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ORIGINAL

INVESTIGATING THE IMPACT OF HIGH-INTENSITY INTERVAL TRAINING AND CROSSOVER POINT TRAINING ON BLOOD LIPID METABOLISM IN OVERWEIGHT FEMALE COLLEGE STUDENTS

Pengwang Zhao[1], Xuesheng Zhang[2*], Jinlin Ma[3], Jia Huang[4]

[1] School of Strength and Conditioning, Beijing Sport University, Shenzhen 518067, Guangdong, China.
[2] Institute of Physical Education, North China Institute of Science and Technology, Sanhe 065201, Hebei Province, China.
[3] Department of Medical Informatics, Harbin Medical University, Daqing 163000, Heilongjiang Province, China.
[4] Second Clinical College of Medicine, Lanzhou University, Lanzhou 730000, Gansu Province, China.
E-mail: zxs_97@163.com

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ABSTRACT

Background and purpose of the study: There is a significant correlation between the level of lipid metabolism markers in serum and the incidence of cardiovascular and metabolic diseases, based on which, maintaining the health of lipid metabolism is of great significance in improving the quality of life and preventing the occurrence of diseases. At the same time, with the gradual improvement of living standards and economic level, people's demand for health is also increasing, so there is an urgent need to find ways to exercise to maximize the health benefits within a limited period of time. **Study subjects and methods:** A total of 30 female college students with BIM test results ≥24kg/m2 and <27.9kg/m2 were selected for this study. The 30 female college students were randomly divided into three groups, which were labeled as the control group (SSC group), the high-intensity interval training group (HIIT group), and the cross-point training group (COP group) in accordance with the differences in the implementation of the research methods. Prior to the implementation of the exercise intervention, a maximal oxygen uptake test and a crossover point test were completed to pinpoint the acceptable exercise intensity for each individual. A 10-week exercise intervention program was implemented 3 times per week for 10 weeks for female students in the HIIT and

COP groups to ensure that the daily physical activity of female students in the SSC group remained unchanged. In the HIIT group, the female students were required to complete 5 sets of high-intensity interval training for a total of 35 minutes per session, with each set consisting of 4 minutes of running (at 85% of maximal oxygen uptake) interspersed with 3 minutes of walking (at 50% of maximal oxygen uptake). Female undergraduates within the COP group were required to complete a total of 45 minutes of cross point exercise training per session at a sustained intensity. Morphological and blood indices of 30 female students were collected before and after the implementation of the corresponding exercise intervention program, and were statistically and scientifically analyzed. **Study Results:** After a 10-week exercise intervention, there were no significant changes in morphological indicators, blood indices, and related ratio indices of female college students within the SSC and HIIT groups ($P > 0.05$); After the 10-week exercise intervention, the morphological indicators, blood indicators, and related ratio indicators of female college students within the COP group improved significantly ($P < 0.05$); Compared with the pre-intervention period, the morphological indicators of the female students in the COP group showed a decrease in BMI and body fat percentage ($P < 0.05$), and a decrease in waist and hip circumference ($P < 0.05$), and the blood indicators showed a decrease in serum Apo B ($P < 0.05$) and a decrease in the ratio of Apo B to Apo AI ($P < 0.05$). **Research Conclusion:** Cross-point training intensity sustained can significantly improve the morphological indexes, blood indexes and related ratio indexes of overweight female college students, and it is an effective exercise training modality that can improve the risk factors of abdominal obesity, lipid health, and cardiovascular disease in female college students.

KEYWORDS: High-intensity interval training; Cross-point training; Overweight; Lipid metabolism; Morphological indices; Blood indices

1. INTRODUCTION

In recent decades, the number of patients with dyslipidemia in China has increased significantly due to dramatic changes in dietary structure, lifestyle, and work pressure (Mueller et al., 2021). According to the latest data released by the World Health Organization, more than 50% of coronary heart disease cases worldwide are associated with elevated cholesterol levels. The prevalence of dyslipidemia among adults in China has risen dramatically compared with 2002, with the prevalence among adults over 18 years old as high as 40.4%, making the prevention of dyslipidemia particularly important (Andrade-Mayorga, Díaz, & Salazar, 2021). Over the past decade, serum total cholesterol, triglyceride and HDL cholesterol levels in Chinese adults have shown an increasing trend, with total cholesterol levels being particularly significant, in contrast to the decrease in physical activity levels in urban residents.

