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The Impact of Exercise Snacking on Body Composition and Cardiovascular Function Indicators in Obese College Students

Objective This study aimed to investigate the effects of exercise snacking (ES) on body composition, carotid-femoral pulse wave velocity (cfPWV), and serum resistin in male and female obese college students.

Material and methods A total of 50 male and 50 female college students, each with a body mass index (BMI) ≥28 kg/m^2, were enrolled in the study. The male and female groups were each further divided into an exercise snacking group (ES group, n=25) and a moderate-intensity, continuous training group (MICT group, n=25). The ES group conducted two 5-min high-intensity interval training (HIIT) sessions and one 30-min session of aerobic exercise incorporating HIIT elements daily, while the MICT group performed 45 min of running at the maximal fat-burning intensity each day. All participants were tested for body composition, including body weight (BW), body mass index (BMI), body fat mass (BFM), trunk fat mass (TFM), skeletal muscle mass (SMM), arterial stiffness, and serum resistin concentrations before and after a 12 wk exercise program. Arterial stiffness was evaluated by measuring carotid-femoral pulse wave velocity (cfPWV).

Results After the exercise program, the ES and the MICT groups both had reduced BW, BMI, BFM, and TFM ($p<0.01$). Only in the ES group, were significant changes observed in SMM, cfPWV, and serum resistin, ($p<0.01$). Pearson correlation analysis revealed that for obese male students, changes in serum resistin correlated positively with cfPWV ($r=0.67$, $p<0.01$) and negatively with the increase in muscle mass ($r=-0.68$, $p<0.01$). For obese female students, changes in serum resistin tended to show a positive correlation with TFM, however, no statistically significant difference was observed ($r=0.35$, $p=0.09$). There was a positive correlation with cfPWV ($r=0.44$, $p<0.05$), and a negative correlation with the increase in muscle mass ($r=-0.90$, $p<0.01$).

Conclusion An ES protocol can serve as an effective exercise strategy to help obese college students significantly improve their body composition and cfPWV indicators of arterial stiffness.

Keywords Exercise snacking; college students; body composition; cardiovascular system; physical activity; obesity

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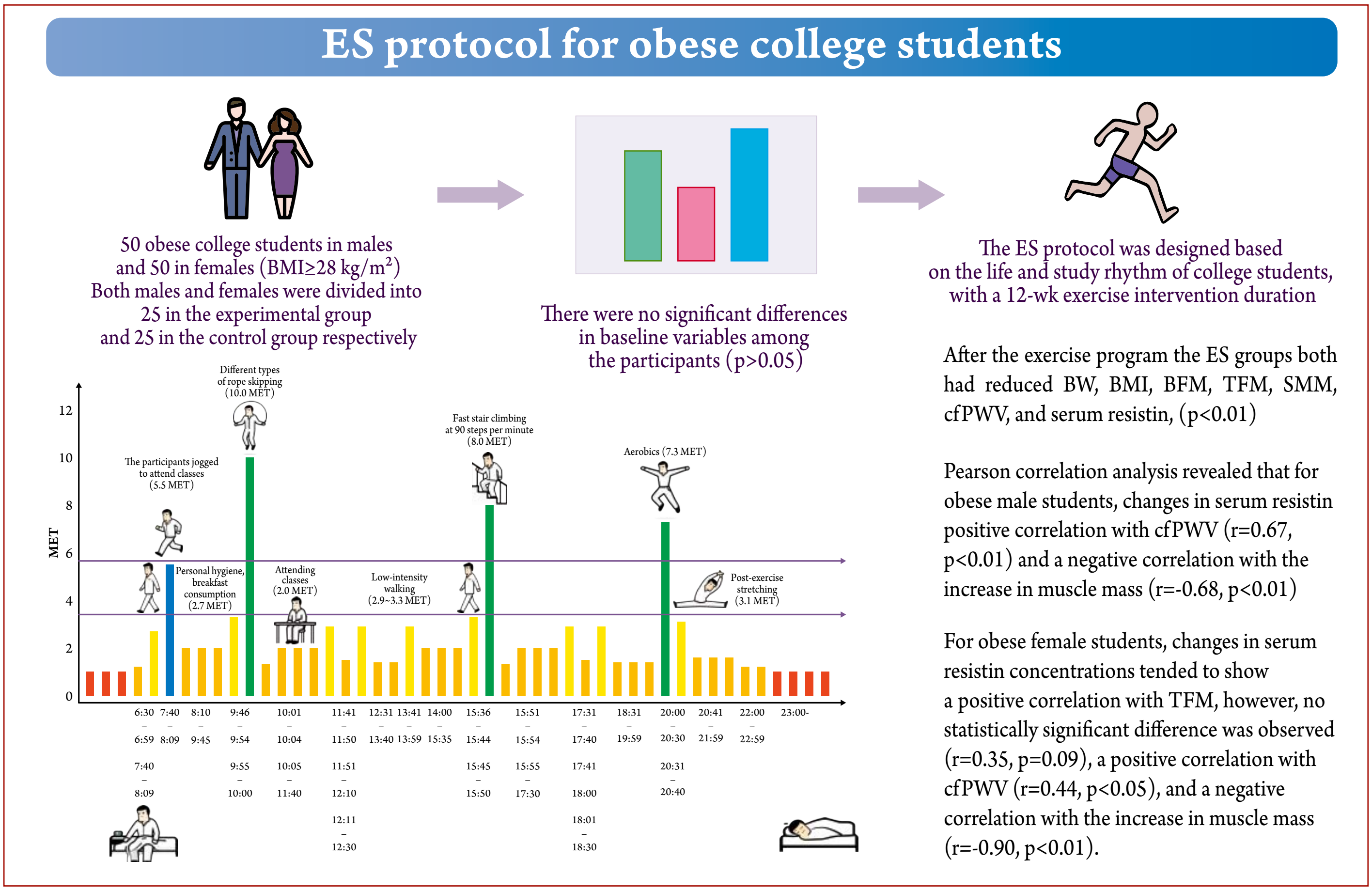
Introduction

