

Effects of combined aerobic and resistance training compared to aerobic training alone on physical fitness and cognitive function in overweight and obese older adults: A randomized controlled trial

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ABSTRACT

The problem of obesity among older adults is becoming increasingly serious, leading to declines in physical fitness and cognitive function. While aerobic exercise (AE) is widely recommended for improving cardiometabolic health, combining it with resistance training (CARE) may yield broader functional benefits. This study aimed to evaluate and contrast the impacts of AE and CARE interventions on physical fitness and cognitive performance among older adults with overweight or obesity. A 12-week randomised controlled trial was conducted involving 46 overweight and obese older adults. Participants were randomized to aerobic exercise (AE) or AE + resistance training (CARE). Outcomes included body composition, senior fitness, and neuropsychological assessments. Both improved, with distinct effects: AE yielded greater reductions in weight, BMI, fat mass, and waist-hip ratio; CARE increased skeletal muscle mass, had larger strength gains, and showed greater improvements in Mini-Mental State Examination and memory tasks. Both benefit physical and cognitive outcomes in obese older adults. AE is particularly effective for fat reduction, while CARE confers additional advantages in muscle preservation, strength, and cognition. CARE may therefore represent a more comprehensive intervention to enhance health aging and maintain daily independence in this population.

Keywords: Sport medicine, Combined training, Aerobic exercise, Physical fitness, Cognitive function, Older adults with obesity.

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INTRODUCTION

Globally, rates of overweight and obesity among older adults have been steadily increasing. In the last thirty years, the obesity rate among adults has more than doubled (World Health Organization, 2024), making it a significant public health issue. This rising trend is particularly concerning, as obesity in older adults substantially elevates the risk of chronic conditions, including cardiovascular disease, type 2 diabetes, metabolic syndrome, and certain cancers (Caterson et al., 2004; Smith et al., 2005). These comorbidities contribute significantly to morbidity and healthcare burden in aging populations. From a physical fitness perspective, obesity exacerbates age-related declines in mobility, muscular strength, and endurance (Cortes et al., 2025; Zamboni et al., 2008). It accelerates the progression of sarcopenia, impairs balance, and increases the risk of falls, thereby threatening physical independence (Cruz-Jentoft et al., 2019). Finally, from a cognitive perspective, obesity can adversely affect the central nervous system and further affect cognitive domains such as executive function, memory and learning ability (Deng et al., 2025). Therefore, overweight and obesity diminish the quality of life in older adults and raise the risk of frailty, disability, and institutionalisation.

Physical exercise is widely acknowledged as a non-drug strategy for combating aging and obesity. Among various exercise modalities, aerobic exercise (AE) has received extensive attention because it can enhance physical fitness, cardiovascular health, lipid metabolism, as well as cognitive functions such as memory and attention (Bai et al., 2022; Hu et al., 2024). However, AE alone may be insufficient to address the multifaceted challenges encountered by older adults with obesity, including deficits in muscle strength, balance capacity, and executive function. In contrast, resistance training (RE) has demonstrated superior efficacy in improving muscular strength, power, and glucose metabolism (Andersson et al., 2017). Recently, researchers have begun investigating combined aerobic and resistance exercise (CARE) approaches, hypothesising that such integrated regimens may yield superior benefits across both physiological and cognitive domains.

Multiple studies have demonstrated that CARE yields greater improvements than single-modality programs in health outcomes in older adults. Firstly, compared with AE and anaerobic exercise, aerobic exercise combined with anaerobic exercise can improve cardiovascular indicators in the elderly more effectively, and reduce inflammation markers (Marzolini et al., 2012; Ihalainen et al., 2018). Secondly, from a physical performance perspective, CARE significantly enhances functional mobility, muscular strength, and overall physical capacity (Bai et al., 2022; Burich et al., 2015]. Thirdly, from a cognitive perspective, CARE may promote brain health by improving cerebral perfusion, lowering inflammatory responses, and stimulating the release of neurotrophic molecules such as brain-derived neurotrophic factor (BDNF), which play key roles in neural plasticity, neurogenesis, and overall cognition (Marinus et al., 2019; Cefis et al., 2023). However, although evidence on CARE has grown, few trials have directly contrasted its effects with AE in terms of physical performance and cognitive health among obese older adults.

