status. Participant demographic characteristics are presented in Table 1.

Table 1. Demographic characteristics of the participants

Variable	Category	IG (n = 10)	CG (n = 10)	p
Sex	women	5	4	0.653
	men	5	6	
Age	60–64 years	5	3	0.371
	65–69 years	2	5	
	≥70 years	3	2	
Education	primary education	0	3	0.235
	vocational education	1	0	
	secondary education	4	3	
	higher education	5	4	
Living arrangement	alone	1	2	0.531
	with family	9	8	
Marital status	single	7	5	0.361
	partnered	3	5	

Note: IG, intervention group; CG, control group; n, number of participants. p values refer to between-group comparisons of the distribution of each characteristic.
Source: Authors' own work

The study was conducted in compliance with the Declaration of Helsinki and was approved by the Bioethics Committee of the Karol Marcinkowski Medical University, Poznań, Poland (No. 163/125).

The study was designed and reported in accordance with the CONSORT 2025 statement for randomized trials (Hopewell et al., 2025) and, with respect to its pilot design, the CONSORT extension for randomized pilot and feasibility trials (Eldridge et al., 2016). These guidelines provided a methodological framework for transparent reporting of the study design, pilot objectives, recruitment process, eligibility criteria, randomization procedure, group allocation, intervention characteristics, feasibility and safety assessments, cognitive outcomes, and statistical analysis (Fig. 1).

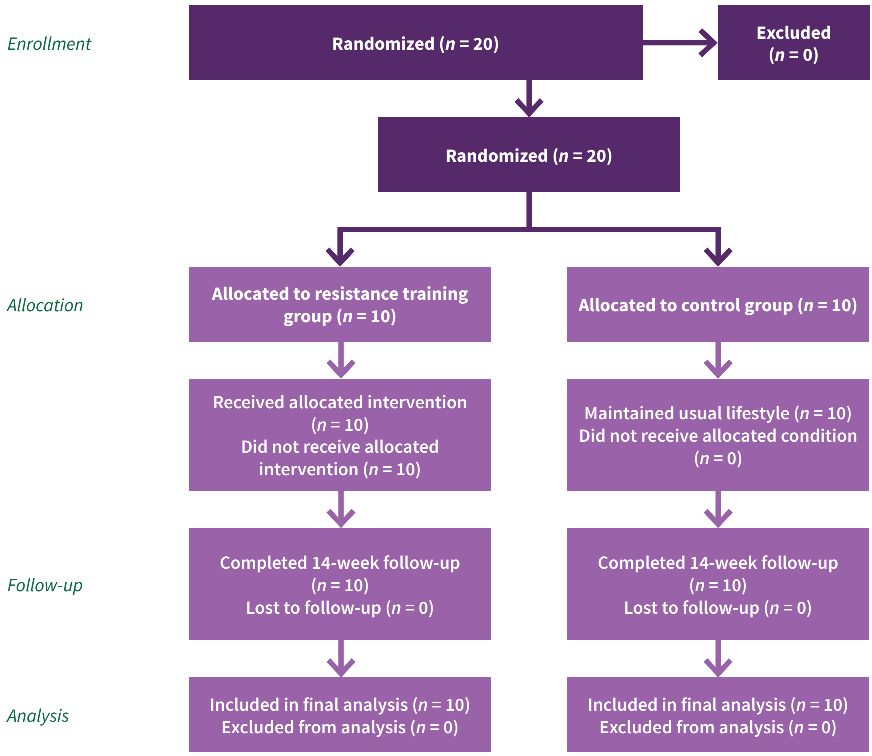

Fig. 1. CONSORT 2025 participant flow diagram
Source: Authors' own work

3.2. Assessment Procedures and Outcome Measures

Assessments were performed under standardized conditions in a quiet room and at a similar time of day. Participants were instructed to avoid strenuous physical activity for 24 hours before each assessment.

