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Original Study

Exercise and Nutritional Supplementation on Community-Dwelling Elderly Japanese Women With Sarcopenic Obesity: A Randomized Controlled Trial

Hunkyung Kim PhD [a,*], Miji Kim PhD [a,†], Narumi Kojima MS [a], Ken Fujino DVM [a], Erika Hosoi BS [a], Hisamine Kobayashi DVM [b], Shinji Somekawa MS [b], Yoshifumi Niki MS [c], Yukari Yamashiro PhD [c], Hideyo Yoshida MD, PhD [a]

[a] *Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan*
[b] *Ajinomoto Co. Inc., Kawasaki, Japan*
[c] *Kao Corporation, Human Health Care, Tokyo, Japan*

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A B S T R A C T

Objectives: To investigate the effects of exercise and/or nutritional supplementation on body composition, blood components, and physical function in community-dwelling elderly Japanese women with sarcopenic obesity.
Design: Randomized controlled trial.
Setting: Urban community in Tokyo, Japan.
Participants: Among 1213 community-dwelling elderly women over 70 years of age, 307 were defined with sarcopenic obesity, and 139 women participated in the study.
Intervention: Participants were randomly assigned to one of four intervention groups. The exercise and nutrition (Ex + N) and exercise only (Ex) groups attended 60-minute exercise classes twice a week for 3 months. The Ex + N and nutrition only (N) groups were provided with essential amino acid supplementation and tea fortified with catechins to be taken daily for 3 months. Health education classes were provided to the control (HE) group every 2 weeks.
Measurements: Bioelectric impedance analysis was used to measure body composition. Skeletal muscle mass index was calculated using measures of muscle mass and height. Physical function measures included grip strength, knee extension strength, usual walking speed, and walking parameters (stride, step length, width, walking angles). Blood samples were obtained to analyze levels of albumin, triglycerides, cholesterol, hemoglobin A1c, leptin, cystatin C, vitamin D, interleukin-6, and high-sensitivity C-reactive protein.
Results: Significant between-group × time interactions were observed in usual walking speed ($P = .012$), stride ($P = .004$), right step length ($P = .003$), average number of steps ($P = .029$), and vitamin D ($P < .001$). Compared to the HE group, the Ex + N intervention significantly decreased total body fat mass ($P = .036$) and increased stride ($P = .038$) and vitamin D ($P < .001$). Significant reductions in trunk fat were observed in the Ex group compared with HE ($P = .014$). The Ex + N and Ex interventions were over four times as likely (odds ratio [95% confidence interval]) to reduce body fat mass than the HE group (4.42 [1.21-16.19]; 4.50 [1.13-17.9], respectively). Significant odds ratios of the Ex + N intervention improving walking speed (3.05 [1.01-9.19]), vitamin D (14.22 [1.64-123.02]), and leptin (3.86 [1.19-12.47]) were also observed.
Conclusion: Although exercise and nutrition have beneficial effects on individual variables of body composition, blood components, and physical function, improvements in muscle mass and variable

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Conflict of interest: Authors from Ajinomoto Co., Inc. and Kao Corporation assisted in the data collection but had no role in the development of the study design and interpretation of the data. Co-authors Hisamine Kobayashi and Shinji Somekawa are employed by Ajinomoto Co., Inc.; and Yoshifumi Niki and Yukari Yamashiro by Kao Corporation. Ajinomoto Co., Inc. provided the amino acid supplementation, and Kao Corporation provided the tea catechin supplementation. The authors included in this publication affiliated with either corporation assisted in the data collection and analysis. The terms of this arrangement have been reviewed and approved by the Tokyo Metropolitan Institute of Gerontology in accordance with its policy on objectivity in research.

* Address correspondence to Hunkyung Kim, PhD, Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, 35-2 Sakaecho, Itabashi-ku, Tokyo 173-0015, Japan.
E-mail address: kimhk@tmig.or.jp (H. Kim).
† Current affiliation: East-West Medical Research Institute, Kyung Hee University, Seoul, South Korea.

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combinations such as percent fat + skeletal muscle mass index or percent fat + physical functions were not observed in this population. Further large-scale and long-term investigation is necessary.

The separate influences of sarcopenia and obesity on adverse health outcomes have been topics of interest within the research community. There has been an increased interest in the combination of both sarcopenia and obesity, or sarcopenic obesity, which has originally been characterized by reduced muscle mass and high body fat percentage.[1,2] More recently, research has shown that dynapenic obesity, the loss of muscle strength with age and high body fat, is associated with poor physical function and mobility.[3,4] Sarcopenic obesity has been found to be closely associated with knee osteoarthritis,[5] metabolic syndrome and arterial stiffness,[6] instrumental activities of daily living disability,[7] gait abnormalities, falls,[1] and all-cause mortality.[8,9]

The benefits of resistance exercise in older people has been well established. The literature clearly shows that resistance exercise is effective for improving muscle mass, strength, and walking ability in older adults.[10,11] Aerobic exercise is the optimal type of exercise for the reduction of fat mass, although the combination of aerobic and resistance exercise may have greater benefits for weight loss, fat loss, and cardiorespiratory fitness.[12,13] Recent studies have shown that nutrition is an important factor regarding sarcopenic obesity. Although solid evidence to recommend specific interventions for sarcopenia has yet to be established, nutritional supplementation in combination with exercise has been effective in the treatment of sarcopenia.[14] One review concluded that randomized controlled studies containing exercise programs including both strength and aerobic exercises combined with nutritional investigation was the most promising approach to sarcopenic obesity based on current evidence.[15]

Essential amino acid ingestion can induce muscle protein anabolism in elderly adults.[16,17] Furthermore, leucine-rich amino acids have improved aspects of functional status and increase lean body mass.[18,19] An investigation we conducted in 2011 revealed that a leucine-rich essential amino acid supplementation in congruence with exercise effectively improved muscle strength, as well as the combined variables of muscle mass and walking speed in sarcopenic women.[20]

Previous studies have reported that green tea containing catechins can reduce body fat,[21] systolic blood pressure, LDL cholesterol,[22] abdominal fat, and serum triglycerides.[23] Additionally, in combination with exercise, green tea catechins had beneficial effects on walking ability and muscle mass in Japanese sarcopenic women.[24] Whether such interventions are beneficial for elderly people with sarcopenic obesity is unknown.