Obesity is closely associated with the development of several chronic diseases, including hypertension, diabetes, and dyslipidemia, and it is usually accompanied by an increase in arterial stiffness [1–4]. Pulse wave velocity (PWV) is an indicator arterial stiffness [5]. Studies have confirmed that carotid-femoral pulse wave velocity (cfPWV) can independently predict cardiovascular risk in healthy adults and in patients with cardiovascular disease, since cfPWV, is highly correlated with hypertension and obesity-mediated arteriosclerosis [6]. Resistin, a polypeptide hormone secreted by adipocytes, is closely associated with obesity, insulin resistance, the regulation of lipid metabolism, and the occurrence and progression of diabetes mellitus [7]. Resistin is mainly secreted by monocytes and macrophages, and it plays a key role in the treatment of atherosclerosis and coronary heart disease [8].

Moderate-intensity, continuous training (MICT) typically requires a duration of more than 30 min, with exercise intensity maintained at 40%–70% of maximum heart rate (HRmax). MICT has been shown to decrease body weight and fat mass in obese individuals [9]. However, limitations of MICT have become apparent. Specifically, MICT has a high time cost and often results in training burnout [10]. High-intensity interval training (HIIT) typically involves single training bouts, ranging from short (<45 s) to relatively long (2–4 min), and has a total exercise duration of approximately 20 min. Meanwhile, the exercise intensity should reach 80–95% of maximal oxygen uptake HIIT, characterized by short training duration and high efficiency, has become a preferred exercise intervention for a growing number of obese individuals [11, 12]. Nevertheless, due to the combined characteristics of "high intensity" and "insufficient rest interval" in HIIT, it is suitable for fitness enthusiasts with a certain level of basic

Central illustration. ES protocol implemented by obese college students on workdays



physical fitness, while for the sedentary college student population, it is prone to cause symptoms such as dizziness and chest tightness. Thus, while both MICT and HIIT can significantly treat obesity, they can hardly meet the needs of sedentary, obese college students for an exercise program with "short duration, high efficiency, and with some flexibility".

A new form of rehabilitation therapy, exercise snacking (ES), has been gaining increasing attention. ES involves engaging in three sessions of high-intensity, intermittent physical activity per day (each lasting 1 or 2 min). Stamatakis et al. reported that ES reduced the risk of all-cause mortality and cancer mortality by 38%–40%, and the risk of cardiovascular disease mortality by 48%–49% [13].

Prior research on ES has focused on the general population [14], and training frequency, duration, and intensity of ES varies [15]. Prior studies have not systematically delineated the ES specific training-related effects of ES on body composition and cardiovascular function health in young, obese subjects [16].

Thus, this study compared the therapeutic effects of 12-wk ES and MICT in obese college students. Body composition, cfPWV, and serum resistin were measured. Ultimately, this study aimed to provide support for ES as a more effective weight-loss method to improve the cardiovascular health of obese college students.

Material and methods

Study design and participants

Based on the results of the 2024 physical fitness tests of college students at Heihe University, 50 obese female students and 50 obese male students, with a body mass index (BMI) ≥28 kg/m^2, were selected. Each gender group was randomly divided into two subgroups: the ES group (25 participants) and the MICT group (25 participants). Independent samples t-tests were performed to compare the age, height, weight, and BMI of participants in the two groups before beginning the respective exercise programs. No statistically significant differences were found between the two groups p>0.05 for all (Table 1).

The criteria for participants:

1) No exercise or diet program during the 6 mos prior to the trial;
2) No medications or recreational drugs in the 3 mos prior to the trial and during the trial period;
3) No cardiovascular disease, kidney disease, or exercise contraindications.

All participants and their parents were informed of the purpose of the experiment, and the students voluntarily participated in the study program. All participants gave written informed consent before beginning the respective exercise program.