The assessment procedure included measures of cognitive function, functional fitness, and PA level. Polish versions of the instruments and standardized administration instructions were used at before and after the intervention. Tests were administered in a fixed order: TMT-A, TMT-B, Digit Span Test, Stroop A, and Stroop B. Before each formal test, the participants completed a practice trial to confirm that they understood the instructions. The same test order and versions were used at T1 and T2.

In TMT-A, the participants connected consecutively numbered items in ascending order; the test assessed processing speed, visual attention, and psychomotor performance. In TMT-B, the participants alternately connected numbers and letters in sequence, additionally engaging cognitive flexibility and attention switching. Outcomes for both parts were recorded as completion time in seconds, with shorter times indicating better performance (Tombaugh, 2004).

The Digit Span Test included the Forward and Backward conditions. In the Forward condition, the participants repeated orally presented digit sequences in the same order, whereas in the Backward condition they repeated the sequences in reverse order. The total score was the sum of the scores obtained in both conditions. Higher scores indicated better short-term memory and working memory performance. The Digit Span Test was designated as the primary cognitive outcome (Wechsler, 2008).

Cognitive control and the ability to inhibit an automatic response were assessed using the Stroop Test. Part A represented the baseline condition, whereas part B was an interference condition requiring inhibition of the dominant response and a response consistent with the instructions. Outcomes for both parts were recorded as completion time in seconds, with shorter times indicating better performance (Stroop, 1935).

Cognitive testing was supervised by a psychologist who was unaware of the participants' group allocation. The psychologist remained blinded at both assessment time points.

The Senior Fitness Test (Fullerton Functional Fitness Test; Rikli & Jones, 2013) was administered to assess functional fitness. The test evaluated lower- and upper-body muscle strength, aerobic endurance, flexibility, and dynamic balance. PA level was assessed using the Polish version of the Physical Activity Questionnaire for the Elderly (PAQE-PL), which measures activities associated with daily functioning and recreational activity (Król-Zielińska et al., 2019).

3.3. Resistance Training Intervention

The training program comprised two sessions per week for 14 weeks. Each session lasted 45 min, and all the participants in the IG followed the same training schedule. Attendance in the IG was 100%. Sessions were supervised by an experienced trainer who had worked with older adults for many years.

The training program included primary and supplementary exercises. The primary exercises were the leg press, leg curl, bench press, and lat pulldown. Supplementary exercises included dumbbell lateral raises, abdominal exercises, back extensions, and calf raises.

Exercise intensity was monitored using the Borg Category-Ratio 10 (CR10) scale, which provides a subjective rating of perceived exertion from 0 to 10, with higher values indicating greater exertion (Borg, 1998). Training intensity and volume were progressively increased throughout the program. During the first 2 weeks, the primary goal was to teach correct exercise technique, and intensity was maintained at 4–5 on the Borg CR10 scale. The participants performed two sets of 12–15 repetitions. During weeks 3–6, intensity was increased to approximately 6, and the participants performed two sets of 10–12 repetitions. During weeks 7–10, intensity was approximately 7, and training volume comprised three sets of 8–10 repetitions. During the final phase, weeks 11–14, intensity was approximately 8, and the participants performed three sets of 8–10 repetitions. Rest intervals between sets were 120 sec.

Training loads were individualized according to each participant's capabilities and subjective rating of exertion. Immediately after each exercise, the participants rated their perceived exertion using the Borg CR10 scale. When the reported intensity was below the target level, the load was increased by 2–5% for upper-body exercises and by 5–10% for lower-body exercises.

Adverse events were monitored throughout the intervention, including pain, dizziness, injuries, and deterioration in well-being. No adverse events related to participation in the training program were recorded.

3.4. Control Group

Members of the CG did not take part in any organized training intervention and were instructed to maintain their usual lifestyle throughout the study. They were also asked not to change their PA level, diet, sleep habits, or medications and reported no changes in these areas during the 14-week observation period.

