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Integrating physical and cognitive training to reduce sarcopenia risk and improve cognitive function in middle-aged women

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ABSTRACT

Background: Muscle deterioration and cognitive changes are usually discussed as problems of later life, although early decline may begin during midlife, particularly among women. Preventive strategies during this period are therefore important, yet evidence remains limited regarding community-based programs that combine physical exercise and cognitive stimulation to address sarcopenia-related indicators and cognitive function simultaneously. This study examined the effects of a moderate-intensity multicomponent training program on handgrip strength, skeletal muscle mass, body fat percentage, and cognitive function in middle-aged women.

Methods: This quasi-experimental study used a pretest–posttest control group design involving eight women aged 35-45 years. Participants were assigned to an intervention group (n = 4) and a control group (n = 4). The intervention was conducted for eight weeks, three sessions per week, with each session lasting 45-60 minutes at moderate intensity. The program consisted of resistance exercises, functional movement training, and dual-task cognitive stimulation. Handgrip strength, skeletal muscle mass, body fat percentage, and cognitive function were assessed before and after the intervention. Data were analyzed using pre-post statistical testing and effect size estimation.

Results: All participants completed the study and were included in the final analysis. After the intervention, the intervention group showed increased handgrip strength (+5.29 kg, $p < 0.001$) and skeletal muscle mass (+2.75 kg, $p < 0.001$), accompanied by a reduction in body fat percentage (-2.25%, $p < 0.001$). Cognitive function also improved after the program (+1.03 points, $p < 0.001$). The magnitude of change was greatest for handgrip strength, suggesting that the program had its clearest effect on muscular function, while the cognitive improvement should be interpreted as preliminary.

Conclusion: An eight-week moderate-intensity multicomponent training program may support improvements in sarcopenia-related physical indicators and cognitive function among middle-aged women. Because of the small sample size and community-based design, the findings should be interpreted cautiously. Nevertheless, the program appears feasible as an early preventive exercise strategy during midlife.

Keywords: cognitive function, dual-task training, middle-aged women, physical activity, sarcopenia.
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INTRODUCTION

Sarcopenia is a progressive condition characterized by a decline in skeletal muscle strength, mass and function.[1] Whilst often associated with older age, the biological processes which lead to sarcopenia do not begin abruptly in old age. Unrecognized changes in muscle quality, strength, body composition and function may occur earlier, especially in middle age, as changes in lifestyle, hormonal status and reduced physical activity begin to impact health outcomes later in life.[2-5] This is particularly relevant for women, as midlife is often accompanied by physiological changes that can lead to decreased muscle strength, increased body fat and reduced metabolic resistance.[4,5]

From a public health perspective, sarcopenia is no longer viewed only as a geriatric problem. Global estimates suggest that sarcopenia affects a considerable proportion of the adult and older population, although prevalence varies according to diagnostic criteria, age range, sex, and measurement method.[4] The burden is clinically important because reduced muscle strength and muscle mass are associated with impaired mobility, lower physical independence, increased risk of falls, cardiometabolic disorders, and poorer quality of life.[2,3] These consequences indicate that preventive strategies should not be delayed until older adulthood. Rather, middle age may be a critical window of opportunity for early intervention, particularly in women who may already have subtle declines in strength and body composition prior to the clinical presentation of sarcopenia.

Apart from the physical decline, the association of sarcopenia-related markers with cognitive function has been increasingly concerned. Cognitive

function includes a variety of domains such as memory, attention, orientation, executive function, and information processing. Previous research showed that low muscle mass and reduced muscle strength are associated with poor cognitive performance.[6,7] Several biological pathways may explain such an association including chronic low-grade inflammation, oxidative stress, hormonal dysregulation, insulin resistance, and reduced production of muscle-derived factors essential for brain health.[7,8] Myokines released during muscle contraction may promote neurogenesis, synaptic plasticity, and cerebral blood flow, suggesting that skeletal muscle is involved not only in movement but also in the maintenance of cognitive function.8 Therefore, an interventions targeting both muscular and cognitive health may provide a wider preventive benefit than strategies focusing solely on physical fitness.