The busy lifestyles and work-study characteristics of people in today's society result in a sedentary lifestyle for most of the day; however, those who are sedentary and less active are more likely to suffer from metabolic syndrome than those who exercise regularly (Moholdt et al., 2021). The benefits of exercise training on the health of lipid metabolism have been confirmed by numerous studies. Therefore, it is essential to improve people's lifestyles in a timely manner and to explore the most efficient and effective exercise intensity. High-intensity interval training has become a hot research topic in recent years, both in the field of competitive sports and in public fitness. Among them, based on high-intensity interval training can make people get good health benefits in a shorter period of time, and cross-point training as the intensity of continuous aerobic exercise has also been proved to be a practical way to improve the health level efficiently (Gao et al., 2021). However, as of now, there is a paucity of literature comparing the two methods in a comprehensive manner. The current study will compare the effects of high-intensity interval training and cross-point strength training on lipid metabolism in overweight female college students, adding more reliable evidence on the effects of these two different exercise modalities on lipid metabolism health. It seeks to be able to provide more effective exercise training guidance for overweight female college students to effectively maintain or improve their lipid health status.

2. Research Design

2.1 Research Subjects and Methods

2.1.1 Research Subjects

2.1.1.1 Recruitment and Screening of Study Subjects

This study recruited overweight female students in higher education institutions as subjects through the Internet and posters, and required the subjects to complete physical examination and physical activity questionnaire before participating in the research practice, so as to collect the basic information and physical health status of the subjects in detail. Subjects who did not meet the requirements of this study were excluded, and overweight female college students who fully met the inclusion criteria of this study were screened out. The selected subjects were instructed not to take any medication that might affect the results of the study practice before and during their participation in this study practice. All subjects were required to fully understand the process and content of this research practicum and complete the informed consent form before participating in this research practicum.

Inclusion criteria for the study population: ①Female college students aged 18 to 21 years old; ②BIM test results $\geqslant$24kg/m^2 and $<$27.9kg/m^2; ③ Sedentary and inactive, participating in moderate and above intensity exercise training $<$3 times per week and the duration of each session $<$30min; ④No abnormality in menstrual cycle; ⑤No recent medication or treatment; ⑥Stable weight and no purposeful increase or decrease in weight; ⑦ Have no contraindications to exercise and be able to participate in strenuous physical training activities.

Exclusion criteria for study subjects: ①Taking anti-hypertensive drugs (e.g., diuretics, calcium channel blockers, β-blockers, etc.), hypoglycemic drugs (e.g., insulin, sulfonylureas, bisphosphonates, etc.), statins, hormones, and other medications affecting the lipid metabolism of the body; ②Clinically diagnosed with cardiovascular disease or metabolic disease; ③Smoking, drinking and other bad habits.

2.1.1.2 Grouping of Research Subjects

A total of 30 overweight female college students who fully met the above inclusion criteria were divided into three groups using a randomized numeric table method, and according to the differences in the implementation of the research method, they were recorded as the control group (SSC group) (n=10), the high-intensity interval training group (HIIT group) (n=10), and the cross-point training group (COP group) (n=10), respectively.

2.2 Research Methods

2.2.1 Baseline Test

2.2.1.1 Morphological and Physiological Index Collection

(1) Body weight: Place the weight measuring device on a flat surface and calibrate it before using it by taking two measurements, ensuring that the error between the two is within 0.1%. Subjects need to stand in the center of the measuring device wearing close-fitting clothes, wait for the value to stabilize, and then read and record the data accurately.

(2) Height: The height measuring device also needs to be calibrated before use. After calibration, the position of the height measuring device's column and horizontal pressure plate should be checked to see if they are in place. Subjects should be barefoot, with heels close together and toes apart at an angle of 60°, with the back close to the column of the height measuring device, keeping the torso naturally erect and standing upright on the base plate. Check that the heels, sacrum and scapulae are in contact with the column of the height measuring device. Position the head and look straight ahead. Measuring staff need to be located at the side of the subject, gently slide down the horizontal platen until it touches the top of the subject's head, read and accurately record the data on the display screen.

(3) Body Mass Index (BMI): Calculation formula (BMI = weight

(kg)/height to the nearest square (m^2)). Normal values range from 18.5 to 23.9 kg/m^2 and overweight values range from 24 to 27.9 kg/m^2.