3.5. Statistical Analysis

Given the small sample size ($n = 20$; 10 in the IG and 10 in the CG), the analyses were exploratory, with emphasis not only on statistical significance but also on the direction and magnitude of the observed between-group differences. The primary comparative estimate was the between-group difference between T1 and T2. In addition, analysis of covariance (ANCOVA) was performed with the T2 score as the dependent variable, group as the between-subject factor, and the T1 score as the covariate. This approach controlled for potential baseline differences between groups.

Statistical analyses were based on descriptive statistics and comparative tests for repeated measurements. For quantitative variables, the mean, standard deviation, median, minimum, and maximum were calculated; for categorical variables, counts and percentages were reported. The normality of variable distributions and within-participant changes was assessed using the Shapiro-Wilk test.

Baseline differences between groups were explored using the independent-samples Student t-test or Mann-Whitney Utest, depending on the data distribution. Within-group changes from baseline to postintervention were analysed using the paired-samples Student t-test or Wilcoxon signed-rank test. For each variable, the difference between T2 and T1 was also calculated and the magnitude of change was compared between the IG and CG. The analysis was exploratory and no adjustment for multiple comparisons was applied. Statistical significance was set at $p < 0.05$.

4. Results

No participants withdrew or were lost during the intervention. Attendance in the IG was 100%, and no adverse events occurred during the program.

PA level was assessed using the PAQE-PL (Table 2). The total *PAQE* score was similar in the IG and CG, with mean scores of 26.05 ± 4.64 points and 24.22 ± 4.18 points, respectively. This difference was not statistically significant. A statistically significant between-group difference was observed for the physical activity subscale, on which the IG had a higher score than the CG. No between-group differences were found for domestic activities, recreational activity, or the total PAQE score. Domestic activities, physical activity, and recreational activity are components of the PAQE-PL. Domestic activities refer to routine household tasks, physical activity includes exercise and other forms of purposeful activity, and recreational activity refers to activities undertaken during leisure time.

Table 2. Physical activity level assessed using the PAQE-PL

Variable	IG, M ± SD	CG, M ± SD	IG-CG difference	95% CI for difference	*p*
Domestic activities	19.70 ± 4.47	19.80 ± 4.44	−0.10	[−4.29, 4.09]	0.961
Physical activity	4.29 ± 1.74	2.58 ± 1.85	1.71	[0.03, 3.40]	0.047
Recreational activity	2.06 ± 1.53	1.84 ± 1.05	0.22	[−1.01, 1.46]	0.710
Total PAQE score	26.05 ± 4.64	24.22 ± 4.18	1.83	[−2.32, 5.99]	0.366

Note: PA, physical activity; IG, intervention group; CG, control group; PAQE-PL, Polish version of the Physical Activity Questionnaire for the Elderly; M, mean; SD, standard deviation; CI, confidence interval. Domestic activities, physical activity, and recreational activity are components of the PAQE-PL. The IG-CG difference represents the difference in means between the intervention and control groups. *p* values refer to between-group comparisons.
Source: Authors' own work

Functional fitness was assessed using the component tests of the Senior Fitness Test. No statistically significant between-group differences were observed for most tests (Table 3). The only significant difference was found for the 30-sec arm curl test, in which the IG achieved a higher score than the CG.

Table 3. Functional fitness assessed using the Senior Fitness Test

Test	IG, M ± SD	CG, M ± SD	IG-CG difference	95% CI for difference	*p*
30-sec chair stand [repetitions]	19.20 ± 4.02	17.20 ± 5.61	2.00	[−2.59, 6.59]	0.373
30-sec arm curl [repetitions]	19.40 ± 4.14	15.30 ± 3.56	4.10	[0.47, 7.73]	0.029
2-min step test [steps]	139.10 ± 44.21	119.60 ± 27.12	19.50	[−14.96, 53.96]	0.253
Chair sit-and-reach [cm]	−0.10 ± 9.96	−1.30 ± 6.58	1.20	[−6.73, 9.13]	0.755
Back scratch [cm]	−2.30 ± 8.96	−1.60 ± 5.27	−0.70	[−7.61, 6.21]	0.834
8-foot up-and-go test [sec]	7.46 ± 1.88	7.43 ± 1.21	0.03	[−1.46, 1.51]	0.972