Table 1. Basic information of obese college students before the exercise program

Variable	ES Group	MICT Group	t	p
Male Participants (n=50)				
Age (yrs)	19.48±1.00	19.32±0.75	0.639	0.526
Height (cm)	178.12±4.66	177.80±4.55	0.402	0.691
Weight (kg)	92.62±5.97	91.88±5.96	0.437	0.665
BMI (kg/m²)	29.20±0.40	29.02±0.44	1.476	0.147
Female Participants (n=50)				
Age (yrs)	19.48±0.87	19.52±0.77	–0.172	0.864
Height (cm)	163.20±3.73	162.68±3.08	0.538	0.593
Weight (kg)	77.23±4.06	77.53±4.02	- 0.260	0.796
BMI (kg/m²)	28.98±0.48	29.28±0.94	–1.067	0.292

Data are mean±SD. ES, exercise snacking; MICT, moderate-intensity, continuous training; BMI, body mass index.

Exercise protocols

Based on the basis of Cases of Fragmented Exercise by Chinese Sedentary Office Workers on Workdays [17] and the 2022 Reference Values for Physical Activity Energy Expenditure of Healthy Chinese Adults [18], a specialized ES protocol for obese college students was developed by integrating the living and learning habits and characteristics of college students.

Participants in the ES group and the MICT group completed a 12-wk (5 sessions/wk) exercise protocol. In the ES protocol and MICT protocols, exercise intensity was measured using metabolic equivalents (METs).

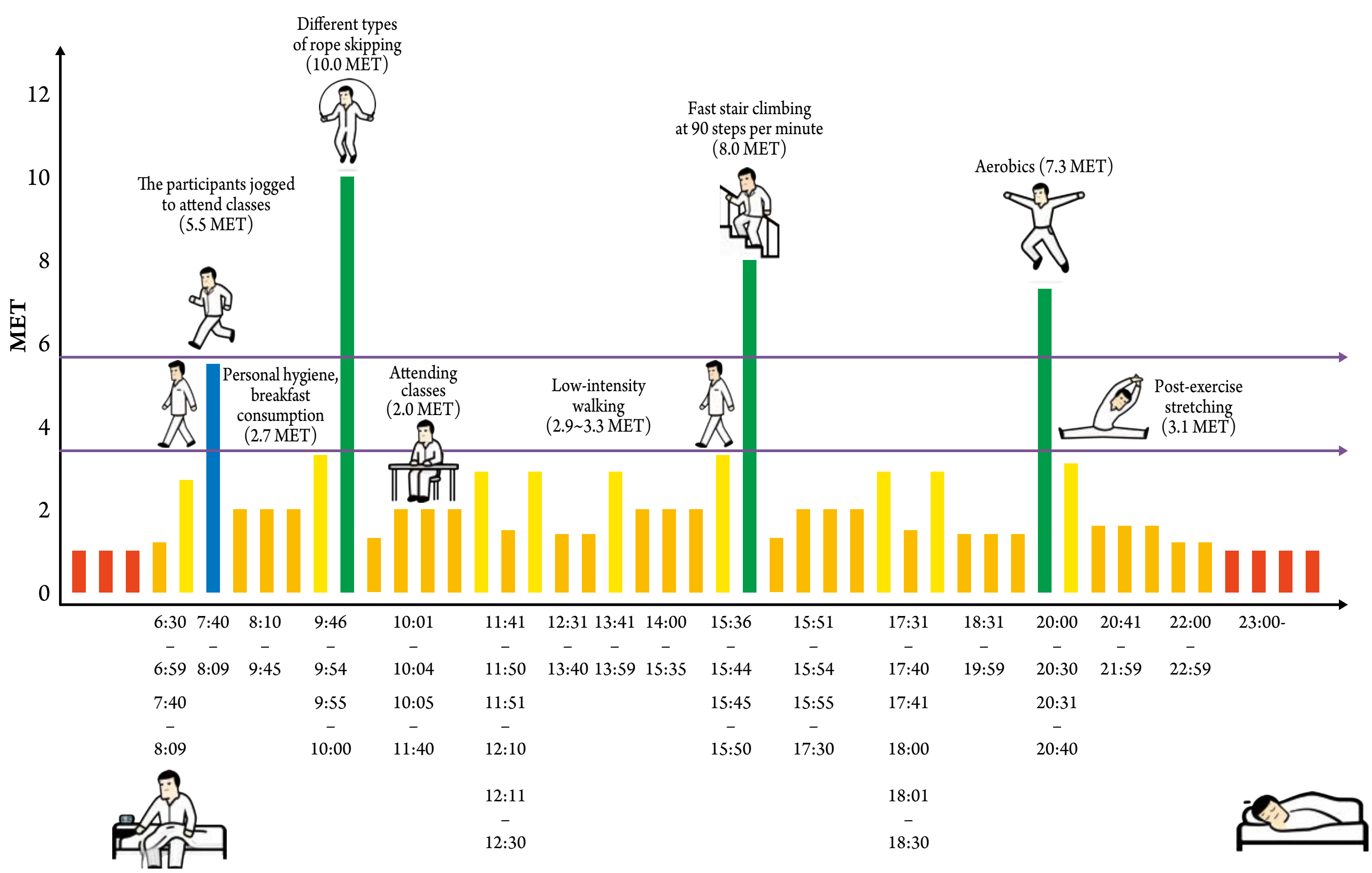
During class days, the students in the ES exercise program performed personal activities (eating, walking, and attending classes) (2.7 Met). Intermittently they jogged, approximately 30 min (5.5 Met), skipped rope, 5 min (10.0 Met), stair climbed (90 steps per min), 5 min (8.0 Met), session of aerobic exercise incorporating HIIT elements, 30 min (7.3 Met), and stretched post-exercise (3.1 Met). On weekends, the students performed only personal activities. The ES exercise program is illustrated in Figure 1.