We hypothesized that resistance training combined with amino acid supplementation would increase muscle mass, and aerobic exercise in combination with tea catechins may reduce body fat. No studies, to the best of our knowledge have examined the effects of exercise and nutrition, in combination and separately. The purpose of this study was to investigate the effects of exercise, amino acid and tea catechin supplementation on body composition, blood components, and physical function in community-dwelling elderly Japanese women with sarcopenic obesity.

Materials and Method

Subjects

A letter inviting elderly people over 70 years old in the community (Itabashi ward, Tokyo) to participate in a follow-up comprehensive geriatric health examination survey in 2012 was sent to 1289 elderly women who had completed an initial baseline survey in 2008. Among them, 575 women participated in the follow-up survey in 2012. Invitation letters were also sent to a separate cohort in 2013, to 957 people who had originally participated in a baseline survey in 2006. There were 638 people who participated in the follow-up survey in 2013. Detailed descriptions of the 2008 cohort[25] and 2006 cohorts[26] are available in previous publications. A total of 1213 people who had participated in both follow-up surveys in 2012 and 2013 were screened for sarcopenic obesity (Figure 1).

Sarcopenic obesity was operationally defined as body fat percent of 32% or greater, measured by dual x-ray energy absorptiometry (DXA, Hologic QDR 4500A), combined with skeletal muscle mass index less than 5.67 kg/m^2; body fat percent of 32% or greater and grip strength less than 17.0 kg; and body fat percent of 32% or greater and walking speed under 1.0 m/s. The exclusion criteria were: (1) severely impaired mobility; (2) impaired cognition (Mini-Mental State Examination score < 24); (3) missing baseline data; and (4) unstable cardiac conditions such as ventricular dysrhythmias, pulmonary edema, or other musculoskeletal conditions. Based on these criteria, 307 (25.3%) were operationally defined as having sarcopenic obesity, and information on "treatment strategy" was mailed to the potential patients. A total of 168 people were excluded from the study (Figure 1).

The study protocol was approved by the Clinical Research Ethics Committee of Tokyo Metropolitan Institute of Gerontology (ID2014-693). Procedures were fully explained to all participants, and written informed consent was obtained.

Randomization

Randomization was performed after the baseline assessment, and any variable that identified personal information was not included in the randomization process. Computer-generated random numbers were assigned to 139 participants (45.3%), who were then sorted and equally divided into four groups. These groups were then allocated to one of four intervention groups: (1) exercise and nutritional supplementation (Ex + N; n = 36), (2) exercise (Ex; n = 35), (3) nutritional supplementation (N; n = 34), and (4) health education (n = 34). All participants agreed to the group allocations. There was no attempt to equalize the size of the groups based on their characteristics or to recruit subjects with specific characteristics.

Outcome Measures

Interview

Face-to-face interviews were conducted to assess history of falls, fractures, pain, frequency of urination (daytime and nighttime), and chronic conditions such as history of heart disease, hyperlipidemia, dyslipidemia, diabetes, osteoporosis, osteoarthritis, OA and more.

Anthropometric and physical function measures

Measurements of height and weight were converted to BMI. Muscle mass, body fat mass, and body fat percent were determined using bioelectrical impedance analysis (InBody 720). Skeletal muscle mass index (SMI) was calculated using measures of muscle mass and height. Grip strength was measured using a handheld Smedley-type dynamometer in the dominant hand, and the better of two trials was used for analysis. Peak isometric force was measured to assess knee extension strength where the participants extended the knee with maximum power with their knee joint at 90°. A dynamometer was placed at the ankle joint to measure the force of extension. The greater measurement of two trials was recorded. Usual walking speed

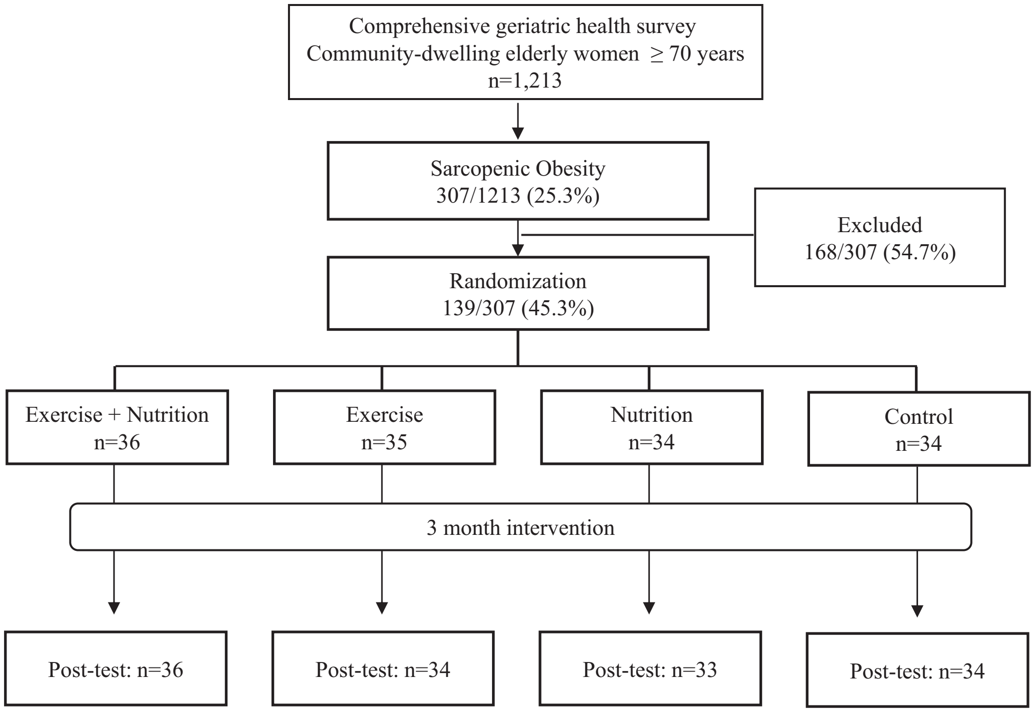

Fig. 1. Flow chart of participant selection.

was measured on a flat walking path of 11 m with markers at the 3-m and 8-m mark. A stopwatch was used to measure the time taken to walk 5 m between the markers, and the faster time of two trials was recorded. Assistive walking devices were allowed in measures of walking speed if the participant expressed concerns about walking without a device, or if the investigators suspected dangers of falling. Walking parameters were measured using a 2.4-m sensor gait analyzer (Sheet Type Gait Analyzer Walk Way MW-1000, Anima, Tokyo, Japan), where stride, cadence, step length, step width, and walking angles were assessed.