Considering the rapid decline in physical and cognitive ability among overweight and obese older adults, this study compared the effects of a 12-week CARE program with AE alone. By focusing on this high-risk population, the research fills a key gap and provides evidence for developing personalised exercise intervention programs to promote healthy aging and overall well-being.

MATERIALS AND METHODS

Research design

This research employed a randomised controlled trial conducted at the community fitness centre of Xiangshuwan Community in Weifang, Shandong Province, China. Participants were recruited between October 2024 and January 2025 through posted announcements at local senior activity centres and residential bulletin boards. After completing baseline assessments and providing written informed consent,

eligible individuals were randomly allocated to either the CARE or AE group. Randomisation was computer-generated, and allocations were concealed in numbered, sealed envelopes by independent researchers not involved in other study procedures.

All exercise sessions were carried out over a 12-week intervention period and were fully supervised by certified instructors at the community gym. Outcome measurements were performed by assessors blinded to group assignments. To ensure blinding integrity, assessors were: (1) not involved in intervention delivery, (2) physically separated from training sessions, and (3) provided with anonymised participant IDs during testing. Primary outcome measures included physical fitness and cognitive function, assessed both at baseline and post-intervention (12 weeks). To minimise external confounding factors and ensure comparability between groups, all participants were instructed to maintain their habitual diet and lifestyle throughout the intervention period and to avoid additional exercise during the trial. The protocol was approved by the Ethics Committee of Zhucheng People's Hospital (Approval No. 2025CY007).

Figure 1 shows the flowchart of the participants. Among the 78 subjects who passed the screening, 28 were excluded for not meeting the criteria ($n = 15$), refusing to participate ($n = 8$), or for other reasons ($n = 5$). Fifty eligible participants were randomised equally into the CARE group ($n = 25$) or the AE group ($n = 25$). During the 12-week intervention, 1 participant in the CARE group and 3 in the AE group were lost to follow-up or discontinued the intervention. Final analyses included 24 participants in the CARE group and 22 in the AE group.

Figure 1 shows the flowchart of the test participants. Among the 78 subjects who passed the screening, 28 were excluded for not meeting the criteria ($n = 15$), refusing to participate ($n = 8$), or for other reasons ($n = 5$). Ultimately, 50 qualified subjects were randomly and equally assigned to the CARE group ($n = 25$) and the AE group ($n = 25$). During the 12-week intervention period, one subject in the CARE group and three subjects in the AE group withdrew halfway. Ultimately, the CARE group retained 24 subjects, while the AE group retained 22 subjects.

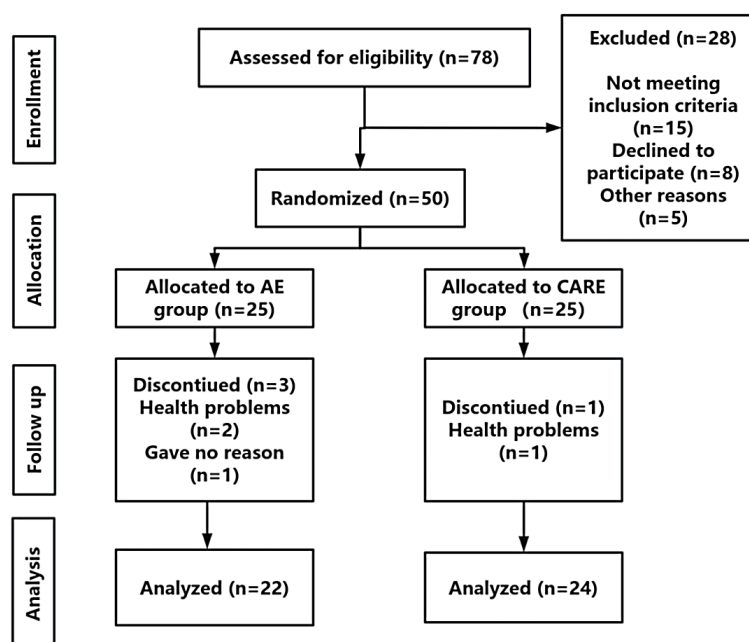


Figure 1. Participant flow diagram

Participants

Inclusion criteria for participants were as follows: Aged 60–74 years; body mass index (BMI) ≥ 24 kg/m², based on the diagnostic criteria for overweight and obesity in Chinese adults (Chen et al., 2023); no regular participation in exercise interventions within the past six months; and adequate cognitive and physical function to independently complete the training tasks. Exclusion criteria included any severe cardiovascular disease, neurological disorders, or musculoskeletal and joint conditions that could impair exercise performance. All subjects who met the inclusion criteria were randomly assigned to the CARE group or the AE group after signing written informed consent.