Regular physical activity is one of the most promising non-pharmacological strategies to preserve muscle health and to support cognitive function.[9,10] Resistance exercise and functional movement training have been shown to improve muscle strength, to preserve or increase skeletal muscle mass, and to support healthier body composition.[11-13] Exercise may also influence cognitive health through increased cerebral blood flow, increased metabolic regulation, and increased stimulation of neuroprotective factors such as brain-derived neurotrophic factor (BDNF).[14,15] Recently, dual-task interventions have garnered increasing attention as they combine physical movement with cognitive stimulation, requiring participants to coordinate motor control, attention, working memory, and executive processing in the same activity.16 This type of training may be particularly useful for preventive programs because it reflects the cognitive-motor demands of daily life.

However, there are several gaps in the current literature. First, most of the studies that examined sarcopenia and exercise interventions focused on older adults or vulnerable patients, and middle-aged women have rarely been targeted for early prevention.[4,9,10] Second, studies have tended to examine physical and cognitive outcomes separately and it is unknown whether a combined intervention can impact both domains in a single program. Third, many exercise interventions require clinical facilities, specialized equipment, or close supervision, which may limit their feasibility in community fitness settings. These gaps are important because preventive strategies for middle-aged women need to be feasible, accessible, and transferable to real-world settings.

The present study contributes scientifically by focusing on an integrated, community-based intervention for middle-aged women, prior to the onset of more advanced age-related decline. The program involved moderate-intensity resistance exercise, functional movement training, and dual-task cognitive stimulation all in one multicomponent intervention. Investigating handgrip strength, skeletal muscle mass, body fat percentage, and cognitive function together, this study provides preliminary evidence on whether a feasible training model can target sarcopenia-related indicators and cognitive performance simultaneously. As such, the objective of this study was to investigate the effects of an eight-week multicomponent physical and cognitive training program on sarcopenia-related physical indicators and cognitive function among middle-aged women.

METHODS

Study design and setting

This study used a quasi-experimental pretest–posttest control group design to examine the effects of a multicomponent physical and cognitive training program on sarcopenia-related indicators and cognitive function in middle-aged women. A quasi-experimental approach was selected because the study was conducted in a community-based fitness setting where full random allocation was not feasible.[17] The study was carried out at Garasi Bootcamp Fitness Club, Bandung, West Java, Indonesia.

Participants

The participants were women aged 35–45 years who were members of Garasi Bootcamp Fitness Club. Participants were recruited using purposive sampling based on age, willingness to participate, and ability to follow the intervention schedule. The inclusion criteria were: women aged 35–45 years, physically able to perform moderate-intensity exercise, willing to attend the training program for eight weeks, and able to complete pretest and posttest assessments. The exclusion criteria were current musculoskeletal injury, diagnosed cardiovascular disease, neurological disorder, uncontrolled metabolic disease, or any medical condition that could limit safe participation in exercise.

Eight women met the eligibility criteria and were included in the study. They were allocated into an intervention group (n = 4) and a control group (n = 4). Participants in the intervention group received the structured multicomponent training program, whereas those in the control group continued their usual daily activities and regular exercise habits without receiving the additional structured program. All participants completed the study and were included in the final analysis.

Ethical approval

This study has been approved by Health Research Ethics Committee, Faculty of Health Sciences, Universitas Jenderal Soedirman, Indonesia (No. 2284/EC/KEPK/V/2026; approval date: 4 May 2026). The study procedures followed the ethical principles of the Declaration of Helsinki 2008. Before data collection, all participants received an explanation of the study objectives, procedures, potential benefits, and possible risks. Written informed consent was obtained from all participants. Participants were also informed that their involvement was voluntary and that they could withdraw from the study at any stage without any consequence.

Intervention program

The intervention lasted 8 weeks with 3 sessions per week, each session was about 45–60 min and performed at moderate intensity. The intensity of the training was adjusted according to the tolerance of the participants and was supervised directly by the instructor in an effort to ensure the safety and quality of the exercises. The program was designed

as a multicomponent intervention, incorporating resistance exercise, functional movement training and dual-task cognitive stimulation.