Blood pressure was measured prior to the physical function measurements using automatic blood pressure monitors (TM-2657, A&D, Japan). The Lifecorder EX activity monitor (Suzuken, Japan) was used to record step count and calorie expenditure and was worn at the hip at all times except for bathing and sleeping. The average step count and calorie expenditure values of the 2 weeks prior to baseline testing and 2 weeks postintervention testing was recorded.

Blood Indicators

Nonfasting blood samples were collected in a seated position at baseline and post-intervention. Analyses were carried out centrally in one laboratory (Special Reference Laboratories, Tokyo, Japan). Lipid levels (total cholesterol, HDL cholesterol, and triglycerides) were obtained. Cystatin C concentrations were measured with the sol particle homogeneous immunoassay method (Nescauto GC Cystatin C, Alfresa Pharma, Osaka, Japan).[27] The specific assays used for each measure and methods were as follows: serum albumin (bromocresol green), leptin and serum 25-hydroxyvitamin D (double antibody radioimmunoassay), high-sensitivity C-reactive protein and HbA1c (latex agglutination), and interleukin-6 (chemiluminescence enzyme immunoassay).

Intervention

Exercise

The participants in the exercise intervention went through a physical comprehensive training program aimed to increase muscle mass and reduce body fat. Each exercise class was 60 minutes, held at the Tokyo Metropolitan Institute of Gerontology twice per week for 3 months. The exercise groups (exercise and nutritional supplementation and exercise-alone groups) were further divided into four subclasses offered throughout the day in order to maintain small enough classes to provide proper instruction. There was one instructor for all four classes, and three assistant trainers present at every class to assist, ensure proper form, and exercise technique, as well as observe each participant's level.

The exercises were performed in a progressive sequence from seated to standing exercises, gradually increasing weights and the use of weight machines, and progressively increasing the resistance in bicycle ergometer training. Each exercise session was divided into warm-up, weight/machine training, stationary bicycle aerobic exercise, and chair/standing exercise.

Resistance and weight-bearing exercise

Chair exercise. Repetitions of toe raises, heel raises, knee lifts, and knee extensions were performed while seated on a chair. To increase difficulty and resistance, participants then performed hip flexions, lateral leg raises, and repetitions of other exercises while standing upright behind the chair and holding the back of it for stability. Standing exercises were also performed gradually progressing from one to three sets of 10 squats, standing knee lifts, gluteal kicks, etc.

Resistance band exercise. Resistance bands were used for upper and lower body strengthening. Lower body exercises consisted of leg extensions, hip flexions, and more. Upper body exercises included double-arm pulldowns, bicep curls, and others.

Hydraulic exercise machine. The participants rotated training machines (Mizuno, Japan) between seated row, leg press, abduction, leg extension, and abdominal crunch machines, beginning with one set of 10 repetitions to three sets.

Aerobic training

The participants pedaled on a stationary bicycle (Aerobike 900U-ex, COMBI Wellness, Japan) for 12 minutes, including 1 minute of cooldown, starting at 40 watts. The watt level was gradually increased throughout the 3 months based on each individual's progress.

Nutrition

Amino acid supplementation. Packets containing 3.0 g of leucine-enriched essential amino acid (1.20 g leucine, 0.50 g lysine HCl, 0.33 g valine, 0.32 g isoleucine, 0.28 g threonine, 0.20 g phenylalanine, and 0.17 g other) and 20 μg vitamin D (Ajinomoto Co., Inc) were provided for the participants every 2 weeks to be taken daily with water for 3 months.

Tea catechin. Plastic bottles containing 350 mL of tea fortified with 540 mg of catechin (Kao Co.) were given to the participants every 2 weeks. The participants were provided with one bottle to drink daily, for 3 months and were instructed to record the volume of tea consumed (the whole bottle, half, or one-quarter) on record sheets.

Participants in the nutrition group were asked to take both amino acid supplementation and tea catechins daily and were instructed to record the time of day the supplementation was taken in diary logs, which were collected every 2 weeks to monitor adherence along with empty packets and bottle caps to accurately monitor intake.

Health education

A general health education class was provided once every 2 weeks for 3 months, a total of six times. The classes focused on topics of interest among elderly people including cognitive function, long-term care insurance, etc, but did not include exercise or nutrition. Participants were asked to continue their regular lifestyle habits, and no specific instructions on diet or physical activity were given.

Data Analysis

The sample size was calculated to allow detection of a 5.0% reduction of percent body fat between groups with 80% power and a significance level of 0.05. Based on these calculations, 28 people were required per group (total n = 112), and estimating for a potential attrition rate of 18%, more than 34 participants were included in each group. Means and standard deviations were calculated, and differences in baseline values between groups were compared using one-way analysis of variance (ANOVA) for continuous variables, and chi-square tests for categorical variables. The generalized estimating equation was used to analyze any pre- to postintervention group × time interactions between the groups. Percent changes in percent body fat, fat mass, muscle mass, functional fitness, walking parameters, and blood components were calculated using the formula: % change = [(post intervention value − baseline value)/baseline value × 100%], and one-way ANOVA was performed to determine significant differences in percent changes within or between the groups from baseline to postintervention, with values expressed as differences with 95% confidence intervals. The Scheffe post hoc method was used when significance was found.

Multiple logistic regressions were performed to compare the effects of the four intervention groups on body composition and physical fitness after 3 months. All analyses were performed using SPSS software, Windows version 20.0 (SPSS, Inc., Tokyo, Japan).

Results

Out of 139 intervention participants, 137 completed the intervention, and there were two dropouts. Two participants dropped out due to spouse care and moving to another area, and there were no adverse events caused by the interventions.

No baseline differences in the continuous and categorical variables were observed between groups (Table 1).

Comparisons of pre- and postintervention changes in physical function and walking parameters showed that there were significant group × time interactions between the groups in usual walking speed ($P = .012$), stride ($P = .004$), right step length ($P = .003$), and average number of steps ($P = .029$). Further, significant differences were seen in total calorie consumption ($P = .036$) and vitamin D levels ($P < .001$) between the groups (Table 2).