During class days, the students in the MICT exercise program performed personal activities (eating, walking, and attending classes) (2.7 Met). Running at the maximal fat-burning intensity, 45 min (6.5 Met), and stretched post-exercise (3.1 Met). On weekends, the students performed only personal activities. The MICT exercise program is illustrated in Figure 2.

Exercise monitoring

Subjects recorded their exercise daily and self-monitored their activities using the Rating of Perceived Exertion (RPE) Scale [19].

Figure 1. ES protocol implemented by obese college students on class days



Red sleep; Orange, sedentary behavior; Yellow, low-intensity exercise; Blue, moderate-intensity continuous exercise; Green, high-intensity interval training.

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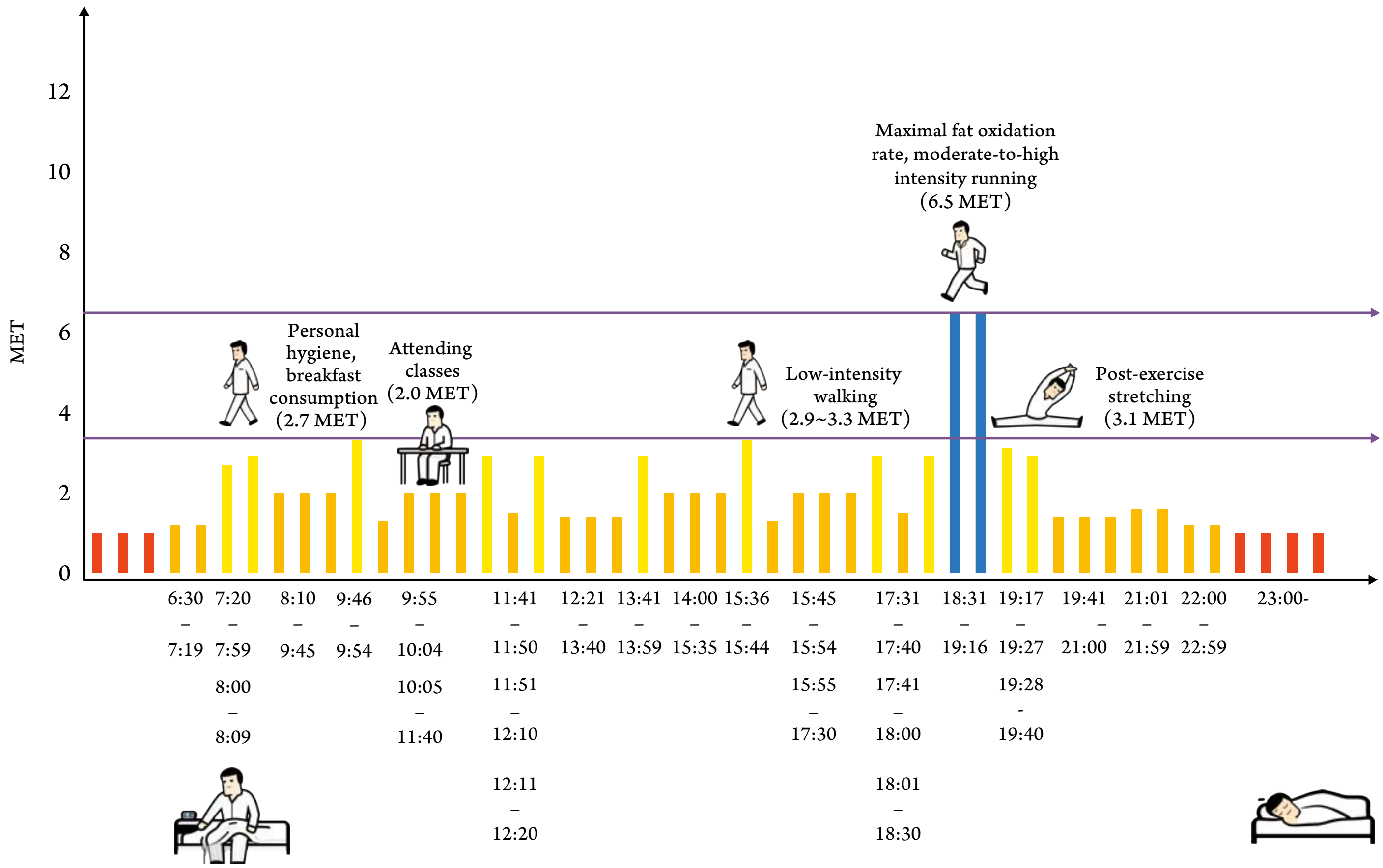
Figure 2. MICT protocol implemented by obese college students on class days



Red sleep; Orange, sedentary behavior; Yellow, low-intensity exercise; Blue, moderate-intensity continuous exercise.