The warm-up phase lasted approximately 10 min and consisted of light aerobic movements and dynamic stretching. The core exercise phase lasted approximately 25–30 min and consisted of body-weight and resistance-band exercises including squats, lunges, push-ups, glute bridges and planks. Participants performed two to three sets of 10–12 repetitions for each exercise, depending on individual capacity and movement quality. Exercise load and complexity were progressed gradually every 2 weeks by modifying repetitions, sets, movement variation or resistance level.

The cognitive stimulation phase lasted approximately 10–15 min and was integrated with physical movement using a dual-task approach. Activities included walking while counting backward, remembering while moving and word association tasks, and were intended to promote attention, working memory, concentration and executive processing while participants continued to perform simple physical tasks. Each session concluded with a cool-down period of about 5 to 10 minutes with breathing exercises and static stretching.

Outcome measures

The primary end points were handgrip strength, skeletal muscle mass, body fat percentage and cognitive function. All measurements were performed pre- and post- the 8-week intervention using the same methods and test order. Handgrip strength was measured using a Camry Electronic Hand-Grip Dynamometer (Model EH101). Handgrip strength was chosen because it has been widely used as a practical marker of overall muscle strength and functional status related to sarcopenia.[18,19] The subjects were tested in an upright sitting position with the shoulder adducted, the elbow flexed to approximately 90° and the forearm in a neutral position. Each subject performed three maximal grip trials with each hand, with short rest periods between trials to avoid fatigue. The highest value recorded in kilograms was used for analysis.

Body composition was assessed using the Omron Karada Scan Body Composition Analyzer based on bioelectrical impedance analysis.[20] The variables recorded were skeletal muscle mass and body fat percentage. Participants stood barefoot on the device and held the electrodes according to the manufacturer's instructions. Measurements were conducted under similar testing conditions before and after the intervention to reduce potential variability related to hydration status, recent physical activity, and daily measurement timing.

Cognitive function was assessed using the Mini-Mental State Examination (MMSE). The MMSE is a brief cognitive screening tool that assesses orientation, registration, attention and calculation, recall, language and visuospatial ability.[21,22] Total score ranges from 0 to 30, with higher scores denoting better global cognitive function. Assessment was conducted in a quiet room using standard instructions.

Assessment procedure and evaluator status

Baseline assessments were conducted before the intervention period. Posttest assessments were conducted after the completion of the eight-week program using the same instruments, testing sequence, and assessment procedures. The same evaluator conducted the pretest and posttest measurements to maintain procedural consistency. However, the evaluator was aware of the participants' group allocation and assessment sequence; therefore, assessor blinding was not implemented. This condition was considered when interpreting the findings, particularly for outcomes that may be influenced by measurement expectation or repeated testing.

Statistical analysis

Data were analyzed using SPSS version 26.0. Descriptive statistics were presented as mean and standard deviation. Normality of the data was checked using the Shapiro–Wilk test and homogeneity of variance was checked using Levene's test. Paired-sample t-tests were used to analyze within-group changes from pretest to posttest for normally distributed data. When the normality assumption was not adequately met, the Wilcoxon signed-rank test was used as a non-parametric alternative. Between-group comparisons were examined using independent-sample t-tests or the Mann–Whitney U test, as appropriate.

The level of statistical significance was set at $p < 0.05$. To be able to interpret the magnitude and practical importance of the observed changes, effect size values were reported and not only p-values were used.

RESULTS

Participant flow and final analysis

Eight middle-aged women were enrolled in this study and allocated into two groups: the intervention group (n = 4) and the control group (n = 4). All participants completed the eight-week study period, and no participant withdrew from the intervention or posttest assessment. Therefore, all eight participants were included in the final analysis.

Descriptive outcomes

The descriptive results of the intervention group before and after the eight-week multicomponent training program are presented in **Table 1**. Overall, the intervention group showed favorable changes in all measured outcomes. Handgrip strength increased from 17.69 ± 1.18 kg at pretest to 22.98 ± 2.23 kg at posttest. Skeletal muscle mass increased from 23.60 ± 0.87 kg to 26.35 ± 0.75 kg, while body fat percentage decreased from 30.81 ± 3.38% to 28.56 ± 3.47%. Cognitive function score also improved from −3.75 ± 1.04 to −2.72 ± 1.20.