Note: IG, intervention group; CG, control group; M, mean; SD, standard deviation; CI, confidence interval. The IG-CG difference represents the difference in means between the intervention and control groups. *p* values refer to between-group comparisons.
Source: Authors' own work

Before the intervention, no statistically significant between-group differences were observed in cognitive test scores, including TMT-A, TMT-B, the Digit Span Test, and both parts of the Stroop Test. No statistically significant baseline differences were detected; however, given the small sample size, this finding should not be interpreted as evidence of baseline equivalence between the groups. Lower scores indicated better performance on timed tests, whereas higher scores indicated better performance on the Digit Span Test (Table 4).

Table 4. Comparison of cognitive test scores at T1

Variable	IG, M ± SD	CG, M ± SD	IG-CG difference	95% CI for difference	*p*
TMT-A [sec]	26.86 ± 6.01	31.19 ± 14.03	−4.33	[−14.47, 5.81]	0.387
TMT-B [sec]	50.70 ± 6.78	43.33 ± 11.88	7.37	[−1.71, 16.46]	0.110
Digit Span [points]	14.50 ± 4.81	14.30 ± 3.20	0.20	[−3.64, 4.04]	0.914
Stroop A [sec]	27.81 ± 4.47	25.71 ± 4.48	2.10	[−2.10, 6.31]	0.307
Stroop B [sec]	51.64 ± 5.12	45.60 ± 10.28	6.03	[−1.60, 13.66]	0.120

Note: T1, baseline assessment; IG, intervention group; CG, control group; M, mean; SD, standard deviation; CI, confidence interval; TMT, Trail Making Test; sec, seconds. The IG-CG difference represents the difference in means between the intervention and control groups. *p* values refer to between-group comparisons.
Source: Authors' own work

After the 14-week resistance training programme, the IG showed improvement across all cognitive tests. For timed tests, improvement was reflected by shorter completion times, whereas for the Digit Span Test it was reflected by a higher score. Statistically significant within-group improvements were observed in the IG for TMT-A, TMT-B, the Digit Span Test, Stroop A, and Stroop B. No statistically significant changes were observed in the CG for any cognitive test (Table 5).

Table 5. Changes in cognitive test scores in the IG and CG

Test	Δ IG, M ± SD	Δ CG, M ± SD	ΔIG-ΔCG difference	95% CI for Δ difference	*p* for Δ	Hedges' g
TMT-A [sec]	−5.13 ± 4.23	−1.78 ± 8.06	−3.35	[−9.40, 2.70]	0.260	−0.50
TMT-B [sec]	−7.63 ± 5.57	−0.60 ± 5.43	−7.03	[−12.20, −1.87]	0.010	−1.23
Digit Span [points]	2.40 ± 1.90	−0.10 ± 1.45	2.50	[0.91, 4.09]	0.004	1.42
Stroop A [sec]	−2.84 ± 2.94	4.76 ± 10.70	−7.59	[−14.96, −0.22]	0.044	−0.93
Stroop B [sec]	−4.63 ± 5.62	4.78 ± 9.93	−9.41	[−16.99, −1.83]	0.018	−1.12

Note: Δ, change from T1 to T2 (T2-T1); IG, intervention group; CG, control group; M, mean; SD, standard deviation; CI, confidence interval; TMT, Trail Making Test; sec, seconds. For timed tests, negative values indicate improvement, whereas for Digit Span, positive values indicate improvement. A 95% CI excluding 0 indicates evidence of a between-group difference in change.
Source: Authors' own work

ANCOVA showed that, after adjustment for baseline values, a statistically significant group effect remained only for the Digit Span Test. The effects for TMT-B, Stroop A, and Stroop B did not reach the prespecified significance threshold of $p < 0.05$ (Table 6).Because TMT-A, TMT-B, Stroop A, and Stroop B were secondary exploratory outcomes and no adjustment for multiple comparisons was applied, their findings should be interpreted cautiously and as hypothesis-generating.