(4) Waist circumference and hip circumference: The subjects need to relax their shoulders, stand naturally with both legs, and maintain normal breathing; when measuring waist circumference, the measurement staff needs to use a soft tape measure to horizontally circle around the waist of the subjects for one week, and it needs to be passed by the navel above the 0.5～1cm; when measuring hip circumference, the measurement staff needs to use a soft tape measure to horizontally circle around along the gluteus maximus muscle where the subjects are most abundant for one week, and then read and accurately record the values. When the waist circumference of female college students is ≥80cm or waist-hip ratio ≥0.8, it can be judged as central obesity.

(5) Measurement of body composition: A dual-energy X-ray instrument was used to measure the body composition of the subjects to obtain their lean body mass and body fat percentage. The subjects need to urinate and defecate, cannot take in water and food, need to wear tight clothes, sports pants and sports shoes, need to remove jewelry and other metal objects before the measurement starts, the subjects need to lie supine on the experimental bed of the instrument, and the measurement staff need to help fix the lower limbs of the subjects, and instructed not to move in the process of the measurement, to avoid affecting the validity of the results of the measurement. The staff should help to fix the lower limbs of the subjects and instruct them not to move during the measurement to avoid affecting the validity of the measurement results.

2.2.1.2 Collection of blood indicators

(1) Subjects should not consume alcohol, coffee and tea, smoke, or take any medication for 24 hours prior to the physical examination, should not engage in strenuous activities, should not consume excessive amounts of food, need to eat a light diet, ensure adequate sleep and rest, and need to fast for more than 12 hours.

(2) Blood collection will be performed during the follicular phase of a woman's menstrual cycle, i.e., within 12 days after the end of the subject's menstrual cycle.

(3) At 7:00 a.m. on the day of blood collection, venous blood was drawn from the elbow of the subject, and then the collected blood samples were put into a water bath (at a constant temperature of 37 degrees Celsius) and taken out after 30 minutes, and leveled with a balance, and then the tubes were put into a centrifuge, and centrifuged at a speed of 3,000 rpm for 15 minutes, and then the serum obtained after centrifugation was sucked out for spare use.

(4) The determination of the blood indexes should be completed on the

same day, and various blood indexes were measured on a Hitachi automatic biochemical analyzer using the following methods: Serum total cholesterol and triglycerides were determined by oxidase method; Serum high-density lipoprotein cholesterol was determined by the selective elimination method; Serum LDL cholesterol was determined by a selective masking method; Determination of apolipoprotein AI and apolipoprotein B by immunoturbidimetric assay; Serum free fatty acids were determined by a colorimetric method.

2.2.1.3 Exercise test

(1) Maximum oxygen uptake test: ①The test time was selected to avoid the subjects' menstrual period; ②The Bruce running table protocol, as shown in Table 1, was used to perform incremental loading exercise, and, the portable Cortex-3B gas metabolism analyzer was used to obtain gas metabolism indexes at different levels of exercise training; ③The portable Cortex-3B gas metabolism analyzer needs to be calibrated for barometric pressure before each test, and the temperature of the testing environment needs to be adjusted to 20～25°C; ④Before starting the test, we need to explain the test procedure in detail to the subjects and help the students to wear the portable gas metabolism analyzer; ⑤In the course of the experiment, the heart rate, blood pressure and electrocardiogram of the subjects in the exercise state were monitored in real time by using a polarimeter, an ambulatory sphygmomanometer and an electrocardiogram, and the heart rate data were recorded once every one minute, and the blood pressure and the subjective sensation of fatigue were recorded once every three minutes; ⑥The subjects were actively encouraged to do their best to cooperate in accomplishing the corresponding experimental tasks; ⑦The termination criteria of the trial were set to meet any of the following criteria: the subject reached the maximum heart rate plateau (maximum heart rate = 220 - age) or the difference from the maximum heart rate was less than 10 beats per minute, subjective fatigue > 19, respiratory quotient > 1.10, oxygen uptake plateau, and consciously could not continue to participate in the exercise training.