Sample size calculations were conducted in G*Power 3.1. Using a repeated-measures ANOVA with interaction effects, the study parameters were defined as follows: effect size $f = 0.25$, significance level $\alpha = .05$, statistical power $(1-\beta) = 0.90$, groups = 2 (CARE vs. AE), measurement points = 2 (baseline and week 12), and an assumed correlation among repeated measures of 0.5. The calculation shows that a minimum of 46 participants was needed. To maintain adequate statistical power and account for potential attrition, a total of 50 participants were planned for recruitment.

To minimise the influence of non-exercise-related factors on study outcomes, all participants were asked to keep their usual dietary patterns and daily routines during the intervention period and to avoid additional lifestyle or other exercise programs. To further account for lifestyle-related confounding effects, baseline dietary intake and physical activity were also assessed.

Intervention programme

Each formal training session was preceded and followed by a 10-minute warm-up and a 10-minute post-exercise relaxation, including both dynamic and static stretching exercises, all supervised by certified fitness instructors.

Participants in the CARE group attended three training sessions every Monday, Wednesday and Friday. Each session began with 30 minutes of moderate-intensity AE performed on a motorised treadmill (Johnson Fitness, USA). According to the definition of the American College of Sports Medicine (ACSM) (Garber et al., 2011), by separately adjusting the speed and slope of the treadmill, an exercise intensity equivalent to 64–76% of the subject's maximum heart rate (HR_{max}) can be achieved and maintained. HR_{max} was estimated using the equation $HR_{max} = 220 - \text{age}$, and heart rate was continuously monitored via a Polar H10 heart rate monitor (Polar Electro, Finland). In addition, participants' heart rates were recorded at the beginning, midpoint, and end of each aerobic session to ensure that they stayed within the target zone.

Immediately after AE, participants performed moderate-intensity resistance training at 50–69% of their one-repetition maximum (1RM), determined according to ACSM guidelines (Pollock et al., 1998). The resistance training component was machine- and dumbbell-based and targeted major upper body, core, and lower body muscle groups. Exercises were organised into two alternating routines: on Mondays and Fridays, participants performed Dumbbell Half Squat, Dumbbell Front Raise, Bent-Over Dumbbell Row, Dumbbell Shoulder Press, Dumbbell Bicep Curl, and Dumbbell Fly; on Wednesdays, Seated Chest Press, Lat Pulldown, Seated Row, Dumbbell Lunge, Seated Leg Curl, and Back Extension. Each exercise was performed in 3 sets, with 12 to 15 repetitions in each set. There was a 60–90 second break between sets, totalling approximately 20 minutes of resistance training. Training loads were progressively increased by 2–5% once participants could complete the upper limit of repetitions (15 reps) in all sets with correct form.

Participants in the AE group performed only the aerobic component at the same frequency (three times per week) and intensity (64–76% HRmax) as the CARE group. Each AE session lasted 50 minutes, with treadmill speed and incline adjusted to maintain the target heart rate, and heart rate continuously monitored in the same manner as in the CARE group.

Physical fitness outcome measures

This study employed the Senior Fitness Test (SFT) as the primary assessment tool for evaluating physical fitness. The SFT, developed by Rikli and Jones (1999), is widely applied in the elderly population and has demonstrated strong content, construct, and discriminative validity, as well as high reliability and test-retest consistency across numerous studies (Hesseberg et al., 2015). Moreover, it is also regarded as a practical, easy-to-manage and highly secure detection method, suitable for assessing the functional health of the elderly (Bhattacharya et al., 2016). Guided by this approach, the present study assessed five core aspects of physical fitness, namely body composition, muscular strength, flexibility, agility with dynamic balance, and aerobic endurance, through a series of validated, evidence-supported tests conducted at the start and end of the 12-week program.

