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Article

# The Effects of High-Intensity Interval Training on Body Composition, Blood Lipids, and Lipoproteins in Female College Students with Normal-Weight Obesity

**Yanying Liu, Qingkun Feng and Yongyang Ou**

*School of Physical Education and Health, Zhaoqing University, Zhaoqing 526061, China*

**Abstract:** Objective: To investigate the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on body composition, blood lipids, and lipoprotein in occultly obese female college students. Methods: Female college students who were not majoring in physical education were randomly divided into HIIT group and MICT group. The body composition, blood lipids, apolipoprotein, and lipoprotein levels of the subjects before and after exercise were measured. Results: Both 12 weeks of HIIT and MICT reduced body weight, body mass index, body fat percentage (BF%), degree of obesity, waist-to-hip ratio, and visceral fat area in female college students with normal-weight obesity. The HIIT group showed a significantly lower body fat percentage (BF% ) and visceral fat area compared to the MICT group. Additionally, the HIIT group demonstrated a significant decrease in triglyceride levels and a significant increase in high-density lipoprotein cholesterol levels, whereas the MICT group did not exhibit these effects. Serum apolipoprotein AI (ApoAI) levels were significantly increased in the HIIT group. The levels of apolipoprotein B100 (ApoB100) and lipoprotein (LP(a)) were significantly decreased. Serum ApoB100 levels in the MICT group were decreased, and there was no significant change in the levels of ApoAI and LP(a). Conclusion: Both 12-week HIIT and MICT interventions reduced the degree of obesity in female college students with normal-weight obesity. However, HIIT was more effective than MICT in reducing body fat percentage (BF%) and visceral fat area. High-Intensity Interval Training is an effective exercise modality for improving body composition, blood lipids, apolipoprotein, and lipoprotein levels in this population.

**Keywords:** hidden obesity; body composition; blood lipids; apolipoprotein; lipoproteins

## 1. Introduction

Obesity has become the biggest public health issue worldwide in the 21st century. According to Chinese standards, a BMI within the range of 18.5–23.9 kg/m$^2$ is considered “normal”, while a BMI ⩾ 28 is classified as “obesity” [1]. Normal-weight obesity refers to a condition in which the BMI falls within the normal range, but the body fat percentage (BF%) exceeds the standard [2]. It is characterized by reduced muscle mass, increased fat mass, and a body weight within the normal range, making it a latent form of obesity that is difficult to detect [3]. Since body weight does not exceed the standard, normal-weight obesity is often overlooked, posing serious potential risks to health. Studies have shown that individuals with normal-weight obesity not only experience declines in physical function and stamina, but also tend to accumulate fat primarily around the viscera, leading

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* Corresponding: Yanying Liu (1034494456@qq.com)

to visceral adipose-type central obesity, which can easily trigger chronic diseases such as cardiovascular and cerebrovascular diseases, diabetes, and cancer [4]. Other studies have found that normal-weight obesity can cause abnormal increases in estrogen and inflammatory factors, thereby increasing the risk of chronic diseases such as cardiovascular and cerebrovascular diseases, diabetes, female breast cancer, and endometrial cancer [5].

The physical health of female university students has always been a subject of concern. As female students generally engage in prolonged sedentary behavior, participate less in physical exercise, and have relatively higher estrogen levels leading to lower lean body mass and higher body fat content, they are more prone to having a normal BMI but an excessive BF% [5, 6]. Many surveys have also indicated that the incidence of normal-weight obesity is generally high among female university students [7, 8]. In recent years, high-intensity interval training (HIIT) has gained widespread popularity in exercise-based weight loss practices [9, 10]. Conventional views hold that prolonged low-to-moderate intensity exercise utilizes fat oxidation for energy to achieve weight loss, often overlooking the substantial fat consumption during the recovery period following HIIT. Studies have also found that although high-intensity exercise primarily relies on carbohydrates for energy, the total fat oxidation during the 24-h recovery period (attributable to excess post-exercise oxygen consumption, EPOC) is equivalent to the fat oxidized during 24 h following moderate-intensity continuous exercise [11]. This has significant implications for choosing exercise modalities for weight loss and weight control.However, due to the high intensity of HIIT, which places greater demands on the cardiovascular function and adaptive capacity of individuals not accustomed to regular exercise, its safety and applicability require further investigation [12]. For sedentary female university students with normal-weight obesity, determining the optimal exercise modality remains under-researched. Based on this, our study investigates the effects of two exercise modalities—High-intensity Interval Training (HIIT) and Moderate-Intensity Continuous Training (MICT) —on key body composition indicators and blood lipid profiles in female university students with normal-weight obesity. The indicators monitored include Body Mass Index (BMI), BF%, Waist-to-Hip Ratio (WHR), degree of obesity, visceral fat area, as well as changes in blood lipids, apolipoproteins, and lipoprotein levels. The aim is to provide a reference for developing effective exercise guidance protocols to improve the physical health of individuals with normal-weight obesity.