The largest effect size was observed for handgrip strength, followed by skeletal muscle mass, body fat percentage, and cognitive function score. This pattern suggests that the clearest response to the intervention occurred in muscular strength, while changes in body composition and cognitive function were smaller but still showed a favorable direction.

Effects of the intervention

The statistical comparison between pretest and posttest outcomes is shown in **Table 2**. The intervention group demonstrated significant improvements in all measured

variables after the eight-week program. Handgrip strength increased by 5.29 kg (t = 15.995, p < 0.001), and skeletal muscle mass increased by 2.75 kg (t = 6.340, p < 0.001). Body fat percentage decreased by 2.25% (t = −10.247, p < 0.001), while cognitive function score improved by 1.03 points (t = 7.000, p < 0.001).

Although statistical significance was observed across all variables, the findings should be interpreted together with the magnitude and practical direction of change. The increase in handgrip strength is practically relevant because handgrip strength is widely used as an indicator of general muscle function and sarcopenia-related risk. The increase in skeletal muscle mass and the reduction in body fat percentage also indicate favorable body composition changes after the program. Meanwhile, the improvement in cognitive function score was smaller than the physical changes, suggesting that the cognitive response may require longer intervention duration or more sensitive neurocognitive assessment to be interpreted more firmly.

The observed changes are illustrated in **Figure 1**. The figure shows a consistent pattern of improvement after the intervention, with increased handgrip strength and skeletal muscle mass, reduced body fat percentage, and improved cognitive function score. These results indicate that the eight-week moderate-intensity multicomponent training program produced favorable short-term changes in sarcopenia-related physical indicators and cognitive function among middle-aged women.

Figure 1 illustrates the direction of change in all measured outcomes after the eight-week multicomponent training program. The intervention group showed an increase in handgrip strength and skeletal muscle mass, together with a reduction in body fat percentage. Cognitive function score also showed a favorable post-intervention change, although the magnitude of improvement was smaller than the changes observed in physical outcomes. Overall, the figure supports the statistical findings by showing a consistent pattern of improvement across sarcopenia-related indicators and cognitive function.

Table 1. Descriptive changes in physical and cognitive outcomes after the intervention

Variable	Pretest	Posttest	*p*-value	Effect size
	Mean ± SD	Mean ± SD		
Handgrip strength, kg	17.69 ± 1.18	22.98 ± 2.23	0.000	0.85
Skeletal muscle mass, kg	23.60 ± 0.87	26.35 ± 0.75	0.001	0.79
Body fat, %	30.81 ± 3.38	28.56 ± 3.47	0.015	0.60
Cognitive function	−3.75 ± 1.04	−2.72 ± 1.20	0.020	0.55

%, percentage; kg, kilogram; SD, standard deviation.

Table 2. Pretest and posttest comparison of intervention outcomes

Variable	Mean differences	t-value	p-value
Handgrip strength, kg	+5.29	15.995	0.001
Skeletal muscle mass, kg	+2.75	6.340	0.001
Body fat, %	−2.25	−10.247	0.001
Cognitive function	+1.03	7.000	0.001

%, percentage; kg, kilogram; SD, standard deviation.

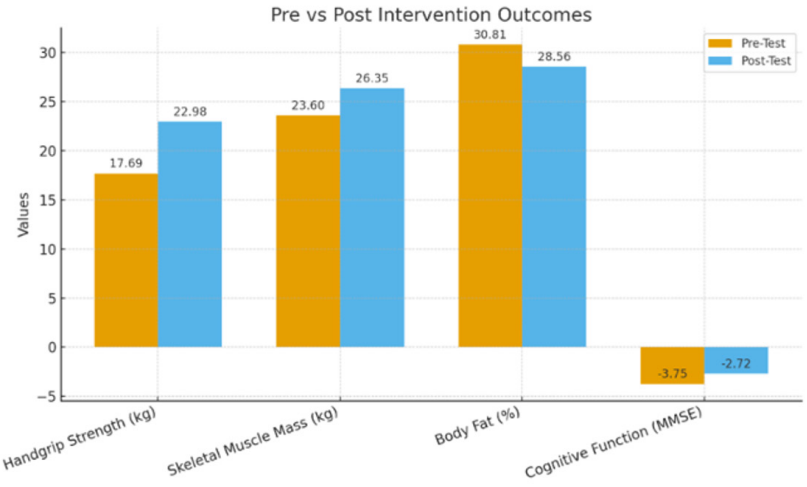


Figure 1. Pretest and posttest comparison of physical and cognitive outcomes after the intervention.