Table 1: Bruce Running Table Program

GRADING	SPEED (KM/H)	GRADIENT (%)	DURATION (MIN)
1	4.0	12	3
2	5.5	14	3
3	6.8	16	3
4	8.0	18	3
5	8.9	20	3
6	9.7	22	3

(2) Measurement of crossing point: ①Cross-point training measurement was selected in the morning after 12 hours of fasting, also need to avoid the subject's menstrual period, the subject is required to accept the test within 24

hours prior to the test did not carry out heavy physical activity, the temperature of the test environment is adjusted to 20 ~ 25 ℃, in the maximum oxygen uptake test, need to be separated from the test, at least 72 hours or more; ②Choose to use the running table as well as portable Cortex-3B gas metabolism analyzer to collect gas samples from the subjects, the intensity corresponding to the highest level of the Bruce protocol completed during the process of maximum oxygen uptake test, that is, the maximum plumbing value, 20%, 30%, 40%, 50%, 60% of the maximum plumbing value of the incremental exercise training loading test, the subjects are required to complete the Bruce program 3 levels of loading, the specific corresponding program is shown in Table 2; ③The heart rate, blood pressure, and electrocardiogram of the subjects in the exercise state were monitored in real time using a polarimeter, ambulatory sphygmomanometer, and electrocardiogram, and, the changes in the subjective feeling of fatigue in the process of exercise were recorded in detail, and the oxidation rate of carbohydrates and lipids was calculated according to the following formula (Carbohydrate oxidation rate (g/min) = 4.55 × CO_2 exhalation (L/min) - 3.21 × oxygen uptake (L/min)) (Fat oxidation rate (g/min) = 1.67 × oxygen uptake (L/min) - 1.67 × carbon dioxide exhalation (L/min))； ④ The fat oxidation rate and carbohydrate oxidation rate of different levels were plotted in Excel, and the cross point of 70% carbohydrate oxidative energy supply and 30% fat oxidative energy supply was taken, and the exercise intensity corresponding to this point was used to guide the exercise intervention for overweight female college students in the cross point group.

Table 2: Cross point determination scheme

GRADING	SPEED (KM/H)	GRADIENT (%)	DURATION (MIN)
20%	2.1	0	3
30%	4.1	0	6
40%	5.0	1	6
50%	5.8	2	6
60%	6.0	4	6

2.2.2 Exercise Intervention

The HIIT and COP groups were administered three times per week for 10 weeks to ensure that the daily physical activity of the female students in the SSC group remained unchanged. The women in the HIIT group were required to complete 5 sets of high-intensity interval training (HIIT) for a total of 35 minutes per session, each consisting of 4 minutes of running (at 85% of maximal oxygen uptake) interspersed with 3 minutes of walking (at 50% of maximal oxygen uptake), while the women in the COP group were required to complete a total of 45 minutes of cross-point exercise at a sustained level of intensity. Morphological and blood indices of 30 female students were collected before and after the implementation of the corresponding exercise intervention program, and were statistically and scientifically analyzed.

2.3 Statistical Analysis

The present study chose to use Microsoft office 2019 Excel for the initial collection and processing of the measured research data, and chose to use SPSS 27.0 to complete further statistics and analysis. The results of this study were expressed as mean ± standard deviation ($\bar{x}$±s), all data were subjected to analysis of variance and normal distribution test, paired samples t-test was used to compare the significance of each group of overweight female college students before and after receiving the exercise intervention, and one-way analysis of variance was used to analyze the differences between the three groups of overweight female college students before and after receiving the exercise intervention. If the variance was not homogeneous and did not conform to normal distribution, non-parametric test was used to compare the differences of each data.

3. Research results

3.1 Basic Status and Baseline Level of Study Subjects

As shown in Table 3, it can be seen that the status of morphological indicators of the three groups of overweight female college students at baseline, there was a significant difference in height between the COP, HIIT and SSC groups ($P < 0.05$).

Table 3: Status of morphological indicators of study subjects at baseline ($\bar{x}$±s)

INDICATORS	COP GROUP (N=10)	HIIT GROUP (N=10)	SSC GROUP (N=10)
HEIGHT(CM)	164.85±4.15*	166.57±6.86*	158.05±2.94
WEIGHT(KG)	71.24±1.29	71.37±8.51	64.43±4.01
BMI(KG/M^2)	25.90±1.90	25.72±0.90	25.80±1.19
WAIST CIRCUMFERENCE(CM)	87.94±5.53**	81.98±8.99	78.66±4.08
HIP(CM)	103.15±6.03	104.51±6.19	99.37±3.55
WAIST-HIPRATIO	0.85±0.03$^{*\#\#}$	0.78±0.06	0.79±0.04

As shown in Table 4, it can be seen that at baseline, there was no significant difference in body composition indexes among the three groups of COP group, HIIT group and SSC group ($P > 0.05$).