Table 3 shows the comparison of percent changes from baseline to postintervention, between and within the groups. Between-group comparisons showed that total fat mass significantly decreased in all intervention groups, where the change in Ex + N was significantly greater than the HE ($P = .036$). Similarly, trunk fat mass decreased in the intervention groups, although the greatest reduction was in the Ex group ($P = .014$). Stride increases were significantly greater in both exercise interventions compared to the N group, and the Ex group was higher than the HE group ($P = .038$). Step length significantly increased in both the Ex + N and Ex groups, where the Ex group was significantly greater than the HE group ($P = .007$). Vitamin D increased in the Ex + N, and N groups, where these groups had significantly greater improvements than the Ex and HE groups ($P < .001$). No significant changes were seen in SMI and grip strength between the groups.

Within-group analyses revealed that appendicular fat mass decreased significantly by 4.9% (95% CI, −6.8 to −2.9) in the Ex + N, 3.4% (−5.4 to −1.4) in Ex, and 2.5% in N (−4.2 to −0.8), and no significant changes were seen in SMI. Knee extension strength significantly increased in the Ex + N by 17.8% (95% CI, 8.6-26.9), Ex 12.8% (4.1-21.5), and N 9.0% (2.7-15.2) groups. Usual walking speed only increased 5.7% in the Ex + N group (95% CI, 1.3-10.1). Furthermore, leptin significantly decreased in the Ex + N group (13.5%, 95% CI, −21.9 to −5.2), Ex (11.9%. −19.6 to −4.2), and N group (7.6%, −14.8 to −0.39). However, no significant between-group differences were observed in these variables.

The multiple regressions analysis revealed that the Ex + N and Ex groups were over four times as likely (odds ratio [OR] [95% CI]) to improve total body fat mass than the HE group (4.42 [1.21-16.19]; 4.50 [1.13-17.9], respectively). Similarly, the Ex + N and Ex interventions were over three times as likely (3.69 [1.28-10.71]; 3.72 [1.24-11.17], respectively) to improve muscle strength than the HE group. The Ex + N group was also significantly more likely to reduce percent body fat (6.83 [1.03-21.13]), trunk fat mass (4.08 [1.08-15.37]), leg muscle mass (3.13 [1.05-9.27]), walking speed (3.05 [1.01-9.19]), vitamin D (14.22 [1.64-123.02]), and leptin (3.86 [1.19-12.47]). The N group was six times more likely to improve vitamin D levels (6.22 [1.19-32.68]). No significant ORs were found for combined variables of percent fat and SMI, muscle strength, and walking speed (Table 4).

Discussion

Previous studies have defined sarcopenic obesity as increased body fat percent combined with loss of skeletal muscle mass, and dynapenic obesity as greater body fat percent with low muscle strength.[1–3,28] However, in this study, we operationally defined sarcopenic obesity as increased body fat percent combined with loss of skeletal muscle mass, muscle strength, as well as walking ability. We conducted a 3-month exercise and/or nutritional intervention on community-dwelling sarcopenic obese women based on the described operational definition. The results showed that the interventions effectively reduced body fat and improved muscle strength and walking ability individually; however, no significant changes in combined variables or SMI were seen.

Many studies have investigated the association between fat mass, muscle mass, muscle strength, and mortality, disability, physical function, or adverse health events. One study conducted on elderly women under 75 years old showed that fat mass was the primary risk

Table 1
Selected Variable Characteristics of Participants at Baseline by Study Group

Variables	Exercise + Nutrition (n = 36) Mean ±SD	Exercise (n = 35) Mean ±SD	Nutrition (n = 34) Mean ±SD	Health Education (n = 34) Mean ±SD	*P* Value*
Anthropometric and body composition					
Age (y)	80.9 ±4.2	81.4 ±4.3	81.2 ±4.9	81.1 ±5.1	.980
Height (cm)	148.3 ±5.4	146.9 ±7.2	150.4 ±5.2	148.2 ±4.4	.092
Body weight (kg)	55.8 ±7.9	55.0 ±7.1	57.1 ±8.1	56.9 ±6.2	.594
BMI (kg/m^2)	24.9 ±3.0	25.1 ±2.5	24.9 ±2.5	25.3 ±2.8	.901
Systolic blood pressure (mm Hg)	132.9 ±16.1	128.3 ±11.0	130.4 ±15.7	135.8 ±13.7	.190
Diastolic blood pressure (mm Hg)	71.5 ±13.3	66.1 ±8.7	68.7 ±9.8	68.2 ±9.7	.215
Total muscle mass, BIA (kg)	35.5 ±4.3	35.5 ±3.9	36.5 ±4.2	35.8 ±3.2	.678
Arm muscle mass, BIA (kg)	3.1 ±0.6	3.1 ±0.5	3.2 ±0.7	3.1 ±0.5	.862
Leg muscle mass, BIA (kg)	9.7 ±1.7	9.7 ±1.7	10.0 ±1.8	9.7 ±1.2	.755
AMM, BIA (kg)	12.8 ±2.2	12.8 ±2.2	13.2 ±2.4	12.8 ±1.6	.792
Percent body fat, BIA (%)	38.1 ±4.3	37.0 ±4.1	37.8 ±3.3	38.5 ±4.9	.519
Muscle strength and mobility					
Grip strength (kg)	19.2 ±5.1	20.6 ±3.8	20.6 ±5.2	21.9 ±4.7	.141
Knee extension strength (N)	178.1 ±51.2	181.8 ±56.8	193.2 ±47.4	198.6 ±60.9	.403
Usual walking speed (m/s)	1.1 ±0.2	1.1 ±0.2	1.2 ±0.2	1.2 ±0.2	.324
Cadence (steps/min)	121.9 ±10.3	125.9 ±11.0	126.8 ±8.6	124.7 ±10.4	.226
Stride (cm)	105.7 ±16.9	104.4 ±16.8	108.2 ±17.6	108.0 ±15.4	.772
Right step length (cm)					
Left step length (cm)	52.7 ±8.2	52.7 ±8.4	54.0 ±9.5	53.4 ±8.1	.915
Right walking angle (°)	10.1 ±4.6	9.9 ±4.4	9.5 ±4.6	9.7 ±4.7	.973
Left walking angle (°)	9.9 ±4.4	9.8 ±4.0	9.7 ±5.8	9.5 ±5.0	.985
Blood components					
Albumin (g/dL)	4.17 ±0.19	4.12 ±0.20	4.23 ±0.18	4.23 ±0.22	.125
Triglycerides (mg/dL)	146.7 ±61.5	135.9 ±63.4	157.2 ±75.5	128.8 ±59.5	.345
Total cholesterol (mg/dL)	210.5 ±39.0	194.8 ±29.0	208.5 ±36.7	207.5 ±38.8	.318
HDL cholesterol (mg/dL)	62.7 ±14.8	62.2 ±15.7	61.4 ±14.1	61.2 ±13.5	.975
Hemoglobin A1c (%)	5.8 ±0.7	5.7 ±0.5	5.8 ±0.8	5.8 ±0.6	.945
Leptin (ng/mL)	18.2 ±1.0	17.2 ±11.8	16.2 ±7.2	18.2 ±9.0	.819
Cystatin C (mg/L)	0.99 ±0.24	0.96 ±0.16	0.94 ±0.21	0.96 ±0.19	.826
Vitamin D (ng/mL)	23.2 ±9.3	25.1 ±8.3	22.5 ±7.1	26.9 ±7.7	.139
Interleukin-6 (pg/mL)	3.1 ±2.5	5.8 ±10.1	3.1 ±1.5	3.0 ±1.5	.102
High-sensitivity CRP (mg/L)	1.1 ±0.9	2.0 ±3.3	1.6 ±2.2	1.4 ±1.7	.389
Chronic conditions and lifestyle variables					
Hypertension (yes, %)	80.6	80.0	57.6	61.8	.068
Hyperlipidemia (yes, %)	30.6	31.4	36.4	24.2	.764
Diabetes (yes, %)	8.3	5.9	9.1	5.9	.937
Hip osteoarthritis (yes, %)	5.6	17.6	9.1	11.8	.427
Knee osteoarthritis (yes, %)	27.8	45.7	30.3	29.4	.350
Falls (yes, %)	5.6	17.1	14.7	17.6	.415
Regular exercise (no, %)	61.1	68.6	70.6	55.9	.560
Urinary incontinence (yes, %)	61.1	60.0	64.7	73.5	.636