DISCUSSION

This study examined whether an eight-week moderate-intensity multicomponent training program could improve sarcopenia-related physical indicators and cognitive function in middle-aged women. The main findings showed favorable pre–post changes in handgrip strength, skeletal muscle mass, body fat percentage, and cognitive function after the intervention. The most pronounced change was observed in handgrip strength, followed by skeletal muscle mass and body fat percentage, while the improvement in cognitive function was smaller. These findings suggest that a community-based program combining resistance exercise, functional movement training, and dual-task cognitive stimulation may provide short-term benefits for physical function and may also support cognitive health during midlife.[23-25]

The improvement in handgrip strength is an important finding because muscle strength is one of the central indicators used to identify sarcopenia-related risk.[1,18,19] Although the present study did not diagnose sarcopenia clinically, the increase in handgrip strength indicates a meaningful shift in muscular function after the training program. This change is practically important as grip strength is

a good indicator of upper-limb strength, overall functional capacity and health status.[26] The improvement seen in this study may be attributable to repeated exposure to resistance and functional exercises that required the coordinated activation of the upper body, trunk and lower limbs. Exercises such as push-ups, squats, lunges, glute bridges, and planks may have caused neuromuscular adaptation, improved motor recruitment, and increased muscular endurance.27 These findings are consistent with prior evidence demonstrating the effectiveness of resistance-based and multicomponent exercise programs on muscle strength and physical performance in adult and older populations.[11,12,13]

The increases in skeletal muscle mass and decreases in body fat percentage are also positive body composition changes. These adaptations are supported by the progressive resistance exercise and functional movement patterns used in the intervention and the duration of the intervention over an eight-week period. Resistance exercise has a well-established potential to stimulate muscle protein synthesis and to maintain muscle mass, especially when applied progressively.[12,13] At the same time, regular moderate-intensity exercise may play a role in increased energy expenditure and metabolic regulation, which can help in the reduction of body fat accumulation. From a preventive perspective, these changes are relevant for middle-aged women because midlife is often accompanied by gradual changes in body composition, including loss of lean mass and increased adiposity.[4,5] Therefore, the present findings support the idea that preventive exercise should be introduced before severe age-related decline becomes evident.

However, the clinical meaning of these changes should be interpreted carefully. A specific minimum clinically important difference for the combination of handgrip strength, skeletal muscle mass, body fat percentage, and cognitive function in healthy middle-aged women is not yet consistently established.[28] For this reason, the practical relevance of the findings was interpreted through the direction of change, statistical significance, and effect size rather than through a single clinical threshold. The most evident effect was observed for handgrip strength, which shows that the program had its most clear practical effect on muscular function. The changes in skeletal muscle mass and body fat percentage should be considered as early positive adaptations rather than as conclusive evidence of long-term body composition improvement. Longer intervention periods and larger samples are needed to see whether these changes can be sustained and translated into clinically significant sarcopenia prevention.[29]

The positive change in cognition also warrants attention but should not be over-exaggerated. Exercise may influence cognition through various mechanisms including higher cerebral blood flow, improved metabolic regulation, reduced inflammation and increased release of neuroprotective factors such as brain-derived neurotrophic factor.[14,15] Moreover, the dual task component of the intervention may have required participants to combine movement with attention, working memory, recall and executive processing. Activities such as walking while counting backwards, word association and memory recall during movement may facilitate cognitive-motor integration, and may help to preserve cognitive engagement during exercise.[16] Nevertheless, the cognitive benefit in this study was less than the physical changes. This may be due to cognitive adaptation requiring a longer intervention period, a more targeted cognitive stimulus or a more sensitive assessment tool than a general cognitive screening instrument.[30]

The current results contribute to the existing body of literature in multiple respects. First, the research cohort included middle-aged women, a sub-group of population that has been less frequently studied in intervention studies for sarcopenia relative to older persons.[4,9,10] Second, the project was performed in a community-based fitness setting with simple equipment and exercises, thereby increasing its feasibility for practical application. Third, the intervention combined physical and cognitive outcomes into one program, rather than treating them as separate targets. This approach is important because daily functioning depends on the interaction of muscular capacity and cognitive regulation. A program that addresses both domains may therefore be more relevant to preventative health promotion in midlife.

