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Effect of high-intensity circuit training on obesity indices, physical fitness, and browning factors in inactive female college students

Jun-Soo Lee[1], Eun-Sun Yoon[2], Sun-Young Jung[3], Ki-Tae Yim[4], Dae-Young Kim[1,5,*]

[1]Institute of Digital Anti-Aging Healthcare, Inje University, Gimhae, Korea
[2]Department of Sports for All, Korea National Open University, Seoul, Korea
[3]Department of Physical Therapy, Hosan University, Gyeongsan, Korea
[4]College of Creative Future Talent, Daejin University, Pocheon, Korea
[5]Department of Sports Healthcare, College of Social Sciences, Inje University, Gimhae, Korea

The recently discovered myokines, irisin and fibroblast growth factor-21, have emerged beneficial for metabolic health due to their role in regulating browning. This study examined the effects of high-intensity circuit training on obesity indices, physical fitness, and irisin and fibroblast growth factor-21 levels in inactive female college students. Ten female college students performed high-intensity circuit training (jogging, stretching, squat jumps, arm walking and push-ups, lunge jumps, burpee test, mountain climbers, side steps, and crunches and side crunches exercises). The exercise program consisted of 40 min of circuit training at 60%–80% hear rate reserve and was conducted 3 times per week for 4 weeks. The body composition, physical fitness, and concentration of plasma irisin and fibroblast growth factor-21 were analyzed before and after the exercise. The body weight ($P=0.001$), waist circumference ($P=0.003$), and body fat percentage ($P=0.003$) decreased, while the muscular strength (handgrip strength test, $P=0.030$; sit-ups test, $P=0.024$) and cardiorespiratory fitness ($P=0.001$) increased after the exercise program. However, there were no significant changes in the irisin and fibroblast growth factor-21 levels. These results suggest that high-intensity circuit training could be the ideal type of exercise in inactive female college students to induce a positive change in the obesity indices and physical fitness. Further studies are needed to determine the effects of exercise on the browning factors.

Keywords: Exercise, Circuit training, Irisin, Fibroblast growth factor-21

INTRODUCTION

Because the overall health management during the undergraduate years has an impact on the entire adulthood, physical activity in this period is critical (Lackman et al., 2015). Currently, female college students in their 20s show a tendency to control their weight through extreme diet control rather than regular exercise, because they perceive the skinny body type as the ideal appearance and lack the time to perform exercises due to the high academic demands. Such weight control techniques can lead to numerous health issues in the future such as metabolic and musculoskeletal diseases (Donaldson and Gordon, 2015; Heilbronn et al., 2007).

Recently, high-intensity circuit training (CT) has attracted interest as an exercise program providing various health benefits by utilizing relatively short time and limited efforts. CT consists of a short series of aerobic and resistance exercises performed in repetition. It is known to be efficient in developing both muscular strength and endurance (Klika and Jordan, 2013). Compared to low-intensity CT, the energy consumption per unit time is higher in high-intensity CT with high additional energy consumption during the resting period; hence, it is preferred by individuals who find it difficult to perform regular exercise due to the lack of time (Paoli et al., 2012). It is effective in improving the physical fitness with respect to the muscular strength, flexibility, and car-

*Corresponding author: Dae-Young Kim https://orcid.org/0000-0002-4662-4463
Department of Sports Health Care, College of Social Sciences, Inje University, 197 Inje-ro, Gimhae 50834, Korea
Email: cdps21@inje.ac.kr
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diorespiratory fitness, as well as in weight loss. Furthermore, it is more interesting than performing repetitive aerobic exercises and more enjoyable because of its sophisticated design that combines both aerobic and resistance exercises (Paoli et al., 2010; Skidmore et al., 2012).