Change-score analyses showed favourable changes across all cognitive tests in the IG, whereas no statistically significant changes were observed in the CG. After ANCOVA, a statistically significant adjusted between-group difference was observed only for the Digit Span Test, while the adjusted differences for TMT-B, Stroop A, and Stroop B did not reach statistical significance. Accordingly, only the Digit Span result remained statistically significant after baseline adjustment; the TMT and Stroop findings should be regarded as exploratory.

Table 6. ANCOVA of T2 outcomes adjusted for T1 scores

Test	Adjusted T2 IG-CG difference	95% CI for adjusted difference	*p* for group effect	Partial η^2
TMT-A [sec]	−4.39	[−10.24, 1.45]	0.131	0.13
TMT-B [sec]	−4.67	[−9.41, 0.08]	0.054	0.20
Digit Span [points]	2.57	[1.55, 3.58]	< 0.001	0.63
Stroop A [sec]	−7.06	[−14.82, 0.71]	0.072	0.18
Stroop B [sec]	−5.74	[−12.39, 0.91]	0.086	0.16

Note: ANCOVA, analysis of covariance; T1, baseline assessment; T2, postintervention assessment; IG, intervention group; CG, control group; CI, confidence interval; TMT, Trail Making Test; sec, seconds; η^2, partial eta squared. The adjusted T2 difference between the IG and CG was estimated after controlling for the T1 score.
Source: Authors' own work

5. Discussion

The present study aimed to assess the effects of a 14-week resistance training programme on cognitive function in adults older than 60 years who regularly engaged in recreational physical activity. The main finding was a favourable change in working memory, assessed using the Digit Span Test, which was the only cognitive outcome for which the group effect remained statistically significant after adjustment for baseline values in ANCOVA. Favourable changes were also observed in the IG for TMT-A, TMT-B, Stroop A, and Stroop B; however, after adjustment for baseline values, the effects for TMT-B, Stroop A, and Stroop B did not reach statistical significance. Accordingly, the TMT and Stroop findings should be regarded as exploratory. The findings should therefore be interpreted cautiously as preliminary evidence suggesting a potentially beneficial effect of resistance training rather than definitive proof of intervention efficacy. The results are consistent with previous evidence indicating that PA may be associated with better cognitive functioning during aging. Northey et al. (2018) found that exercise interventions in adults older than 50 years may improve cognitive functioning, particularly executive function.

Similarly, Chen et al. (2020) reported that executive functions are among the cognitive domains particularly responsive to regular PA.

The present findings are also consistent with intervention studies of resistance training. Cassilhas et al. (2007) found that 24 weeks of moderate- or high-intensity resistance training may improve cognitive function in older adults. Although the intervention in the present study was shorter, lasting 14 weeks, the direction of change was similar, particularly for working memory and selected indicators of executive function.

The improvement in the Digit Span Test, the primary cognitive outcome, was particularly noteworthy. The score increased from 14.50 ± 4.81 to 16.90 ± 3.31 points in the IG, whereas no improvement was observed in the CG. The between-group difference in change was statistically significant. This finding is consistent with the meta-analysis by Coelho-Junior et al. (2022), which showed that resistance training may improve cognitive function in older adults, including memory-related domains. Improvements in working memory may have practical relevance because this cognitive domain contributes to planning, decision-making, and the performance of complex activities of daily living.

In the IG, TMT-B completion time decreased, and the between-group difference in change was statistically significant in the primary change-score analysis. However, TMT-B was a secondary exploratory outcome, and its adjusted group effect did not reach statistical significance in ANCOVA. This finding may suggest a potentially beneficial effect of the intervention on executive function, but it requires confirmation in studies with greater statistical power. Liu-Ambrose et al. (2010) reported a similar pattern, showing beneficial effects of 12 months of resistance training on executive function in older women. Similar caution is warranted when interpreting the Stroop Test results. Between-group change scores for Stroop A and Stroop B favoured the IG, but the effects did not reach statistical significance after ANCOVA. Because no adjustment for multiple comparisons was applied to the secondary outcomes, the TMT and Stroop findings should be considered exploratory and hypothesis-generating. Any potential effects on cognitive control and inhibition of automatic responses therefore require confirmation in larger, adequately powered trials, particularly given the small sample size, individual variability, and repeated test administration.