Table 4: Body composition status of study participants at baseline ($\bar{x}$±s)

INDICATORS	COP GROUP (N=10)	HIIT GROUP (N=10)	SSC GROUP (N=10)
BODY FAT (%)	39.43±4.20	38.23±6.39	36.30±2.72
LEAN BODY MASS (KG)	44.09±4.39	44.03±5.23	40.44±3.09

As shown in Table 5, it can be seen that at baseline, there was no significant difference in maximal oxygen uptake among the three groups (P > 0.05).

Table 5: Maximum oxygen uptake status of study subjects at baseline ($\bar{x}$±s)

INDICATORS	COP GROUP (N=10)	HIIT GROUP (N=10)	SSC GROUP (N=10)
MAXIMUM OXYGEN UPTAKE (ML/KG/MIN)	30.10±1.97	33.50±5.02	33.14±5.51

As shown in Table 6, it can be seen that at baseline, there was no significant difference in lipid metabolism indicators and related ratios among the three groups (P > 0.05).

Table 6: Status of Lipid Metabolism Indicators in Study Subjects at Baseline ($\bar{x}$±s)

INDICATORS	COP GROUP (N=10)	HIIT GROUP (N=10)	SSC GROUP (N=10)
TC (MMOL/L)	4.40±0.61	4.12±0.82	4.30±0.33
TG (MMOL/L)	0.92±0.32	0.84±0.24	0.77±0.19
HDL-C (MMOL/L)	1.50±0.34	1.40±0.22	1.53±0.09
LDL-C (MMOL/L)	2.53±0.55	2.47±0.71	2.56±0.43
APO-AI (MG/DL)	103.42±19.19	100.34±11.36	99.50±10.62
APOB (MG/DL)	85.77±14.26	82.59±20.64	76.00±6.74
FFA (MMOL/L)	0.67±0.02	0.66±0.03	0.65±0.04
LIPOPROTEIN ESTERASE (NG/L)	1147.45±145.37	1220.41±81.36	1453.67±94.44
TC/HDL-C	3.07±0.82	2.97±0.59	2.82±0.26
LDL-C/HDL-C	1.81±0.72	1.78±0.54	1.66±0.32
TG/HDL-C	0.67±0.35	0.63±0.26	0.51±0.14
APOB/APOAI	0.87±0.30	0.79±0.22	0.80±0.14

3.2 Changes in the status of the study subjects before and after the intervention

As shown in Table 7, it can be seen that after the exercise intervention, waist circumference was significantly higher in the COP group than in the SSC group (P < 0.05), and waist-to-hip ratio was significantly higher in the HIIT and SSC groups (P < 0.05).

Table 7(a): Changes in morphologic indices before and after the intervention in the study population ($\bar{x}$±s)

INDICATOR	GROUP	PRE-INTERVENTION	POST-INTERVENTION
BODY WEIGHT (KG)	COP group	71.24±1.29	69.20±3.68
	HIIT group	71.37±8.51	69.41±6.66
	SSC group	64.43±4.01	63.68±2.33

Table 7(b): Changes in morphologic indices before and after the intervention in the study population ($\bar{x}$±s)

BMI (KG/M2)	COP group	25.90±1.90	25.05±2.00$^{\&}$
	HIIT group	25.72±0.90	24.86±1.19
	SSC group	25.80±1.19	25.20±1.14
WAIST CIRCUMFERENCE (CM)	COP group	87.94±5.53**	85.00±6.86$^{\&\&*}$
	HIIT group	81.98±8.99	81.66±8.73
	SSC group	78.66±4.08	76.79±4.53
HIP CIRCUMFERENCE (CM)	COP group	103.15±6.03	100.92±6.70$^{\&}$
	HIIT group	104.51±6.19	103.16±6.63
	SSC group	99.37±3.55	97.44±3.08
WAIST-HIP RATIO	COP group	0.85±0.03$^{*\#\#}$	0.84±0.04$^{*\#}$
	HIIT group	0.78±0.06	0.79±0.06
	SSC group	0.79±0.04	0.79±0.05

As shown in Table 8, it can be seen that compared with the pre-intervention period, after 10 weeks of intervention, the body fat percentage of the COP group was significantly reduced by 1.19% ($P < 0.05$), and the body fat percentage of the remaining two groups did not change significantly ($P > 0.05$).