Measured variables

cfPWV

The participant was placed in a supine position, with the neck relaxed naturally, arms placed on both sides of the body, and remained in a quiet state for 5 min. A Beijing Maibang MB-3000 pulse wave velocity source was used to measure cfPWV, which served as the indicator of the elastic function of the central large arteries. Non-invasive pressure sensing probes were fixed at:

1) The site with the most obvious pulsation of the right common carotid artery, i.e., anterior border of the sternocleidomastoid muscle at the level of the thyroid cartilage); and
2) The site with the most obvious pulsation of the right femoral artery. This was 2 cm below the midpoint of the inguinal ligament.

Body composition

Before and after the exercise program, a Qinghua Tongfang Body Composition Analyzer (Model: BCA-1C) was used to measure body composition. Prior to testing, the instrument was calibrated, and the participants' identification was recorded. The participants stood barefoot on the instrument's footplate, and the placed their palms on the electrode handles with their arms hanging naturally. Throughout the entire process, they maintained a fixed posture with an upright torso, and with the arms not touching the body. The measured variables were body weight (kg), BMI (kg/m^2), body fat mass (kg), trunk fat mass (kg), and skeletal muscle mass (kg).

Serum resistin

Fasting elbow venous blood (5 ml) was collected in the early morning before the exercise program was initiated and 48 h after the end of the program. Fifteen min before the blood collection, the participants were required to sit quietly in a room with temperature of 22~25 °C. After blood collection, the blood samples were held at room temperature for 30 minutes to allow full coagulation. The samples were then centrifuged at 3000 rpm for 15 min at 4 °C. The supernatant was collected, and the serum resistin concentration was measured using the enzyme-linked immunosorbent assay (ELISA) according to the kit instructions.

Statistical analysis

All experimental data were expressed as mean±SD, and statistical analysis was conducted using SPSS statistical software. Paired t-tests were performed to compare the ES group

Table 2. Comparison of variables before and after the ES and MICT exercise programs in male students

Variable	ES Group before the Exercise Program (males, n=25)	ES Group after the Exercise Program (males, n=25)	p
WB (kg)	92.62±5.97	88.85±4.96	<0.01
BMI (kg/m²)	29.20±0.40	27.98±0.26	<0.01
BFM (kg)	26.37±1.97	24.32±1.77	<0.01
TFM (kg)	15.09±1.16	13.67±1.07	<0.01
SMM (kg)	29.89±2.35	30.55±2.10	<0.01
cfPWV (m/s)	8.35±0.18	8.00±0.22	<0.01
Serum Resistin (ng/ml)	6.59±0.56	6.21±0.51	<0.01

Variable	MICT Group before the Exercise Program (males, n=25)	MICT Group after the Exercise Program (males, n=25)	p
WB (kg)	91.88±5.96	89.26±5.31	<0.01
BMI (kg/m²)	29.02±0.44	28.21±0.36	<0.01
BFM (kg)	26.04±2.01	23.98±1.92	<0.01
TFM (kg)	15.08±1.24	14.68±1.10	<0.01
SMM (kg)	29.94±2.07	30.15±1.82	0.10
cfPWV (m/s)	8.26±0.19	8.18±0.23	0.09
Serum Resistin (ng/ml)	6.63±0.58	6.56±0.47	0.08

Data are mean±SD. ES, exercise snacking; MICT, moderate-intensity, continuous training; BMI, body mass index; WB, body weight; BMI, body mass index; BFM, body fat mass; TFM, trunk fat mass; SMM, skeletal muscle mass; cfPWV, carotid-femoral pulse wave velocity.

Table 3. Comparison of variables before and after the ES and MICT exercise program in female students

Variable	ES Group before the Exercise Program (females, n=25)	ES Group after the Exercise Program (females, n=25)	p
WB (kg)	77.23±4.06	75.08±3.71	<0.01
BMI (kg/m²)	28.98±0.48	28.20±0.45	<0.01
BFM (kg)	26.45±2.70	24.57±2.64	<0.01
TFM (kg)	14.40±2.22	13.04±2.31	<0.01
SMM (kg)	22.88±2.41	25.27±2.45	<0.01
cfPWV (m/s)	7.95±0.33	7.57±0.34	<0.01
Serum Resistin (ng/ml)	6.55±0.62	6.23±0.62	<0.01

Variable	MICT Group before the Exercise Program (females, n=25)	MICT Group after the Exercise Program (females, n=25)	p
WB (kg)	77.53±4.02	75.09±4.04	<0.01
BMI (kg/m²)	29.28±0.94	28.32±1.00	<0.01
BFM (kg)	26.54±2.68	24.95±2.50	<0.01
TFM (kg)	14.50±2.21	13.30±1.98	<0.01
SMM (kg)	22.66±2.58	23.08±1.58	0.15
cfPWV (m/s)	7.88±0.35	7.79±0.18	0.16
Serum Resistin (ng/ml)	6.61±0.40	6.56±0.35	0.24

Data are mean±SD. ES, exercise snacking; MICT, moderate-intensity, continuous training; BMI, body mass index; WB, body weight; BMI, body mass index; BFM, body fat mass; TFM, trunk fat mass; SMM, skeletal muscle mass; cfPWV, carotid-femoral pulse wave velocity.

and the MICT group after exercise intervention. Pearson correlation analysis was applied to explore the correlations between the changes in serum resistin and those in other indicators following ES intervention, with the significance level set at α=0.05.