## 2. Objects and Methods

### *2.1. Object*

Following the principle of voluntariness, 89 female university students with normal-weight obesity were recruited from the non-sports major population of Zhaoqing University, 53 of whom participated in the experiment. After excluding individuals with irregular dietary habits, lifestyles, or physical activity levels, as well as those who dropped out during the study, 23 subjects finally completed the experiment from 2 April 2018, to 22 June 2018.Inclusion criteria: Informed of and voluntarily agreed to participate in this experiment; without motor dysfunction; stable body weight in the past three months and no regular exercise habits; $18.5\ kg/m^2 \leqslant BMI \leqslant 23.9\ kg/m^2$ and BF% ⩾ 30% [13]; no history of using weight-loss drugs; no family history of genetic diseases. Exclusion criteria: Conditions including hyperglycemia, hypertension, endocrine diseases, or cardiovascular and cerebrovascular diseases; abnormal heart, lung, liver, or kidney functions; inability to successfully complete a maximal exercise test. The experimental design complied with medical ethics standards and was approved by the Ethics Committee of Zhaoqing University, with informed consent obtained. Before the experiment, all participants' physical condition was assessed, and their height, body weight, body composition, blood indicators, and maximal oxygen uptake ($VO_2$ max) were measured. After one week of adaptive exercise training, they were randomly assigned to either a HIIT group (n = 12) or a MICT group (n = 11), undergoing 12 weeks of HIIT and MICT interventions, respectively. Independent samples t-tests showed no statistically significant differences in age, height, or body weight between the two groups before the experiment. During the experimental period, participants maintained their habitual dietary patterns, lifestyles, and physical activity levels. Prior to the experiment, all participants were informed of the study's purpose and signed informed consent forms.

### *2.2. Methods*

#### 2.2.1. Exercise Training Protocol

The HIIT protocol in this study was designed with reference to an exercise regimen for young obese females [14]. It was performed on a treadmill, consisting of 4-min intervals at 85~95% of peak heart rate (HR peak, the heart rate corresponding to $VO_2$ max) followed by 3-min intervals at 50~60% of HR peak. This was followed by 5 min of passive rest, constituting one cycle. A total of 5 cycles were performed per session. The MICT group performed continuous exercise at 60~70% of HR peak for 35 min per session. For both groups, each formal exercise session was preceded by a 10-min warm-up and followed by a 10-min cool-down period. The training was conducted 5 days per week for a total of 12 weeks. During all exercise sessions, participants were closely monitored, with real-time heart rate and Rating of Perceived Exertion (RPE) recorded to ensure exercise intensity was maintained as prescribed.

#### 2.2.2. Height and Body Weight Measurement

Height and body weight of the subjects were measured using a stadiometer and scale (Model JT-918, Ju Tian).

#### 2.2.3. Body Composition Measurement

Body composition was assessed using a bioelectrical impedance analysis device (Model N20, Daehan Bio, Korea) [15]. Measurements were conducted between 8:00 AM and 9:00 AM, requiring subjects to be in a fasted state and to have refrained from physical activity. Prior to testing, subject information including height, age, and gender was entered into the device. Subjects removed their shoes, socks, and any metal objects or unnecessary clothing. The palms of the hands and soles of the feet were cleaned with electrolyte moist wipes to ensure good contact. Subjects then stood calmly on the analyzer's foot electrodes. During the measurement, subjects held the hand electrodes, kept their arms away from the body, stood still without talking, and were prohibited from moving their feet.

#### 2.2.4. Measurement of Blood Lipids, Apolipoproteins, and Lipoprotein(a)

After a 12 to 14-h fast, approximately 5 mL of venous blood was drawn from the antecubital vein by a specialized nurse between 7:00 and 9:00 AM. The blood sample was allowed to stand at room temperature for 30 min and then centrifuged at 3000 r/min for 15 min to separate the serum. Serum levels of blood lipids, apolipoproteins, and lipoprotein(a) were measured using a Mindray BS-800M automated biochemical analyzer. The specific methodologies employed were as follows: Total cholesterol (TC) and triacylglycerol (TG) were measured using the oxidase method. High-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured using the direct method. Apolipoprotein AI (ApoAI), Apolipoprotein B100 (ApoB100), and Lipoprotein(a) (LP(a)) were measured using the immunoturbidimetric assay. All reagents, calibrators, and quality control materials were products from Mindray Corporation. All procedures were strictly performed according to the manufacturer's operating guidelines.