Table 8: Changes in body composition of study participants before and after the intervention ($\bar{x}$±s)

INDICATOR	GROUP	PRE-INTERVENTION	POST-INTERVENTION
BODY FAT (%)	COP group	9.43±4.20	38.24±4.00$^{\&}$
	HIIT group	38.23±6.39	37.05±5.81
	SSC group	36.30±2.72	35.51±3.36

Note: *Compared to pre-intervention,* $^{\&}P < 0.05$.

As shown in Table 9, it can be seen that compared with the pre-intervention period, the serum Apo B level in the COP group was significantly reduced by 9.79 mg/dl after the exercise intervention ($P < 0.05$).

Table 9(a): Changes in blood indices before and after the intervention in the study population ($\bar{x}$±s)

INDICATORS	COP GROUP (N=10)	HIIT GROUP (N=10)	SSC GROUP(N=10)
TC (MMOL/L)	COP group	4.40±0.61	4.14±0.49
	HIIT group	4.12±0.82	4.18±0.84
	SSC group	4.30±0.33	4.54±0.34
TG (MMOL/L)	COP group	0.92±0.32	1.00±0.43
	HIIT group	0.84±0.24	0.95±0.43
	SSC group	0.77±0.19	0.91±0.63
HDL-C (MMOL/L)	COP group	1.50±0.34	1.57±0.44
	HIIT group	1.40±0.22	1.40±0.25

Table 9(b): Changes in blood indices before and after the intervention in the study population ($\bar{x}$±s)

	SSC group	1.53±0.09	1.54±0.20
LDL-C (MMOL/L)	COP group	2.53±0.55	2.31±0.39
	HIIT group	2.47±0.71	2.48±0.71
	SSC group	2.56±0.43	2.66±0.40
APO-AI (MG/DL)	COP group	103.42±19.19	114.40±27.36
	HIIT group	100.34±11.36	99.10±12.80
	SSC group	99.50±10.62	106.43±11.27
APOB (MG/DL)	COP group	85.77±14.26	75.98±9.28&
	HIIT group	82.59±20.64	82.73±19.84
	SSC group	76.00±6.74	83.57±9.30
FFA (MMOL/L)	COP group	0.67±0.02	0.66±0.04
	HIIT group	0.66±0.03	0.66±0.03
	SSC group	0.65±0.04	0.68±0.02
LIPOPROTEIN ESTERASE (NG/L)	COP group	1147.45±145.37	1463.98±166.99
	HIIT group	1220.41±81.36	1551.70±178.04
	SSC group	1453.67±94.44	1280.60±141.94

Note: *Compared to pre-intervention, $^{\&}P < 0.05$.*

As shown in Table 10, it can be seen that compared with the pre-intervention period, Apo B/Apo AI was significantly reduced in the COP group after exercise intervention, and the ratios of the rest of the blood indicators did not change significantly (P > 0.05).

Table 10: Changes in ratios related to blood indicators before and after the intervention in the study population ($\bar{x}$±s)

INDICATORS	COP GROUP (N=10)	HIIT GROUP (N=10)	SSC GROUP (N=10)
TC/HDL-C	COP group	3.07±0.82	2.75±0.45
	HIIT group	2.97±0.59	3.03±0.54
	SSC group	2.82±0.26	3.01±0.54
LDL-C/HDL-C	COP group	1.81±0.72	1.55±0.38
	HIIT group	1.78±0.54	1.81±0.48
	SSC group	1.66±0.32	1.84±0.56
TG/HDL-C	COP group	0.67±0.35	0.70±0.39
	HIIT group	0.63±0.26	0.73±0.41
	SSC group	0.51±0.14	0.62±0.46
APOB/APOAI	COP group	0.87±0.30	0.69±0.13$^{\&}$
	HIIT group	0.79±0.22	0.86±0.20
	SSC group	0.80±0.14	0.77±0.13

Note: *Compared to pre-intervention, $^{\&}P < 0.05$.*

4. Discussion

4.1 Analysis of the results of the study

The research subjects selected for this study were all overweight female college students, and compared to those with normal BMI, overweight and obese people have a higher probability of developing dyslipidemic diseases and are more likely to suffer from other metabolic diseases (Zhang et al., 2021). In the case of age, gender, BMI, waist circumference, blood pressure and many other aspects are not significant differences, regularly engaged in physical activity in the healthy population of lipid metabolism status is more favorable, fasting serum triglycerides significantly lower, high HDL cholesterol and apolipoprotein B is also significantly lower (Zhou et al., 2022).