Nagamatsu et al. (2012) showed that resistance training may improve cognitive function and functional brain plasticity in older adults with probable mild cognitive impairment. Their population differed from that of the present study because it included individuals with reduced cognitive functioning. Nevertheless, those findings support the premise that resistance training may influence cognitive mechanisms related to executive control. The present study included older adults without self-reported or diagnosed neurological or psychiatric conditions affecting cognition. However, because no formal cognitive screening test was administered, the participants should not be characterized as cognitively unimpaired.

The present findings may also be considered in relation to studies of the long-term effects of resistance training. Best et al. (2015) found that resistance training may have lasting effects on cognitive function and brain volume in older women. The present study did not include long-term follow-up or neuroimaging assessment. Further research is therefore needed to determine whether improvements observed after 14 weeks persist after the training program ends. The Study of Mental and Resistance Training (SMART) is also relevant: Fiatarone Singh et al. (2014) reported beneficial effects of resistance training on cognitive function in individuals with mild cognitive impairment (MCI). However, SMART involved individuals with MCI, whereas the present study included older adults without self-reported or diagnosed neurological or psychiatric conditions affecting cognition. Taken together, these findings suggest that resistance training may have potential relevance across populations with different levels of cognitive functioning, but this requires further adequately powered randomized trials. The mechanisms underlying the observed changes are likely multifactorial.

Stillman et al. (2020) suggested that the beneficial effects of PA on brain function may be associated with enhanced neuroplasticity, improved cerebral perfusion, regulation of glucose metabolism, and changes in neurotrophic factors. In resistance training, neuromuscular adaptations and gains in muscle strength may also be important. Mavros et al. (2017) further showed that improvements in cognitive function after resistance training may be partly mediated by strength gains.

6. Conclusion and Implications

It is important to note that the groups were comparable in baseline cognitive test scores. No significant baseline differences were observed for TMT-A, TMT-B, the Digit Span Test, Stroop A, or Stroop B. However, the IG achieved a higher score on the 30-sec arm curl test and a higher score on the PAQE-PL physical activity subscale. These differences should be considered when interpreting the findings because they may indicate a slightly higher baseline level of selected activity and fitness components in the IG. The ANCOVA was therefore important: the postintervention score was treated as the dependent variable, group as the between-subject factor, and the baseline score as the covariate. After adjustment for baseline values, a statistically significant group effect remained only for the Digit Span Test. The effects for TMT-B, Stroop A, and Stroop B did not reach statistical significance, although the corresponding partial eta-squared values were moderate. These findings identify the Digit Span Test as the only cognitive outcome with a statistically significant adjusted group effect and reinforce the need to treat the TMT and Stroop findings as exploratory, particularly given the pilot design and small sample size.

Potential practice effects associated with repeated cognitive testing should also be considered. TMT, Stroop, and Digit Span were administered twice, and some improvement may have resulted from greater familiarity with the procedures at the postintervention assessment. The presence of the CG reduced, but did not eliminate, this concern. In addition, members of the IG attended supervised sessions, had regular social contact, followed a structured activity schedule, and received instructor support, whereas the CG received no active comparison intervention. The absence of an active control condition limits the extent to which the observed changes can be attributed specifically to resistance training. A future definitive trial will include an active control group completing a programme of comparable frequency and duration, such as stretching, relaxation exercises, health education, or regular meetings. This design will provide better control for the effects of social contact, instructor supervision, participant expectations, and participation in a structured program.