Body composition was measured using the InBody 270 bioelectrical impedance analyser, which is highly consistent with dual-energy X-ray absorptiometry and is widely used in clinical and sports science research (Czartoryski et al., 2020). Indicators obtained included weight, BMI, skeletal muscle mass (SMM), body fat mass (BFM), body fat percentage (BFP), and waist-to-hip ratio (WHR). Muscular strength was tested through three methods: the 30-second chair stand (30s CS) for lower-limb strength, the 30-second arm curl (30s AC) for upper-limb strength, and grip strength (GS) using a CAMRY EH101 digital dynamometer with established reliability (Sánchez-Aranda et al., 2024). Flexibility was measured with the sit-and-reach test (SR) and the back scratch test (BS). Agility and balance were evaluated by the 2.4-meter up-and-go (2.4m UG) and the single-leg stance (SLS). Finally, aerobic endurance was evaluated using the 2-minute step test (2-min ST), a practical tool for estimating cardiorespiratory fitness in this population.

In summary, the assessment framework provided a comprehensive, well-structured approach for evaluating the multidimensional impact of exercise interventions on the physical fitness of older adults with obesity.

Cognitive function outcome measures

Cognitive function is typically divided into several core areas, including global cognition, memory, attention, language, executive function, visuomotor coordination, and processing speed (Harvey, 2019). To comprehensively assess these domains, this study employed a battery of validated cognitive tests.

Cognitive function was assessed using the Mini-Mental State Examination (MMSE), a commonly adopted screening instrument for older adults that is concise, straightforward to administer, and supported by strong evidence of reliability and validity (Baek et al., 2006). To further measure attention and memory, the Digit Span Test (DST) was applied, including the forward sequence (DST-F), which reflects immediate attentional capacity, and the backward sequence (DST-B), which evaluates working memory and the ability to mentally manipulate information (Ostrosky-Solís & Lozano, 2006).

Executive function was examined through the Trail Making Test (TMT), including Part A (TMT-A) and Part B (TMT-B), which also capture participants' processing speed, cognitive flexibility, and task-switching capabilities (Cangoz et al., 2009). Additionally, the Simple Reaction Time Test (SRT) measured participants' response speed, while the Grooved Pegboard Test (GPT) evaluated visuomotor coordination and fine motor

skills—key parameters for assessing hand-eye coordination in neuropsychological evaluation (Johnson et al., 1985, Heintz Walters et al., 2021).

Overall, the cognitive assessment tools employed in this study demonstrated high reliability, validity, and feasibility, proving particularly suitable for evaluating overweight and obese older adults both before and after interventions.

Statistical analysis

Data analysis was performed with IBM SPSS Statistics 26.0. A per-protocol framework was applied, retaining participants who fulfilled the assessment schedule and attended at least 80% of sessions, without substitution for missing cases.

First, to evaluate the changes within the group before and after the intervention, we first used the Shapiro Wilke test to conduct a normality test on the continuous variables. For the data that conform to the assumption of normal distribution, paired-sample t-tests assessed within-group differences. When data violated normality assumptions, non-parametric tests such as the Wilcoxon signed-rank test were adopted.

Second, to compare post-intervention outcomes between groups, this study employed covariance analysis (ANCOVA) and adjusted the baseline measurements to control for their potential impact. ANCOVA was performed only if its underlying assumptions were met, including a linear relationship between the covariate and the dependent variable, homogeneity of regression slopes, and equivalence of covariate distribution across groups. If these assumptions were not satisfied, a difference score approach (post-test minus pre-test) was adopted, and between-group differences were analysed using the Mann–Whitney U test. All tests were two-tailed, with significance defined as $p < .05$.

RESULTS

Baseline characteristics

Table 1 illustrates the baseline characteristics. Participants in the AE group and the CARE group demonstrated comparable values across all demographic, physical, and cognitive variables. The AE group had a mean age of 66.36 ± 4.46 years, compared with 65.54 ± 4.37 years in the CARE group. Height and weight were similar between groups. Measures of body composition, including BMI, SMM, BFM, BFP, and WHR, showed no notable differences. Performance on physical fitness assessments such as the 30s CS, 30s AC, GS, SR, BS, 2.4m UG, SLS, and 2-minute ST were broadly comparable between the two groups. Baseline cognitive function, as assessed by the MMSE, DST-F, DST-B, GPT, SRT, TMT-A and TMT-B, also showed no observable group differences.

Physical fitness

Effects of aerobic exercise and combined aerobic and resistance exercise on body composition

Significant within-group improvements were found in both the AE and CARE groups after the intervention. In the AE group, weight, BMI, BFM, BFP, SMM, and WHR all showed significant reductions following the intervention ($p < .05$). In the CARE group, weight, BMI, BFM, BFP, and WHR significantly decreased post-intervention, while SMM increased ($p < .05$), as shown in Table 2.