#### 2.2.5. Statistical Analysis

Data were analyzed using SPSS software (version 17.0). Intra-group comparisons of experimental data were performed using the paired-sample *t*-test. Inter-group comparisons of experimental data indicators were conducted using the independent-sample *t*-test. The experimental results are expressed as mean ± standard deviation ($\bar{x} \pm SD$). A significance level was set at $p < 0.05$, and a highly significant level was set at $p < 0.01$.

## 3. Results

### *3.1. Effects of 12-Week HIIT and MICT on Obesity Indices in Female University Students with Normal-Weight Obesity*

The results in Table 1 show that compared with pre-training levels, the HIIT group exhibited highly significant decreases in body weight, BMI, BF%, degree of obesity, WHR, and visceral fat area post-training (*t* = 7.68, 7.52, 8.91, 3.78, 0.40, 6.22, respectively; all $p < 0.01$). The MICT group showed highly significant decreases in body weight, BMI, and BF% (*t* = 8.10, 5.31, 6.64, respectively; all $p < 0.01$), and significant decreases in the degree of obesity, WHR, and visceral fat area (*t* = 5.12, 0.31, 7.81, respectively; all $p < 0.05$). Before the training intervention, no statistically significant differences were observed between the two groups for any of the indices: body weight, BMI, BF%, degree of obesity, WHR, and visceral fat area (all $p > 0.05$). After the training intervention, no statistically significant differences were found between the two groups in body weight, BMI, degree of obesity, or WHR (all $p > 0.05$). However, the BF% and visceral fat area in the HIIT group were significantly lower than those in the MICT group (*t* = 3.51 and 2.28, respectively; both $p < 0.05$).

**Table 1.** Changes in Body Composition and Adiposity-Related Indicators in Female University Students with Normal-Weight Before and After Exercise Intervention.

| | HIIT Group (n = 12) | | | | | | MICT Group (n = 11) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Before and after the Intervention** | **Weight (kg)** | **BMI** | **BF%** | **Obesity Level** | **WHR** | **Visceral Fat Area** | **Weight (kg)** | **BMI** | **BF%** | **Obesity Level** | **WHR** | **Visceral Fat Area** |
| Before intervention | 54.01 ± 3.10 | 21.81 ± 0.48 | 31.94 ± 3.85 | 100.08 ± 5.58 | 0.82 ± 0.02 | 39.71 ± 7.57 | 53.5 ± 2.47 | 21.47 ± 0.93 | 32.54 ± 4.01 | 101.71 ± 8.28 | 0.82 ± 0.02 | 41.89 ± 10.57 |
| Following the intervention | 49.22 ± 3.51 | 19.79 ± 0.76 | 25.38 ± 3.42 | 97.40 ± 4.82 | 0.79 ± 0.02 | 27.12 ± 5.18 | 50.37 ± 2.59 | 20.01 ± 0.63 | 27.47 ± 3.85 | 99.10 ± 8.29 | 0.80 ± 0.02 | 37.47 ± 10.87 |
| *t-value* | 7.68 | 7.52 | 8.91 | 3.78 | 0.40 | 6.22 | 8.10 | 5.31 | 6.64 | 5.12 | 0.31 | 7.81 |
| *p-value* | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.010 | 0.013 | 0.000 | 0.042 | 0.028 | 0.024 |

*3.2. Effects of 12-Week HIIT and MICT on Blood Lipid Levels in Female University Students with Normal-Weight Obesity*

The results in Table 2 show that compared with pre-training levels, the HIIT group exhibited significant decreases in TC and TG levels post-training (*t* = 0.58 and 0.01, respectively; both $p < 0.05$), and a significant increase in HDL-C level (*t* = -0.67, $p < 0.05$). The change in LDL-C level was not statistically significant (*t* = 0.78, $p > 0.05$). In the MICT group, TC level decreased significantly (*t* = 0.22, $p < 0.05$), while the changes in TG, HDL-C, and LDL-C levels were not statistically significant (*t* = 0.87, −0.31, and −0.12, respectively; all $p > 0.05$).