Results

Among the obese male students, both exercise programs produced significant decreases in, WB, BMI, BFM, and TFM ($p<0.01$, for all). SMM, cfPWV, and serum resistin significantly increased only in the ES group ($p<0.01$) (Table 2).

Among the obese female students, both exercise programs produced significant decreases in, WB, BMI, BFM, and TFM ($p<0.01$, for all). SMM, cfPWV, and serum resistin significantly increased only in the ES group ($p<0.01$) (Table 3).

After 12-wk of the exercise program, Pearson correlation analysis revealed that for obese male students, changes in serum resistin concentrations showed no statistically significant correlations with the body composition indicators, (BW, BMI, BFM, and TFM), with r-values of 0.06, 0.02, 0.11, and –0.07, respectively, ($p>0.05$, for all). These changes in serum resistin were positively correlated with cfPWV ($r=0.67$, $p<0.01$) and negatively correlated with the increase in muscle mass ($r=–0.68$, $p<0.01$) (Figure 3).

For obese female students, changes in serum resistin concentrations showed no statistically significant correlations with the body composition indicators, (BW, BMI, and BFM), with r-values of –0.15, –0.17, and 0.24, respectively, ($p>0.05$, for all). Changes in serum resistin concentrations tended to show a positive correlation with TFM ($r=0.35$, $p=0.09$), a positive correlation with cfPWV ($r=0.44$, $p<0.05$), and a negative correlation with the increase in muscle mass ($r=–0.90$, $p<0.01$) (Figure 4).

Discussion

In a 12-wk randomized controlled trial, this study found that, the ES program significantly reduced serum resistin concentrations and increased SMM and improved cfPWV in male and female obese college students compared with a MICT exercise program.

In the ES protocol, it is likely that brief HIIT reduced adipose tissue inflammation by enhancing lipoprotein lipase (LPL) activity and decreasing fat accumulation, thereby indirectly reducing resistin release [20]. The HIIT in the ES protocol can stimulate muscle cells to produce more glucose transporters, promote glycolysis and energy metabolism, and may indirectly facilitate the repair and synthesis of muscle fibers [21, 22]. In contrast, the continuous mild intensity of MICT exerts relatively weaker stimulation on muscles [21, 22].