Both groups showed marked enhancements in body composition post-intervention. Weight and BMI showed no significant differences between groups, and effect sizes were small, indicating similar outcomes. However, CARE training significantly increased skeletal muscle mass compared to AE ($p < .001$, $ES = 0.257$), whereas

AE produced greater reductions in body fat mass ($p = .035$, $ES = 0.311$) and waist-hip ratio ($p = .001$, $ES = 0.218$). Body fat percentage decreased markedly in both groups without a notable between-group difference. Overall, AE was more effective for fat reduction, while CARE was superior in preserving and increasing muscle mass.

Table 1. The characteristics of the study subjects at baseline.

Test item	AE group, n = 22	CARE group, n = 24	p-value
Age	66.36 ± 4.46	65.54 ± 4.37	.51
Height	164.66 ± 6.33	163.23 ± 8.23	.52
Weight	72.81 ± 7.57	71.51 ± 9.26	.606
BMI	26.83 ± 2.52	26.67 ± 1.5	.794
SMM	25.41 ± 3.8	24.58 ± 5.05	.531
BFM	25.81 ± 5.98	25.85 ± 3.3	.975
BFP	35.36 ± 6.03	36.44 ± 4.48	.491
WHR	0.97 ± 0.06	0.96 ± 0.05	.748
30s CS	19.59 ± 4.07	19.54 ± 5.98	.974
30s AC	25.05 ± 5.28	25.83 ± 3.61	.555
GS	30.23 ± 7.86	30.5 ± 8.76	.912
SR	8.47 ± 8.83	2.83 ± 10.9	.061
BS	-22.1 ± 11.61	-19 ± 12.97	.279
2.4m UG	5.78 ± 0.61	6.02 ± 0.72	.233
SLS	4.01 ± 2.68	3.77 ± 2.5	.753
2-min ST	97.91 ± 10.74	95.5 ± 11.63	.471
MMSE	26.86 ± 2.73	26.21 ± 2.89	.434
DST-B	3.84 ± 0.67	3.5 ± 0.78	.145
DST-F	7.59 ± 1.84	7.58 ± 1.93	.989
GPT	74.04 ± 7.06	74.95 ± 4.71	.614
SRT	520.59 ± 96.66	556.13 ± 127.52	.296
TMT-A	61.94 ± 26.51	61.5 ± 14.67	.946
TMT-B	93.61 ± 18.96	96.04 ± 20.4	.687

Note: Values are presented as mean ± standard error (SE). The following abbreviations are used throughout the text and tables: BMI = body mass index; SMM = skeletal muscle mass; BFM = body fat mass; BFP = body fat percentage; WHR = waist-hip ratio; 30s CS = 30-second chair stand test; 30s AC = 30-second arm curl test; GS = grip strength; SR = sit-and-reach test; BS = back scratch test; 2.4m UG = 2.4-meter up-and-go test; SLS = single-leg stance; 2-min ST = 2-minute step test; MMSE = Mini-Mental State Examination; DST-F = forward digit span test; DST-B = backward digit span test; GPT = grooved pegboard test; SRT = simple reaction time; TMT-A and TMT-B = Trail Making Test Part A and B. The p value for the inter-group comparison of baseline data between the AE and CARE.

Table 2. Effects of aerobic exercise and aerobic resistance training on body composition.

Test item	AE group, n = 22			CARE group, n = 24			Between-group	
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value	p-value	ES
Weight	72.81 ± 7.57	70.12 ± 7.17	< .001*	71.51 ± 9.26	70.16 ± 9.29	< .001*	.817	0.034
BMI	26.83 ± 2.52	25.87 ± 2.34	< .001*	26.67 ± 1.5	26.21 ± 1.58	< .001*	.248	0.17
SMM	25.41 ± 3.8	25.22 ± 3.72	.012**	24.58 ± 5.05	25.19 ± 5.21	< .001*	< .001#	0.257
BFM	25.81 ± 5.98	23.51 ± 5.69	< .001*	25.85 ± 3.3	24.8 ± 3.88	< .001*	.035#	0.311
BFP	35.36 ± 6.03	33.66 ± 6.38	< .001*	36.44 ± 4.48	35.6 ± 4.9	.011**	.104	0.24
WHR	0.97 ± 0.06	0.93 ± 0.06	< .001*	0.96 ± 0.05	0.95 ± 0.06	.065	.001#	0.218

Note: Values are presented as mean ± standard error (SE) unless otherwise indicated. *: significant intra-group difference ($p < .01$); **: $p < .05$. #: significant between-group difference ($p < .05$, CARE vs. AE). ES = effect size. Abbreviations: BMI = body mass index; SMM = skeletal muscle mass; BFM = body fat mass; BFP = body fat percentage; WHR = waist-hip ratio.