**Table 2.** Changes in Blood Lipid Levels in Female University Students with Normal-Weight Obesity Before and After the Exercise Intervention.

| **Before and after the Intervention** | **HIIT Group (n = 12)** | | | | **MICT Group (n = 11)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **TC (mmol/L)** | **TG (mmol/L)** | **HDL-C (mmol/L)** | **LDL-C (mmol/L)** | **TC (mmol/L)** | **TG (mmol/L)** | **HDL-C (mmol/L)** | **LDL-C (mmol/L)** |
| Before the intervention | 4.64 ± 0.93 | 1.08 ± 0.59 | 1.43 ± 0.26 | 2.32 ± 0.50 | 4.53 ± 0.59 | 0.89 ± 0.21 | 1.51 ± 0.23 | 2.40 ± 0.25 |
| After the intervention | 4.26 ± 0.44 | 0.90 ± 0.59 | 1.71 ± 0.29 | 2.18 ± 0.39 | 4.38 ± 0.60 | 0.73 ± 0.21 | 1.66 ± 0.36 | 2.50 ± 0.39 |
| *t-value* | 0.58 | 1.01 | −0.67 | 0.78 | 0.22 | 0.87 | −0.31 | −0.12 |
| *p-value* | 0.032 | 0.045 | 0.040 | 0.33 | 0.038 | 0.653 | 0.520 | 0.961 |

*3.3. Effects of 12-Week HIIT and MICT on Apolipoprotein and Lipoprotein(a) Levels in Female University Students with Normal-Weight Obesity*

The results in Table 3 show that compared with pre-training levels, the HIIT group exhibited a significant increase in ApoAI level (*t* = 0.43, $p < 0.05$) and significant decreases in both ApoB100 and LP(a) levels (*t* = 0.56

and 1.23, respectively; both $p < 0.05$) post-training. In the MICT group, ApoB100 level decreased significantly ($t = 0.37$, $p < 0.05$), while the changes in ApoAI and LP(a) levels were not statistically significant ($t = 0.25$ and 1.45, respectively; both $p > 0.05$).

**Table 3.** Changes in Apolipoprotein and Lipoprotein(a) Levels in Female University Students with Normal-Weight Obesity Before and After the Exercise Intervention.

| Before and after the Intervention | HIIT Group (n = 12) | | | MICT Group (n = 11) | | |
|---|---|---|---|---|---|---|
| | ApoAI (g/L) | ApoB100 (g/L) | LP(a) (mg/L) | ApoAI (g/L) | ApoB100 (g/L) | LP(a) (mg/L) |
| Before the intervention | 1.33 ± 0.24 | 0.87 ± 0.14 | 112.40 ± 35.00 | 1.42 ± 0.20 | 0.79 ± 0.21 | 108.10 ± 28.16 |
| After the intervention | 1.65 ± 0.27 * | 0.71 ± 0.16 * | 97.01 ± 39.5 * | 1.58 ± 0.14 | 0.68 ± 0.12 * | 101.01 ± 29.1 |
| *t-value* | 0.43 | 0.56 | 1.23 | 0.25 | 0.37 | 1.45 |
| *p-value* | 0.027 | 0.042 | 0.038 | 0.631 | 0.040 | 0.782 |

* $p < 0.05$.

**4. Discussion**

Exercise intensity is a primary factor influencing substrate utilization during exercise. Prolonged exercise at low-to-moderate intensity primarily relies on fat oxidation for energy supply, thereby consuming a substantial amount of fat during the activity. Studies have found that HIIT requires a shorter duration to achieve energy expenditure equivalent to that of prolonged low-intensity exercise, and the energy substrates consumed within 24 h are nearly identical between the two exercise intensities [16]. Therefore, compared to prolonged low-to-moderate intensity exercise, HIIT may lead to a greater reduction in body fat. However, given the high intensity of HIIT, which places greater demands on the cardiovascular function and adaptive capacity of individuals not accustomed to regular exercise, its safety and applicability require further investigation [12]. Furthermore, compared to MICT, HIIT demonstrated a more significant effect in improving BF% and visceral fat area in female university students with normal-weight obesity. One study found that both 12-week HIIT and continuous aerobic exercise significantly reduced body weight, BMI, WHR, and BF% in obese female university students, but HIIT was superior to continuous aerobic exercise in improving BF% [17]. Another study revealed that both 10-week high-intensity interval aerobic exercise and continuous exercise at the intensity of maximal fat oxidation significantly improved body composition in general female university students, with high-intensity interval aerobic exercise appearing superior to continuous exercise at maximal fat oxidation intensity in reducing BF% [18]. Although the aforementioned studies did not measure visceral fat area, their findings regarding the improvement in BF% are consistent with the results of our study. It is worth noting that BF% can reasonably reflect the accumulation of visceral or abdominal fat [19]. Female university students with normal-weight obesity not only experience declines in physical function and stamina but also tend to accumulate fat primarily around the viscera, leading to visceral adipose-type central obesity [20]. Considering the improvement effects of HIIT and MICT on BF% and visceral fat area observed in this study, it is reasonable to infer that long-term HIIT is more effective than MICT in improving the obese state of female university students with normal-weight obesity. Moreover, for this specific population, HIIT appears to be a safe and applicable exercise modality.