Some limitations should be noted however. The small sample size provided limited statistical power and generalizability of findings. The quasi-experimental design and lack of random allocation may increase the risk of selection bias. Moreover, the evaluator was aware of the participants' group allocation and assessment sequence, meaning that assessor blinding was not used. This may have introduced measurement bias, especially in assessments that depend on participant effort or evaluator instruction. Future research should use blinded outcome assessment when possible.

Another limitation is that diet and nutritional intake were not closely monitored during the intervention period. This is important as factors other than exercise can affect skeletal muscle mass and % body fat, including protein intake, total caloric intake, hydration or dietary pattern. Physical activity outside the organized intervention was not objectively monitored. While participants were asked to maintain their usual routines, unrecorded changes in daily activities may have explained the reported changes. For a better understanding of the efficacy of the intervention, future studies should include food records, protein intake monitoring or objective activity tracking.

Potential learning effects should also be acknowledged. Participants may have been more familiar with the testing procedures at posttest as the same physical and cognitive tests were performed pre- and post-intervention, which may have influenced performance, especially for handgrip testing and cognitive screening. Also, bioelectrical impedance analysis was used to assess body composition, which is feasible for the community setting but may be influenced by hydration status and measurement conditions. Although testing procedures were standardized as much as possible, more accurate techniques may be considered in future studies.

The external validity of the findings is also limited, as the participants were recruited from a community fitness club and may not be representative of

all middle-aged women. Women who are already interested in participating in fitness activities may differ in motivation, health awareness and baseline physical capacity from the general population. Therefore, results should be considered as preliminary evidence from a community-based sample and not as final evidence for all middle-aged women.

Overall, this study indicates that moderate-intensity multicomponent training may be a feasible strategy to improve sarcopenia-related indicators and support cognitive function in middle-aged women. The results are promising, particularly for muscular strength, but should be interpreted with caution, due to the small sample size, short duration of the intervention, lack of assessor blinding and limited control for lifestyle factors. Future studies with larger samples, longer follow-up periods, random allocation, blinded assessment, nutritional monitoring and more extensive neurocognitive testing are needed to confirm the effectiveness and clinical relevance of this type of intervention.

CONCLUSION

The present study showed that an eight-week multicomponent training program with moderate intensity led to positive changes in physical parameters related to sarcopenia and cognitive functioning in middle-aged women, with the greatest change in handgrip strength, followed by an increase in skeletal muscle mass, a decrease in body fat percentage and a slight improvement in cognitive performance. The results indicate that a combination of strength training, functional mobility exercises, and dual-task cognitive engagement could be an effective means to improve physical and cognitive well-being in midlife.

ETHICAL CONSIDERATION

The study was approved by the Health Research Ethics Committee, Faculty of Health Sciences, Universitas Jenderal Soedirman, Indonesia (No. 2284/EC/KEPK/V/2026; date of approval: 4 May 2026). The procedures of the study were performed in accordance with the ethical principles of the Declaration of Helsinki 2008. All participants were provided with clear information about the objectives, procedures, possible benefits, and possible risks of the study before their participation. Written informed consent was obtained from each participant before data collection. Participants were told that their participation was voluntary and they could withdraw from the study at any stage without penalty. Personal data were kept confidential and used for research purposes only.

CONFLICT OF INTEREST

The authors state that there is no conflict of interest associated with this study. The study design, data collection, analysis, interpretation, and manuscript writing were all independent of any financial, institutional, professional, or personal relationships.

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AUTHOR CONTRIBUTIONS

B helped to conceptualize the study, supervised the research, organized the intervention, and carried out the intervention. SU and DRN helped with manuscript preparation, translation, language refining, and academic writing improvement. HA, DWC, QSS, and SS participated in the research process and edited the manuscript. All authors have approved the final version for submission.

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