AMM, appendicular muscle mass; BIA, bioelectrical impedance analysis; BMI, body mass index; CRP, C-reactive protein; HDL, high-density lipoprotein.
Notes. All data are presented as M (mean) and SD (standard deviation) for continuous variables and percentage for categorical variables.
*One-way analysis of variance for continuous variables and chi-square test for categorical variables.

factor for disability.[29] Furthermore, although fat mass has been reported to be significantly and inversely correlated with physical capacity, no associations were seen for fat-free mass.[30]

In this study, total body fat mass significantly decreased in all intervention groups. The greatest decrease was in the Ex + N group at 5.5% (Ex + N > HE, *P* = .036); although no additive effects for the combination of exercise and nutrition could be confirmed. The loss of body fat seen in the N group confirms previous reports that 12 weeks of green tea catechin consumption can reduce body fat.[21] While the mechanisms are unclear and the literature inconclusive, there has been some evidence that green tea may promote fat oxidation,[31] which may have played a role in the change in body composition in this study. The results show that trunk fat mass significantly decreased in the N group by 3.4%, the Ex + N group by 6.5%, and by 6.9% in the Ex group (Ex > HE, *P* = .014), where the Ex-only group had the greatest reduction in trunk fat. Hence, this study cannot confirm whether exercise alone or in combination with nutritional supplementation was more effective in sarcopenic obese older women. Further research is required to corroborate these results and to investigate further mechanisms. No significant differences were seen in appendicular fat mass and leg fat mass between the groups.

Low muscle strength is an important public health issue, as it has been associated with poor future health outcomes. Generally, upper extremity strength is measured using hand grip strength, and knee flexion or extension is used for lower extremity strength assessments. One previous study found that muscle strength was more important in estimating mortality risk than muscle mass.[32] As grip strength is a cost-effective, simple method to measure muscle strength, it is likely to be increasingly used in clinical settings, for example, in the assessment of frailty, sarcopenia, and undernutrition in hospitalized older people. In this study, statistically significant changes in grip strength were not observed in the intervention or HE groups. Although grip strength is a measure of upper body strength, the focus of the exercise program provided was placed on the lower body. Therefore, grip strength as an outcome variable may not have been a particularly suitable measure of strength for the exercise intervention conducted. Manini et al suggested knee extension strength as an objective marker to identify the risk of future mobility limitation.[33] The effects of exercise and nutrition alone were insufficient in increasing muscle strength among sarcopenic elderly people, and studies have suggested that exercise with nutrition may be more beneficial.[20] In the current study, significant increases in knee

Table 2
Comparison of Muscle Mass, Functional Fitness, and Blood Indicator Variables Among Groups After 3-Month Interventions