This study has several limitations. The findings should be interpreted cautiously because of the small sample size, lack of long-term follow-up, absence of an active control condition, and potential practice effects associated with repeated cognitive testing. Although the psychologist supervising the cognitive testing was unaware of group allocation, blinding was not possible for the trainer and principal investigator. This may have increased the risk that intervention-related expectations influenced the findings. In the future definitive trial, this issue will be addressed by further separating the roles of those delivering the intervention, collecting the data, and conducting the analyses. Moreover, although ANCOVA showed a statistically significant group effect for working memory, the other cognitive outcomes did not reach statistical significance after adjustment for baseline values. In addition, no adjustment for multiple comparisons was applied to the secondary exploratory outcomes, which further limits confirmatory interpretation of the TMT and Stroop results. Furthermore, the study did not assess biomarkers of neuroplasticity, neuroimaging outcomes, or direct physiological mechanisms that might explain the observed cognitive changes.

Despite these limitations, the study also has several strengths, including its randomized design, the presence of a CG, a structured 14-week training intervention, 100% attendance in the IG, and the use of multiple cognitive tests assessing different domains of cognitive function. The reporting of effect sizes and ANCOVA results is another strength, as statistical significance alone may not fully reflect the magnitude of the observed changes in a small exploratory study.

The preliminary findings indicate that a 14-week supervised resistance training programme for older adults was feasible and safe, as demonstrated by 100% attendance, no withdrawals, and no recorded adverse events. For cognitive outcomes, a statistically significant adjusted group effect was observed only for the Digit Span Test; the TMT and Stroop findings should be considered exploratory. The observed cognitive findings, particularly the working-memory result, should be regarded as preliminary estimates of the direction and magnitude of a potential effect rather than proof of intervention efficacy. These data may help refine study procedures and inform sample size planning for a future adequately powered randomized controlled trial.

CRediT Authorship Contribution Statement

SL: study design, data collection, statistical analysis, manuscript preparation; **BP:** study design, statistical analysis, manuscript preparation.

Declaration of Competing Interest

The authors declare no conflict of interest.

Declaration of Generative AI Technologies in the Manuscript Preparation Process

During the preparation of this manuscript, the authors used ChatGPT only for translation. The authors reviewed and edited the content and take full responsibility for the final version of the manuscript.

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Zmiany funkcji poznawczych po 14-tygodniowym rekreacyjnym treningu siłowym u osób starszych: badanie pilotażowe

Streszczenie. W pilotażowym randomizowanym badaniu kontrolowanym oceniono zmiany funkcji poznawczych po 14 tygodniach nadzorowanego rekreacyjnego treningu siłowego u osób powyżej 60. roku życia. Dwudziestu uczestników losowo przydzielono do grupy interwencyjnej lub kontrolnej (po 10 osób). Interwencja obejmowała dwie nadzorowane 45-minutowe sesje tygodniowo, a intensywność zwiększano według skali Borg CR10. Przed oraz po interwencji oceniano poziom funkcji poznawczych w obu grupach za pomocą Testu Łączenia Punktów, Testu Stroopa i Testu Pamięci Cyfrowej. Korzystne zmiany odnotowano we wszystkich testach w grupie interwencyjnej, natomiast w grupie kontrolnej nie wystąpiły istotne zmiany wewnątrzgrupowe. Zmiany międzygrupowe przemawiały na korzyść treningu siłowego w TMT-B, Teście Powtarzania Cyfr oraz częściach A i B Testu Stroopa, przy czym wyniki TMT i Stroopa miały charakter wtórny i eksploracyjny. Po uwzględnieniu wartości wyjściowych istotny pozostał jedynie efekt dla Testu Powtarzania Cyfr. Trening siłowy może poprawiać wybrane funkcje poznawcze, zwłaszcza pamięć roboczą, u osób starszych. Wyniki te wymagają potwierdzenia w liczniejszych randomizowanych badaniach kontrolowanych.

Słowa kluczowe: trening siłowy, funkcje poznawcze, pamięć robocza, siła mięśniowa, osoby starsze