A related study moderated the exercise intervention of HIIT versus MICT in overweight female college students by calculating energy expenditure to equalize the amount of exercise in both modalities, and after a 4-week exercise intervention, it was found that with similar amount of exercise, the MICT group showed a reduction in fasting blood glucose by 7.5mg/dl ($P<0.05$) and fasting insulin by 21.4mg/dl ($P<0.05$), however, there was no significant change in the HIIT group, and intrahepatic lipids were reduced by 20.1% and 37.0% in both groups ($P<0.05$), suggesting that HIIT may be more effective in improving intrahepatic lipids.

In the present study, we chose to examine the differences in lipid metabolism of overweight female college students when they completed equal amounts of HIIT and cross-training, and to investigate the correlation between lipid metabolism of these two types of exercise and their mechanisms of influence.

In this study, after the subjects completed the 10-week HIIT and cross-training exercise interventions, morphological indicators showed a tendency to improve compared with those before receiving the corresponding exercise interventions, but only the COP group of overweight female college students showed significant changes in waist circumference, hip circumference, and BMI. In addition, body composition measurements showed that there was also a significant decrease in body fat percentage in the COP group, however, no significant changes were observed in either the HIIT or SSC groups.

Finally, in terms of blood indices, a significant decrease in serum Apo B levels and Apo B / Apo AI ratio occurred in the COP group, while no significant changes in lipid indices were observed in the HIIT group compared to the pre-intervention period. Based on the results of this study, it is suggested that a 10-week cross-training program is more effective than the HIIT intervention in improving obesity, lipid metabolism, and cardiovascular health in overweight female college students.

4.2 Effects of high-intensity interval training and cross-point intensity continuous exercise on lipid metabolism of female college students

4.2.1 Changes in high-density lipoprotein cholesterol and low-density lipoprotein cholesterol

HDL cholesterol levels are negatively correlated with the risk of coronary artery disease and is a cardiovascular-protective lipoprotein, and high-intensity interval training creates greater oxygen deficits and stimulates physiological systems, which leads to higher resting metabolic rates and affects cholesteryl ester transport proteins and lecithin-cholesterol acyltransferase activity involved in the regulation of HDL particles (Hintikka et al., 2023). Related studies have shown that long-term exercise is beneficial in maintaining low leptin levels in the body and, influences lipoprotein lipase activity, which is important for the hydrolysis of total cholesterol and the conversion of HDL cholesterol, to promote lipid health (Nambi et al., 2022). Aerobic exercise improves the antioxidant function of HDL in hypertensive patients, and some studies have suggested that although aerobic exercise did not significantly improve HDL levels, however, it also improved the antioxidant capacity of HDL (Hu et al., 2022).

In contrast to the role of HDL cholesterol, elevated levels of LDL cholesterol are an important risk factor for atherosclerotic cardiovascular disease, and the greatest decrease in LDL cholesterol levels was observed in overweight female college students within the COP group in the current study. Consistent with the results of this study, there was no significant difference in HDL cholesterol and LDL cholesterol levels after an 8-week aerobic exercise intervention for obese college students ($P > 0.05$), although there was a trend of increasing and decreasing HDL cholesterol and LDL cholesterol levels, respectively. The decrease in LDL cholesterol levels may be due to the fact that exercise elevates the activity of LDL receptors, the mediators of hepatic degradation and uptake of LDL cholesterol (Nemec et al., 2021). Triglycerides are the main substrate for the synthesis of very low-density lipoprotein, and prolonged exercise induces elevated lipoprotein lipase activity to promote triglyceride catabolism, leading to a decrease in the synthesis of LDL, and therefore a decrease in serum levels of LDL generated from the conversion of LDL (Batrakoulis et al., 2021).

4.2.2 Changes in triglyceride levels

In this study, there was no significant difference in triglyceride levels among the three groups of overweight female college students before and after the exercise intervention. Some scholars followed up and investigated the health differences between those who insisted on regular exercise for one year and those who were sedentary and did not move, and found that although there were no significant differences in age, gender, blood pressure, BMI, waist circumference, etc., the fasting serum triglycerides of those who exercised regularly were significantly lower, suggesting that long-term regular exercise can maintain and improve the health of the serum triglyceride level (Casado, Hanley, Santos-Concejero, & Ruiz-Pérez, 2021). No significant changes in triglycerides were observed in this study, which may be related to the lack of significant changes in the levels of related enzymes that affect triglyceride levels. Hormone-sensitive lipase is a type of lipase that can hydrolyze triglycerides, diglycerides, etc., with weak specificity, and relevant studies have shown that in muscle biopsy samples after 8-week HIIT training and MICT, the protein content of hormone-sensitive lipase in subjects increased by about 2-fold after the HIIT intervention ($P<0.05$), and did not increase significantly after the MICT intervention; while triglycerides, which are capable of specifically breaking down triglycerides, did not change significantly in this study (Haganes et al., 2022). triglyceride lipase, which specifically breaks down triglycerides, did not produce significant changes between the HIIT and MICT exercise interventions, this study also observed an increase in the levels of CGI-58 and G0S2 by approximately 15% to 20% ($P < 0.05$) after training (Cao, Tang, Li, & Zou, 2021).