Variables*	Exercise + Nutrition		Exercise		Nutrition		Health Education		GEE (G×T) †	
	Baseline	Post intervention	Baseline	Post intervention	Baseline	Post intervention	Baseline	Post Intervention	F Value	*P* Value
Body weight (kg)										
SBP (mm Hg)	133.1 ±16.3	135.5 ±13.1	128.6 ±11.0	131.7 ±14.3	130.5 ±16.0	132.1 ±16.9	135.7 ±13.9	133.4 ±15.0	0.771	.513
DBP (mm Hg)	71.6 ±13.5	72.2 ±10.4	66.3 ±8.9	70.0 ±9.0	68.0 ±9.5	69.0 ±8.2	67.2 ±10.0	68.4 ±8.8	0.881	.453
Percent fat (%)	38.0 ±4.3	36.5 ±4.7	36.9 ±4.2	35.5 ±4.5	37.8 ±3.3	36.6 ±3.5	38.6 ±5.2	37.4 ±4.8	0.403	.751
Total body fat mass (kg)	21.0 ±4.8	20.0 ±4.8	20.0 ±4.4	19.1 ±4.4	21.4 ±4.5	20.7 ±4.6	21.4 ±4.9	20.6 ±4.6	0.530	.663
Arm fat mass (kg)	3.1 ±0.9	3.0 ±0.8	2.9 ±0.8	2.8 ±0.8	3.2 ±0.9	3.1 ±0.9	3.2 ±0.9	3.1 ±0.8	0.507	.678
Leg fat mass (kg)	6.7 ±1.6	6.4 ±1.5	6.4 ±1.4	6.3 ±1.5	6.6 ±1.2	6.4 ±1.2	6.7 ±1.4	6.6 ±1.3	0.673	.570
Appendicular fat mass (kg)	9.8 ±2.4	9.4 ±2.3	9.3 ±2.1	9.0 ±2.2	9.8 ±2.0	9.6 ±2.0	10.0 ±2.3	9.6 ±2.1	0.558	.644
Trunk fat mass (kg)	10.1 ±2.4	9.6 ±2.5	9.7 ±2.3	9.0 ±2.2	10.5 ±2.4	10.1 ±2.5	10.4 ±2.6	9.9 ±2.5	0.818	.486
Arm muscle mass (kg)	3.1 ±0.6	3.1 ±0.7	3.1 ±0.5	3.1 ±0.5	3.2 ±0.7	3.2 ±0.7	3.1 ±0.5	3.1 ±0.5	1.324	.270
Leg muscle mass (kg)	9.7 ±1.7	9.9 ±1.8	9.6 ±1.8	9.9 ±1.8	10.0 ±1.8	10.2 ±1.8	9.5 ±1.1	9.8 ±1.2	0.234	.873
ASM (kg)	12.8 ±2.2	13.0 ±2.3	12.7 ±2.2	13.0 ±2.2	13.2 ±2.4	13.4 ±2.4	12.6 ±1.5	12.9 ±1.6	0.065	.978
Grip strength (kg)	19.2 ±5.2	19.6 ±5.2	20.5 ±3.8	20.3 ±3.8	20.4 ±5.3	20.9 ±5.1	21.4 ±4.5	21.1 ±4.1	0.655	.581
Knee extension strength (N)	177.7 ±52.0	205.7 ±62.6	181.3 ±57.8	202.7 ±69.5	189.4 ±46.4	205.2 ±54.4	197.5 ±66.1	204.1 ±64.7	1.795	.152
Usual walking speed (m/s)	1.1 ±0.2	1.2 ±0.2	1.1 ±0.2	1.3 ±0.2	1.2 ±0.2	1.2 ±0.2	1.1 ±0.2	1.2 ±0.2	3.865	.012
Cadence (steps/min)	121.5 ±10.3	124.3 ±8.6	126.5 ±10.5	128.7 ±9.3	127.4 ±7.9	130.1 ±9.9	125.0 ±9.7	125.0 ±10.0	1.198	.314
Stride (cm)	106.0 ±16.5	111.6 ±20.1	108.2 ±15.4	115.6 ±15.0	110.1 ±16.1	111.6 ±15.0	109.6 ±15.3	111.1 ±16.4	4.683	.004
Right step length (cm)	53.2 ±9.1	56.4 ±10.1	51.9 ±9.1	55.4 ±9.7	54.3 ±8.5	55.1 ±8.9	54.8 ±8.3	55.4 ±8.7	4.821	.003
Right walking angle (°)	10.1 ±4.5	9.2 ±4.5	9.8 ±4.5	8.7 ±4.5	9.5 ±4.6	8.8 ±5.6	9.7 ±4.9	8.8 ±4.6	0.183	.908
Left walking angle (°)	10.0 ±4.4	10.0 ±4.8	9.6 ±3.9	9.0 ±4.6	9.6 ±5.9	9.8 ±6.9	9.4 ±5.3	9.0 ±4.8	0.842	.474
Number of steps/day	3652.6 ±2325.7	4712.4 ±2831.9	4157.5 ±2049.3	5004.1 ±2073.2	4392.5 ±2346.6	4287.6 ±1983.8	3473.4 ±1858.9	3646.2 ±2019.4	3.126	.029
Calorie expenditure (kcal)‡	1425.8 ±150.3	1466.3 ±178.2	1454.5 ±182.0	1472.9 ±180.7	1481.2 ±184.7	1467.8 ±167.0	1438.4 ±120.9	1432.1 ±111.5	2.967	.036
Total cholesterol (mg/dL)	209.5 ±39.1	207.2 ±33.3	194.5 ±28.3	197.2 ±29.5	208.8 ±37.3	209.5 ±39.7	206.2 ±40.8	202.5 ±30.3	0.631	.597
Hemoglobin A1c (%)	5.8 ±0.7	5.9 ±0.7	5.7 ±0.5	5.8 ±0.5	5.8 ±0.8	5.9 ±0.8	5.8 ±0.6	5.9 ±0.5	0.547	.651
Leptin (ng/ml)	17.8 ±9.8	14.9 ±8.6	17.1 ±12.2	15.7 ±13.7	16.2 ±7.3	15.0 ±8.5	18.2 ±9.6	17.8 ±9.1	1.966	.123
Cystatin C (mg/L)	1.0 ±0.2	1.0 ±0.3	1.0 ±0.2	0.9 ±0.2	1.0 ±0.2	0.9 ±0.2	1.0 ±0.2	1.0 ±0.2	0.829	.481
Vitamin D (ng/mL)	23.2 ±9.5	33.6 ±9.2	24.2 ±7.6	22.3 ±6.6	22.5 ±7.3	33.8 ±8.1	27.0 ±8.0	23.4 ±5.5	42.393	<.001
IL-6 (pg/mL)	2.7 ±1.1	3.7 ±4.2	3.2 ±1.7	3.7 ±2.3	3.1 ±1.5	3.6 ±2.1	3.0 ±1.5	3.1 ±1.6	2.507	.063
HS-CRP (mg/L)	1.1 ±0.9	1.3 ±2.4	1.3 ±1.8	1.4 ±2.0	1.4 ±1.5	2.3 ±8.4	1.4 ±1.7	1.2 ±2.2	0.407	.748
Triglycerides (mg/dL)	144.6 ±61.2	141.9 ±56.8	137.9 ±65.1	143.4 ±63.7	156.3 ±76.6	162.1 ±67.3	124.0 ±55.6	134.7 ±60.3	0.438	.726

ASM, appendicular skeletal muscle mass; BIA, bioelectrical impedance analysis; DBP, diastolic blood pressure; HS-CRP, high-sensitivity c-reactive protein; IL-6, interleukin-6.

*Data are presented as mean and standard deviation.

†GEE = generalized estimating equation, G = group, T = time.

‡Total calorie expenditure per day.