Effects of aerobic exercise and combined aerobic and resistance exercise on senior fitness test performance
Following the intervention, the AE group demonstrated notable improvements ($p < .05$) in the 30s CS, SR, BS, 2.4m UG, SLS, and 2-minute ST. Similarly, the CARE group exhibited significant post-intervention gains ($p < .05$) in the 30s CS, 30s AC, GS, SR, 2.4m UG, SLS, and 2-minute ST.

After the intervention, both groups improved across most Senior Fitness Test items. A notable between-group difference was observed only in the 30s arm curl test, where CARE showed greater gains than AE ($p = .001$, $ES = 0.235$). CARE also demonstrated a moderate effect in the sit-and-reach test ($ES = 0.271$), suggesting an advantage in flexibility improvement. For other measures—including chair stand, grip strength, back scratch, up-and-go, single-leg stance, and 2-minute step—both groups improved significantly within groups, while between-group differences were nonsignificant, and effect sizes were small. Overall, CARE was more effective in enhancing upper limb strength and flexibility, while both interventions yielded comparable benefits in other fitness domains. These results are detailed in Table 3.

Table 3. Effects of aerobic exercise and aerobic resistance training on Senior Fitness Test.

Test item	AE group, n = 22			CARE group, n = 24			Between-group	
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value	p-value	ES
30s CS	19.59 ± 4.07	21.95 ± 4.43	.009**	19.54 ± 5.98	23.79 ± 4.75	.002**	.184	0.041
30s AC	25.05 ± 5.28	25.82 ± 4.07	.916	25.83 ± 3.61	29.83 ± 3.55	< .001*	.001#	0.235
GS	30.23 ± 7.86	30.94 ± 7.11	.107	30.5 ± 8.76	32.83 ± 8.22	.001**	.488	0.102
SR	8.47 ± 8.83	20.26 ± 14.14	.001**	2.83 ± 10.9	12.23 ± 9.74	.001**	.066	0.271
BS	-22.1 ± 11.61	-19.1 ± 14.63	.006**	-19 ± 12.97	-15.47 ± 15.28	.059	.995	< 0.001
2.4m UG	5.78 ± 0.61	5.23 ± 0.91	.001**	6.02 ± 0.72	5.13 ± 0.59	< .001*	.904	0.018
SLS	4.01 ± 2.68	6.2 ± 2.74	< .001*	3.77 ± 2.5	8 ± 8.44	.002**	1	< 0.001
2-min ST	97.91 ± 10.74	116.64 ± 13.57	< .001*	95.5 ± 11.63	111.38 ± 10.41	< .001*	.211	0.036

Note: Values are presented as mean ± standard error (SE) unless otherwise indicated. *: significant intra-group difference ($p < .01$); **: $p < .05$. #: significant between-group difference ($p < .05$, CARE vs. AE). ES = effect size. Abbreviations: 30s CS = 30-second chair stand test, number of repetitions; 30s AC = 30-second arm curl test, number of repetitions; GS = grip strength, measured in kilograms; SR = sit-and-reach test, measured in centimetres, higher score indicates better flexibility; BS = back scratch test, measured in centimetres, higher score indicates better shoulder flexibility; 2.4m UG = 2.4-meter up-and-go test, measured in seconds, lower score indicates better mobility; SLS = single-leg stance, measured in seconds, higher score indicates better balance; 2-min ST = 2-minute step test, number of steps completed.

Table 4. Effects of aerobic exercise and aerobic resistance training on cognitive function.