4.2.3 Changes in total cholesterol levels

Among the present study, there was no significant difference in the serum total cholesterol levels in all three groups after the intervention compared to the pre-intervention period, and the total cholesterol levels decreased in the COP group, and the trend of change in the decrease may be related to the decrease in the serum LDL cholesterol levels. The results of the existence study were similar to the results of the current study, after an 8-week moderate-intensity aerobic exercise intervention, total cholesterol levels in the obese population showed a decreasing trend, however, no significant difference occurred (Rezaeipour, 2021). Similarly, a study recruited 29 sedentary and inactive overweight women to perform HIIT exercise using a power bicycle 4 times per week for 5 weeks with 60 8s exercises interspersed with 12s recovery, and no significant change in serum total cholesterol levels occurred after the intervention ($P > 0.05$) (Młodzik-Czyżewska, Szwengiel, Malinowska, & Chmurzynska, 2021). It has also been shown that neither the 8-week HIIT nor the MICT intervention had a significant effect on body weight, total fat, abdominal fat, and lipid indices.

4.2.4 Changes in apolipoprotein AI and apolipoprotein B

Apolipoprotein AI is the main apolipoprotein for HDL cholesterol and also plays a role in the body in removing cholesterol and preventing peripheral fat deposition. Apo B is the apolipoprotein required for LDL to bind to the receptor and ultimately absorb cholesterol, which is a good predictor of coronary heart disease risk and a good indicator that lipid-lowering therapy reduces the risk of coronary heart disease, and some scholars have suggested that, in addition to LDL cholesterol and non-HDL cholesterol, Apo B should be used as a therapeutic target (Pettersson et al., 2021). Some studies have shown that ApoB levels are very significantly lower in people who exercise regularly than in people who sit still and move less (D'Amuri et al., 2021). Aerobic exercise significantly improves reverse cholesterol transfer by increasing ApoAI and decreasing ApoB concentrations, thus, reducing the risk of atherosclerosis (Akhavan Rasoolzadeh, Nazarali, & Alizadeh, 2022). In the present study, there was no significant difference in ApoAI concentration in the exercise group before and after the intervention, which is the same as the results of the present study, which showed that there was no significant change in ApoAI in overweight and obese male adolescents after an 8-week interval endurance training program. Among the current study, ApoAI in the COP group increased after the intervention ($P > 0.05$). A Meta-analysis of the effects of exercise on people without cardiovascular disease showed that long-term exercise resulted in a significant increase in ApoAI levels, which is the same trend as in the current study (Bonfante et al., 2022).

Among the current study, Apo B level was significantly reduced in overweight female college students in COP group before and after receiving exercise intervention ($P < 0.05$), while the rest did not change significantly ($P > 0.05$). The results of one study showed that plasma ApoB concentrations were significantly lower in male adolescents who participated in 12 weeks of physical activity ($P < 0.05$), which is consistent with the results of the present study.The significant decrease in ApoB in the COP group may be attributed to the fact that aerobic exercise induces an increase in the activity of enzymes related to the metabolism of glucose, fat, and cholesterol (e.g., skeletal muscle lipase), which promotes the catabolic metabolism of fatty acids, chyme particles, and very low density lipoprotein, and the catabolic activity of hepatic lipoproteins. lipoproteins, increased hepatic cholesterol conversion, and decreased hepatic fat synthesis. Exercise contributes to the enhanced catabolism of chyme and very low-density lipoproteins. Apo B is cleared mainly through the LDL receptor pathway into the hepatocytes for degradation; therefore, the number and activity of LDL receptors is one of the main factors determining blood Apo B levels. Long-term aerobic exercise reduces serum LDL levels and decreases LDL receptor saturation and increases receptor activity, thus, improving ApoB levels.

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