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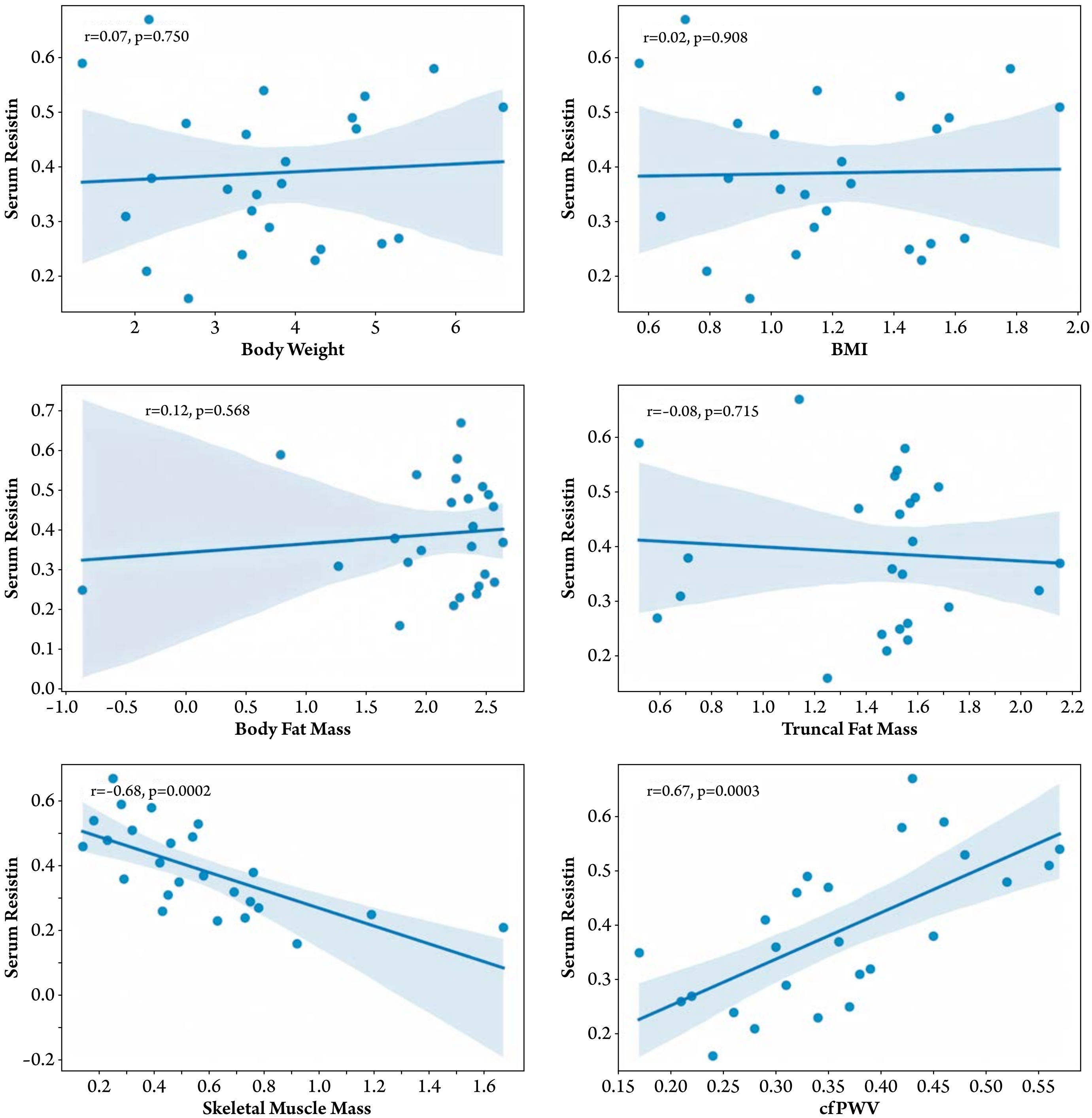
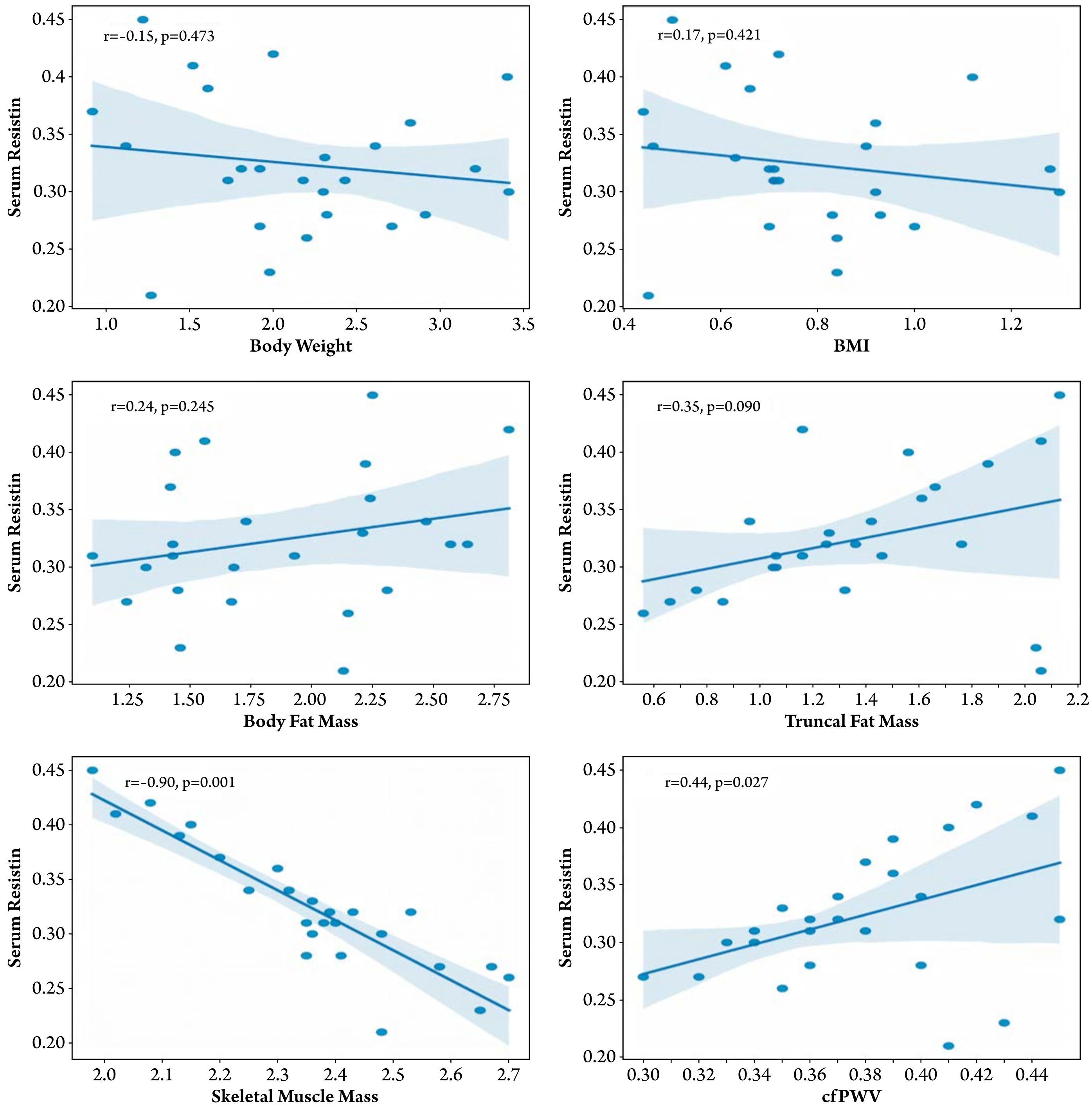
Figure 3. Correlation scatter matrix plot of serum resistin and body composition indices in the obese male students