Table 3
Baseline to Postintervention Percent Change Comparison of Selected Variables Between Groups

Variables	Exercise + Nutrition Mean ±SE	Exercise Mean ±SE	Nutrition Mean ±SE	Health Education Mean ±SE	*P* Value*	Post Hoc Analysis†
Percent body fat (BIA) (95% CI for mean)	−4.0 ±0.9 (−5.8 to −2.2)	−3.9 ±0.8 (−5.6 to −2.3)	−3.0 ±0.7 (−4.4 to −1.6)	−3.0 ±0.7 (−4.4 to −1.5)	.665	
Total body fat mass (95% CI for mean)	−5.5 ±0.9 (−7.3 to −3.6)	−4.9 ±0.9 (−6.9 to −3.0)	−2.9 ±0.8 (−4.6 to −1.2)	−2.2 ±0.9 (−4.0 to −0.3)	.036	Ex + N > HE
Appendicular fat mass (95% CI for mean)	−4.9 ±0.9 (−6.8 to −2.9)	−3.4 ±1.0 (−5.4 to −1.4)	−2.5 ±0.8 (−4.2 to −0.8)	−1.1 ±1.1 (−3.5 to 1.3)	.055	
Trunk fat mass (95% CI for mean)	−6.4 ±1.1 (−8.7 to −4.1)	−6.9 ±1.2 (−9.4 to −4.5)	−3.4 ±1.1 (−5.6 to −1.3)	−2.5 ±0.8 (−4.2 to −0.8)	.014	Ex > HE
Leg fat mass (95% CI for mean)	−4.3 ±1.1 (−6.5 to −2.2)	−2.2 ±1.0 (−4.4 to −0.1)	−2.2 ±0.9 (−4.0 to −0.4)	−0.5 ±1.2 (−2.9 to 2.0)	.088	
Arm muscle mass (95% CI for mean)	1.8 ±0.6 (0.5 to −3.1)	2.4 ±1.0 (0.6 to 4.2)	2.3 ±0.5 (1.2 to 3.4)	2.2 ±0.7 (0.7 to 3.8)	.926	
Leg muscle mass (95% CI for mean)	2.2 ±0.7 (0.7-3.7)	3.5 ±1.1 (1.2-5.7)	2.5 ±0.7 (1.2-3.9)	0.5 ±0.9 (−1.3 to 2.2)	.114	
SMI (95% CI for mean)	1.1 ±0.5 (0.0-2.1)	0.1 ±0.7 (−1.3 to 1.6)	0.6 ±0.6 (−0.6 to 1.9)	1.2 ±0.8 (−0.5 to 2.9)	.664	
Grip strength (95% CI for mean)	2.5 ±2.6 (−2.7 to 7.7)	−0.1 ±2.2 (−4.6 to 4.4)	3.3 ±2.5 (−1.9 to 8.5)	−0.7 ±2.2 (−5.2 to 3.8)	.606	
Knee extension strength (95% CI for mean)	17.8 ±4.5 (8.6-26.9)	12.8 ±4.2 (4.1-21.5)	9.0 ±3.0 (2.7 to 15.2)	4.9 ±3.2 (−1.7 to 11.5)	.119	
Usual walking speed (95% CI for mean)	5.7 ±2.2 (1.3 to 10.1)	1.0 ±2.1 (−3.2 to 5.3)	2.6 ±1.4 (−0.35 to 5.6)	2.4 ±1.6 (−1.0 to 5.7)	.328	
Stride (95% CI for mean)	5.2 ±1.2 (2.8-7.7)	5.7 ±1.4 (2.8-8.6)	1.1 ±1.5 (−2.0 to 4.2)	2.0 ±1.3 (−0.64 to 4.6)	.038	Ex + N, Ex > N; Ex > HE
Step length (95% CI for mean)	6.2 ±1.4 (3.3-9.1)	6.8 ±1.7 (3.4-10.3)	1.5 ±1.5 (−1.6 to 4.6)	1.0 ±1.1 (−1.2 to 3.2)	.007	Ex > HE
Walking angle (95% CI for mean)	−7.8 ±4.8 (−17.6 to 1.9)	−10.1 ±4.4 (−19.0 to −1.1)	−8.3 ±3.6 (−15.6 to −1.0)	−5.9 ±5.1 (−16.5 to 4.7)	.942	
Step count (95% CI for mean)	49.8 ±16.2 (16.9 to 82.8)	30.1 ±8.1 (13.4 to 46.7)	28.5 ±20.6 (−13.6 to 70.6)	11.8 ±9.4 (−7.5 to 31.1)	.362	
Leptin (95% CI for mean)	−13.5 ±4.1 (−21.9 to −5.2)	−11.9 ±3.8 (−19.6 to −4.2)	−7.6 ±3.5 (−14.8 to −0.39)	−0.1 ±4.4 (−9.1 to 8.9)	.093	
Vitamin D (95% CI for mean)	54.4 ±7.6 (38.9-70.0)	−3.2 ±6.1 (−15.7 to 9.3)	60.0 ±8.3 (43.0-76.9)	−10.4 ±3.7 (−18.1 to −2.8)	<.001	Ex + N, N > Ex, HE

BIA, bioelectrical impedance analysis; CI, confidence interval; SE, standard error; SMI, skeletal muscle mass index.
*One-way analysis of variance.
†A post hoc analysis was performed using the Scheffé method.

extension strength were observed in the Ex + N (17.8%), Ex (12.8%), and N groups (9.0%); however as seen in Table 4, the results do not confirm that the Ex + N was better than exercise alone. Interventions primarily based on exercise may be sufficient in improving muscle strength among sarcopenic obese individuals.

A previous study showed that walking speed was a significant risk factor for mortality, while calf skeletal muscle and fat mass were nonsignificant.[34] Baumgartner et al reported that elderly women with sarcopenic obesity were over five times more likely to have gait abnormalities than women with normal muscle mass and body fat.[1] The present study showed that usual walking speed increased in the Ex + N group by 0.096 ±0.129 m/s (mean percent change, 5.7 %; 95% CI for difference = 1.3-10.1) at postintervention. However, the changes were not significant in the Ex, N, and HE groups. The improvement in walking speed observed in the Ex + N group can be considered a clinically significant improvement, as evidence has shown walking speed increases of 0.1 m/s can be considered as such.[35] Further subanalysis showed that change in walking speed among participants with speeds less than 1.0 m/s based on the sarcopenic obesity criteria was 0.143 ±0.085 m/s at postintervention in the Ex + N group

Table 4
Adjusted Odds Ratio for Changes in Selected Body Composition and Functional Fitness Variables After Intervention by Study Group