Test item	AE group, n = 22			CARE group, n = 24			Between-group	
	Pre-test	Post-test	p-value	Pre-test	Post-test	p-value	p-value	ES
MMSE	26.86 ± 2.73	28.23 ± 2.14	.002**	26.21 ± 2.89	28.67 ± 1.86	< .001*	.48	0.104
DST-B	3.84 ± 0.67	4.73 ± 0.99	.003**	3.5 ± 0.78	4.88 ± 1.15	< .001*	.62	0.073
DST-F	7.59 ± 1.84	8.14 ± 1.75	.151	7.58 ± 1.93	8.67 ± 1.76	.006**	.255	0.168
GPT	74.04 ± 7.06	72.62 ± 7.02	.004**	74.95 ± 4.71	72.74 ± 4.68	< .001*	.142	0.049
SRT	520.59 ± 96.66	443.23 ± 91.58	.001**	556.13 ± 127.52	457 ± 101.52	< .001*	.613	0.075
TMT-A	61.94 ± 26.51	57.89 ± 22.46	.046**	61.5 ± 14.67	57.7 ± 13.69	.002**	.952	< 0.001
TMT-B	93.61 ± 18.96	91.1 ± 19.67	.041**	96.04 ± 20.4	95.49 ± 18.79	.762	.312	0.024

Note: Values are presented as mean ± standard error (SE) unless otherwise indicated. *: significant intra-group difference ($p < .01$); **: $p < .05$. #: significant between-group difference ($p < .05$, CARE vs. AE). ES = effect size. Abbreviations: MMSE = Mini-Mental State Examination, score range 0–30, higher score indicates better global cognition; DST-F = forward digit span test, score range 0–9; DST-B = backward digit span test, score range 0–9; GPT = grooved pegboard test, time in seconds, lower score indicates better fine motor control; SRT = simple reaction time, measured in milliseconds, lower score indicates faster response; TMT-A and TMT-B = Trail Making Tests A and B, measured in seconds, lower score indicates better executive function and task-switching ability.

Effects of aerobic exercise and combined aerobic and resistance exercise on cognitive function

Following the intervention, the AE group demonstrated notable gains ($p < .05$) in the MMSE, DST-B, GPT, SRT, and TMT-A and TMT-B, whereas DST-F showed no measurable change. Similarly, the CARE group showed marked enhancements ($p < .05$) in MMSE, DST-B, DST-F, GPT, SRT, and TMT-A, while no significant change was found in TMT-B.

Both AE and CARE groups showed improvements in most cognitive tests after the intervention. CARE had slightly greater gains in DST-B and DST-F, with small to moderate effect sizes ($ES = 0.073$ – 0.168), indicating modest advantages in working and short-term memory. Other measures—including MMSE, grooved

pegboard test, simple reaction time, and Trail Making Tests A and B—showed similar improvements between groups, with negligible effect sizes. Overall, CARE training offered slight benefits in memory tasks, while both interventions produced comparable improvements in global cognition, executive function, and fine motor control. These results are detailed in Table 4.

DISCUSSIONS

This research compared 12-week AE and CARE interventions on physical fitness and cognitive performance in overweight and obese older adults. The findings revealed significant within-group improvements in both interventions, although differences in the direction and magnitude of these improvements was also evident.

Regarding body composition, the AE group exhibited significant decreases in weight, BMI, BFM, BFP, and WHR, indicating a stronger effect in weight and fat control. The CARE group also improved in fat-related measures but achieved a more notable gain in SMM, emphasising the value of resistance training for preserving and increasing muscle mass. Group comparisons supported these patterns: AE was more effective in lowering BFM and WHR, whereas CARE produced a greater rise in SMM, suggesting that the two training approaches complement one another in shaping body composition. Both groups had similar outcomes in weight and BMI, with small effect sizes, pointing to comparable benefits in overall weight control. These results align with earlier findings that resistance-inclusive training not only facilitates fat reduction but also more effectively maintains or augments muscle mass (Villareal et al., 2017; Rodrigues et al., 2023).

The differential effects between AE and CARE observed in the figures may be explained by their distinct physiological mechanisms. AE mainly enhances fat oxidation through elevated aerobic metabolism, thereby contributing to greater fat reduction (Muscella et al., 2020). In contrast, CARE combines aerobic benefits with resistance-induced muscle protein synthesis, increased muscle tension, and enhanced anaerobic capacity, which support muscle preservation and growth (McGlory et al., 2017; Fielding, 1995). These complementary adaptations explain why AE showed relatively larger improvements in fat-related indicators, while CARE demonstrated advantages in muscle-related outcomes. However, the between-group difference in BFP was not significant, likely because BFP reflects the combined influence of both fat and muscle changes, which may offset each other in this composite index.