Dyslipidemia is a major risk factor for cardiovascular diseases. In obese individuals, abnormal lipid metabolism is primarily characterized by elevated levels of TC, TG, LDL-C, and very-low-density lipoprotein cholesterol (VLDL-C), alongside decreased levels of HDL-C [21]. In recent years, numerous studies have identified HIIT as an effective intervention for dyslipidemia [22,23]. Consequently, many studies have begun to investigate the differential effects of HIIT and MICT on blood lipids. A study by Fisher et al. found that both 6-week HIIT and MICT improved BF%, as well as serum levels of TC, TG, VLDL, and HDL-C in overweight or obese men [24]. Another study demonstrated that 12 weeks (4 days/week) of either HIIT or MICT intervention reduced TC concentration in young obese women, with no significant difference in the efficacy between the two exercise modalities [13]. A recent meta-analysis on the impact of HIIT and MICT on cardiovascular risk factors in overweight and/or obese adults revealed that both HIIT and MICT significantly reduced body weight, BMI, BF%, and serum TC levels [25]. These findings are largely consistent with the results of our study. Our research found that after 12 weeks of either HIIT or MICT, serum TC levels decreased significantly in female university students with normal-weight obesity. Specifically, HIIT led to significant decreases in TG levels and a significant increase in HDL-C levels, whereas MICT did not produce these effects. Based on our results, the effectiveness of HIIT and MICT in improving blood lipid levels in this population is generally similar, with HIIT potentially demonstrating a more pronounced improvement effect. It is important to note that increased visceral fat is closely associated with the incidence of cardiovascular diseases [26]. Considering the aforementioned effects of HIIT on reducing BF% and visceral fat area in female university students with normal-weight obesity, it can be inferred that HIIT may not only improve the obese state in this population but also ameliorate blood lipid profiles, thereby potentially reducing the risk of cardiovascular diseases.

Apolipoproteins serve as transporters of lipids and stabilize lipoprotein structure, constituting essential components of plasma lipoproteins. Lp(a) is a plasma lipoprotein whose primary apolipoprotein components are ApoAI and ApoB100. Lp(a) can be taken up by macrophages via the scavenger receptor pathway, leading to intracellular cholesterol accumulation and transformation into foam cells. It can also enter the arterial wall through non-receptor pathways, forming complexes with matrix components and depositing within the arterial wall [27]. ApoAI is the principal structural protein of HDL-C, playing a critical role in reverse cholesterol transport by facilitating the clearance of cholesterol from arteries. ApoB serves as the structural protein for LDL-C and VLDL-C, promoting the uptake of LDL-C by arterial wall cells [28]. ApoB100 is a subclass of ApoB. Research indicates that compared to healthy individuals, obese subjects exhibit significant dyslipidemia, characterized by markedly elevated serum ApoB100 concentrations and significantly reduced ApoAI levels [29]. Currently, studies investigating the effects of HIIT on ApoAI and ApoB100 remain limited. One study demonstrated [30] that after 8 weeks of HIIT, serum ApoAI levels significantly increased in young healthy male participants. The increase observed following MICT was less pronounced than that after HIIT, indicating a superior efficacy of HIIT for elevating serum ApoAI levels. The present study found that after 12 weeks of HIIT, female university students with normal-weight obesity exhibited significantly increased serum ApoAI levels and significantly decreased ApoB100 and Lp(a) levels. Following MICT, their serum ApoB100 levels decreased, while no significant changes were observed in ApoAI and Lp(a) levels. These findings suggest that HIIT is particularly effective in improving apolipoprotein and lipoprotein profiles in female university students with normal-weight obesity, thereby potentially reducing their risk of developing cardiovascular diseases.

In summary, the 12-week HIIT intervention significantly improved body composition, blood lipids, apolipoproteins, and lipoprotein levels in female university students with normal-weight obesity. Compared to MICT, HIIT was more effective in improving BF%, visceral fat area, and serum levels of TG, HDL-C, ApoAI, and Lp(a). It is evident that HIIT is a safe, effective, and applicable exercise modality for enhancing the health status of female university students with normal-weight obesity. It should be noted that this study did not implement strict dietary control. Subsequent related research should place further emphasis on controlling factors such as dietary quantity, composition, and habits.

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**Conflicts of Interest**

The authors declare no conflict of interest.

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