cfPWV is the standard for evaluating aortic stiffness. A relevant study showed that serum resistin concentrations in a high aortic stiffness group (cfPWV >10 m/s) were significantly higher than those in a low stiffness group (10.09 ± 4.46 ng/ml vs 6.07±2.85 ng/ml, $p<0.001$) [23]. A significant correlation between serum resistin, SKMM, and cfPWV was found. This correlation stemmed from mechanisms such as inflammation-mediated vascular injury and endothelial dysfunction [23]. Essentially, this is attributed to resistin's simultaneous regulation of skeletal muscle metabolism and arterial stiffness through three core mechanisms: inflammatory pathways, insulin resistance, and vascular function modulation [24]. Polak-Szczybyło and Tabarkiewicz [25] pointed out that serum resistin is positively correlated with obesity, and, serum resistin is regulated by dietary structure and by some drugs and supplements. Thus, changes in serum resistin can serve as an important reference indicator for evaluating the metabolic inflammatory status and the risk of related diseases in obese populations.

Ashor et al. [26] recruited adults aged 18 yrs and older as participants in a study to compare the effects of high-intensity aerobic exercise and moderate-intensity aerobic exercise.

Figure 4. Correlation scatter matrix plot of serum resistin and body composition indices in the obese female students



They found that aerobic endurance exercise mainly affects brachial-ankle pulse wave velocity, with a smaller impact on cfPWV. Compared with MICT, HIIT can significantly increases systemic blood flow velocity. An increase in blood flow velocity further elevates the shear stress on vascular walls, which activates vascular endothelial cells, prompting them to synthesize and release more nitric oxide (NO). NO relaxes vascular smooth muscle, which in turn triggers vasodilation and reduces peripheral vascular resistance [27]. These physiological responses indicate that the ES program might more effectively enhance vascular adaptability to exercise stimuli.

Place et al. [28] conducted a study on high-intensity interval ES in recreational populations. They found that a single session of high-intensity interval ES can induce adaptive changes in skeletal muscle: through reactive oxygen species (ROS) – dependent fragmentation of the ryanodine receptor 1, which increases sarcoplasmic reticulum Ca^{2+} leakage at rest. These events trigger the regulation of gene expression related to mitochondrial biogenesis. e.g., changes in transcriptional levels of PGC-1α isoforms, ultimately achieving an improvement in muscle function adaptability.

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Previous studies on ES programs have primarily focused on working professionals, individuals with limited fitness experience, or middle-aged and elderly individuals with underlying diseases. A Meta-analysis demonstrated that ES programs significantly increased maximal oxygen uptake (VO_2max) in adults (SMD= 1.43, 95% CI 0.61–2.25, p<0.001) and peak power output (PPO) (SMD= 0.68, 95% CI 0.00–1.36, p=0.050). Additionally, total cholesterol (TC) (SMD= −0.65, 95% CI −1.18 to −0.11, p=0.018) and low-density lipoprotein cholesterol (LDL–C) (SMD=−0.65, 95% CI −1.22 to −0.09, p=0.023) were markedly reduced in adults from the ES group, with this effect being more pronounced in sedentary populations (TC: SMD= −0.72, 95% CI −1.39 to −0.05, p=0.036) [29]. ES programs can targetedly mitigate age-related physiological decline in older adults. Perkin et al. [30] demonstrated that ES programs could significantly enhance leg muscle strength and muscle mass in older adults, thereby effectively counteracting the risk of sarcopenia (muscle loss) in the elderly. Liang et al. [31] performed a mixed-methods study, in which 72% of older adult participants reported that 12-week sustained ES programs had enabled them to experience higher energy levels and a more positive attitude towards life, which effectively alleviated the psychological distress and loneliness commonly encountered in late life. In summary, through the improvement of physiological functions, regulation of psychological states and highly adaptable design, ES serves as an effective intervention for enhancing the physical activity levels of adults with limited fitness experience, working professionals and older adults.

Future studies should adopt a multi-center study design. Obese college students from different regions, from different types of colleges and universities, and different living environments should be studied. Expanding the sample size and using stratified sampling to reduce sampling bias will enhance the national promotion value of the results. The optimal treatment frequency, duration, and exercises of ES remand to be defined.

Limitations of this study

This study has several limitations. The duration of the study was short, and the sample size was small;

The ES protocol was designed for the college student population. This may limit its general applicability;

The impact of different dietary conditions was not evaluated.

Conclusion

ES is a novel weight lose strategy for college students that integrates both application feasibility and health promotion effects. Its high feasibility stems from the low requirements of ES in terms of load and frequency arrangements, equipment, and environmental conditions. Periodic application of ES can effectively improve body composition, muscle mass, and cfPWV. Additionally, as a new direction in exercise science, ES may provide a novel exercise program for other sedentary populations to improve their health.

No conflicts of interest are reported.

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