Regarding physical fitness, both groups improved significantly across multiple tests, including 30s CS, 30s AC, SR, BS, 2.4m UG, SLS, and 2-min ST. Between-group comparisons revealed that CARE showed moderate advantages in upper limb strength (30s AC, ES = 0.235) and flexibility (SR, ES = 0.271), while improvements in other functional measures, including lower limb strength, mobility, balance, and endurance, were largely comparable between groups. This supports the role of resistance training in enhancing muscular function, which is practically important for reducing frailty and fall risk in overweight and obese older adults.

In terms of cognitive function, both AE and CARE groups showed significant within-group improvements across multiple domains, including global cognition (MMSE), working memory (DST-B), short-term memory (DST-F), visuomotor coordination (GPT), processing speed (SRT), and attention/executive functioning (TMT-A). Between-group comparisons revealed that CARE exhibited slight advantages in DST-F (ES = 0.168) and DST-B (ES = 0.073), suggesting marginal benefits for memory-related domains. The MMSE also improved more in the CARE group (2.46 points) than in the AE group (1.37 points), although the between-group effect size was small (ES = 0.104) and did not reach statistical significance. For other outcomes, including GPT, SRT, TMT-A, and TMT-B, both groups demonstrated similar gains, with small or negligible effect sizes.

Despite the lack of significant between-group differences, the numerical advantage of CARE in memory and global cognition may be related to mechanisms such as resistance training-induced upregulation of BDNF, enhanced prefrontal cortex activity, and increased cerebral blood perfusion (Ferris et al., 2007; Suo et al., 2016; Nakamura & Muraoka, 2018). Importantly, previous studies indicate that a change of 1–3 points in MMSE can be considered the minimal clinically important difference (MCID) for older adults. In this context, the 2.46-point improvement observed in the CARE group is likely to be clinically meaningful, while the 1.37-point increase in the AE group, although significant, may be closer to the lower threshold of clinical significance. Overall, both AE and CARE appear to enhance cognition, with CARE offering potential added benefits in memory-related functions.

From a public health perspective, these research findings highlight the multi-dimensional value of CARE in overweight and obese elderly people. Although AE has a significant effect on weight and fat control, CARE has more advantages in maintaining muscle mass, enhancing strength and improving cognitive status. Therefore, CARE can serve as a comprehensive intervention program for older adults, which not only delays the decline of physical functions but also maintains cognitive health, while enhancing their self-care ability and quality of life.

CONCLUSION

The findings indicate that a 12-week program of either AE or CARE led to notable improvements in body composition, physical fitness, and cognitive performance among overweight and obese older adults. While AE proved more effective for reducing weight and fat mass, the CARE protocol has more advantages in maintaining skeletal muscle mass and enhancing muscle strength. Both interventions were associated with cognitive gains, but only the MMSE revealed a significant group difference, with the CARE group achieving greater improvement.

Overall, CARE, in particular, may provide multidimensional health advantages in overweight and obese older adults. However, as most cognitive measures did not differ significantly between groups and individual variability in cognitive responses remains evident, further long-term studies are warranted. Future research should explore the neurobiological mechanisms underlying cognitive changes, including the use of biomarkers such as BDNF, and account for individual factors such as age and baseline cognitive status.

Study limitations

This study has several limitations. Recruiting participants through convenience sampling may restrict generalizability. The 12-week duration of the intervention may have been insufficient to produce significant cognitive improvement effects. The absence of physiological biomarkers limited the ability to examine underlying mechanisms. Future research should expand the sample size, extend the intervention period, and combine biomarker detection or neuroimaging techniques to assess the effects of different training programs on older adults' physical and cognitive health.

AUTHOR CONTRIBUTIONS

Conceptualization: Changyuan Zhao. Methodology: Changyuan Zhao. Data collection: Changyuan Zhao. Data analysis: Changyuan Zhao, Roxana Dev Omar Dev. Writing - original draft preparation: Changyuan Zhao. Writing - review and editing: Changyuan Zhao, Roxana Dev Omar Dev. Visualization: Changyuan Zhao, Roxana Dev Omar Dev. Supervision: Roxana Dev Omar Dev.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author, the data is not publicly available due to their containing information that could compromise the privacy of research participants.

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