Dependent variable*	Type of Intervention						
	Education	Nutrition		Exercise		Exercise + Nutrition	
	Reference	OR	95% CI	OR	95%CI	OR	95%CI
Percent fat	1.00	0.98	0.25-3.90	1.21	0.31-4.72	6.83	1.03-21.13
Total body fat mass	1.00	1.73	0.58-5.65	4.50	1.13-17.9	4.42	1.21-16.19
Trunk fat mass	1.00	2.25	0.67-7.56	2.59	0.73-9.18	4.08	1.08-15.37
Leg muscle mass	1.00	0.78	0.24-2.59	1.04	0.32-3.35	3.13	1.05-9.27
SMI	1.00	0.78	0.25-2.21	0.83	0.29-2.41	0.67	0.23-1.93
Muscle strength†	1.00	2.71	0.96-7.64	3.72	1.24-11.17	3.69	1.28-10.71
Walking speed	1.00	1.53	0.52-4.55	2.06	0.67-6.29	3.05	1.01-9.19
Vitamin D	1.00	6.22	1.19-32.68	0.59	0.19-1.82	14.22	1.64-123.02
Leptin	1.00	2.36	0.77-7.21	3.14	0.96-10.30	3.86	1.19-12.47
Percent fat + SMI	1.00	1.27	0.44-3.70	1.69	0.57-5.04	1.73	0.61-4.93
Percent fat + muscle strength	1.00	0.82	0.27-2.48	1.10	0.36-3.35	1.09	0.38-3.21
Percent fat + walking speed	1.00	0.87	0.29-2.59	1.50	0.50-4.46	1.41	0.49-4.04

CI, confidence interval; OR, adjusted odds ratio; SMI, skeletal muscle index.
Note. 1 = improved, 0 = no change or worsened.
*Dependent variable; change of selected body composition and functional fitness variables.
†Muscle strength = grip strength and knee extension strength.

(Ex = 0.098 ±0.067 m/s, N = −0.012 ±0.149 m/s, HE = 0.065 ±0.049 m/s, F = 4.184; $P = .014$). In those with walking speeds greater than 1.0 m/s, the change was 0.066 m/s at post-intervention in the Ex + N group (Ex = 0.013 ±0.059 m/s, N = 0.028 ±0.105, HE = 0.003 ±0.102). Greater improvements were observed in participants with slow walking speed, and combined exercise and nutrition supplementation was effective for improving walking ability in sarcopenic obese women with walking speed less than 1.0 m/s.

Significant changes were observed in fat, blood components, and physical function as single, independent variables. However, based on the operational definition of sarcopenic obesity in this study, which combines body fat with muscle mass, strength, and function, there were no significant changes in the combined variables (Table 4). In order to effectively treat sarcopenic obesity, improvements in single variables may not be sufficient. Although investigation into the reversal rate of sarcopenic obesity was beyond the scope of this study, future research should focus on interventions that could improve combined variables and effectively reverse sarcopenic obesity.

The results of the current study did not show improvements in metabolic or lipid status with the intervention, as no significant changes in HbA1c, triglyceride, or cholesterol levels were seen. Perhaps the intervention period of 3 months was insufficient in affecting lipid status in older adults. Regardless, significant changes in vitamin D and leptin were found in this study.

The fat-derived hormone, leptin, has been known to regulate body weight. Research has shown that leptin is positively correlated with BMI or changes in waist circumference,[36] and greater weight loss has been associated with decreases in leptin.[37] In the current study, significant decreases in leptin were observed in the Ex + N (−13.5 ±4.1%), Ex (−11.9 ±3.8%), and N (−7.6 ±3.5%) groups. We performed further subanalyses to investigate changes in leptin by quartiles of change in body fat percent. In the highest quartile (ie, smallest change in body fat percent), leptin was reduced by −1.02 ±3.86%; in the middle two quartiles (25%-75%), the change in leptin was −11.65 ±2.84%, and in the lowest quartile (ie, greatest change in body fat percent, change in leptin was −11.87 ±3.68% [F = 2.907; $P = .059$]). While statistically non-significant, a trend toward leptin reduction with greater body fat percent decline was observed.

In previous studies, low 25(OH)D levels have been correlated with cardiovascular disease, various autoimmune diseases, diabetes mellitus, malignancy, falls, fractures, depression, and cognitive function.[38–40] Moreover, a strong inverse association between 25(OH) D level and sarcopenia has been reported in older populations.[41] One meta-analysis showed that the prevalence of vitamin D deficiency was associated with obesity in Asian (OR, 3.70; 95% CI, 1.98-6.90) and European-American (OR, 3.09; 95% CI, 1.89-5.04) people.[42] Furthermore, a review summarized that 25(OH)D levels of 30 ng per milliliter would be sufficient.[38] Based on this standard/criterion, 78.4% of participants in this study (Ex + N = 85.3%; Ex = 70.0%; N = 80.6%; HE = 76.7%, chi-square = 2.35; $P = .503$) were vitamin D deficient (<30 ng/mL) at baseline. After the 3-month intervention, a smaller percentage, 49.6% (Ex + N = 31.4%; Ex = 81.2%; N = 15.2%; HE = 77.8%, chi-square = 41.68; $P < .001$) were vitamin D deficient. Vitamin D levels significantly increased by 54.4% in the Ex + N group, where the number of vitamin D-deficient participants decreased from 28 at baseline to eight participants postintervention (McNemar chi-square = 20.05; $P < .001$) and 60.0% in the N group, where the number of vitamin D deficient participants significantly decreased from 24 at baseline to four postintervention (McNemar chi-square = 20.63; $P < .001$). These results can be explained by the 20 μg of vitamin D that was provided within the amino acid supplementation. Daily intake of vitamin D supplementation can prevent vitamin D deficiency in sarcopenic obese elderly women.

There are several limitations in this study. First, we were unable to investigate the effects of the nutrition supplementation against placebos in a four-group design including E + N, exercise + placebo, nutrition, and placebo groups. Furthermore, the nutrition supplementation combined both the amino acid and tea catechins; hence, the separate effects of each supplementation could not be determined. Readers should be aware that the results observed in the nutrition supplementation groups reveal the effects of combined amino acids and tea catechins. Second, the exercise intervention incorporated both aerobic and resistance training. The results of this study cannot confirm the separate effects of aerobic and resistance exercise. Third, DXA was used to screen for sarcopenic obesity, while other measures of body composition were assessed using bioelectrical impedance analysis for pre- and postintervention comparisons.

In conclusion, the combination of exercise and nutrition effectively improved body fat, blood components, and physical function in sarcopenic obese elderly women, although no additive effects of the combination intervention could be confirmed.

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