Myocytes produce various myokines that regulate the metabolism along with other tissues including adipose tissue, liver, and pancreas (Pedersen et al., 2007). The recently discovered myokines, irisin and fibroblast growth factor-21 (FGF-21), are known to influence the metabolism rate by increasing the lipid metabolism and energy consumption (Giralt et al., 2015; Xiong et al., 2015). Irisin can activate energy consumption through the browning of white adipose tissue, leading to heat generation, weight control, and blood glucose homeostasis (Boström et al., 2012). FGF-21 increases the energy availability by promoting the use of glucose from the adipose and muscular tissues (Hojman et al., 2009) and plays a role in fatty acid oxidation and degradation (Potthoff et al., 2009) and adipogenesis inhibition (Coskun et al., 2008). In a previous study by Boström et al. (2012) on human subjects, the level of irisin significantly increased by approximately 2-fold after a 10-week moderate-intensity aerobic exercise program. Subsequently, studies have attempted to verify the positive effect of exercise on irisin and FGF-21 levels, but the results have been inconsistent and without any definite conclusion. Such discrepancies among the studies could be due to the variations in the participants' characteristics (age, level of obesity, level of physical fitness, etc.), exercise type and intensity, duration of exercise, and initial level of myokines (Fox et al., 2018). Acute high-intensity exercise has been shown to significantly increase irisin and FGF-21 concentrations. Tsuchiya et al. (2014) reported that acute high-intensity exercise causes greater irisin responses compared with low-intensity exercise in young male adults. Also, Kim et al. (2013) reported similar result that high-intensity exercise increases FGF-21 in healthy young adult.

The findings of previous studies collectively suggest that high-intensity exercise is more effective than low-intensity exercise in increasing the levels of irisin and FGF-21. However, although previous finding showed grater increase of irisin an FGF-21 via high-intensity exercise, such reports are lacking in female young adults. Thus, this study aimed to verify the effect of a short-term high-intensity CT exercise program on the physical fitness and irisin and FGF-21 browning factor levels in inactive female college students in their 20s.

Table 1. Physical characteristics of the subjects (n=10)

Characteristic	Mean ± SD
Age (yr)	21.00 ± 1.00
Height (cm)	159.17 ± 7.23
Weight (kg)	63.48 ± 9.01
Body fat (%)	30.46 ± 3.95
Body mass index (kg/m^2)	25.14 ± 2.51

SD, standard deviation.

MATERIALS AND METHODS

Research participants

This study included 10 female college students aged 20–23 years, who did not have any medical conditions and did not perform regular exercise. Participants were recruited from the Inje University and advertisement was placed on the University notice board. The purpose and contents of the study were adequately explained to all the subjects in advance, and the voluntary participants providing signed informed consent were included in this study. The experimental procedure was approved by the Ethics Committee of the Inje University (INJE2019-05-006). The characteristics of the subjects are summarized in Table 1.

Exercise program

The exercise program used in this study was high-intensity CT performed 3 times a week for 4 weeks in total. The exercise intensity was set as a score of 13–14 on the rating of perceived exertion (RPE) scale and 60%–70% heart rate reserve (HRR) for the first 2 weeks, followed by a slight increase to 14–18 RPE scale score and 65%–80% HRR in the subsequent 2 weeks. To monitor the heart rate during exercise, the POLAR heart rate monitor (Polar M400, Polar Electro, Espoo, Finland) was used. The time of a single round of exercise was set at 40 min, which included the warm-up (5 min), main exercise (30 min), and cool-down (5 min). The exercise program comprised aerobic exercises and muscular strength exercises in a balanced combination to facilitate the use of the global muscles. Each exercise was performed for 30 sec followed by 15 sec of rest, and three sets were performed with 1 min break between the sets. The details of the exercise program are shown in Table 2.

Analysis categories and methods

All the measurable variables were measured at the same time both before and after the exercise to analyze its effect. To exclude any temporary effects of the exercise, postexercise measurements

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Table 2. High-intensity circuit exercise program

Exercise stage	Program	Intensity	Time	Week
Warm-up	• Jogging • Stretching		5 min	
Main exercise	• Squats • Arm walking • Lunges • Burpee test • Mountain climbers • Side step • Crunches • Jogging • Stretching	60%–70% HRR (RPE 13–14)	30-sec exercise; 15 sec rest/set 3 sets 30 min	1–2
	• Squat Jumps • Arm walking & push-ups • Lunge jumps • Burpee test • Mountain climbers • Side step • Crunches & side crunches • Jogging • Stretching	65%–80% HRR (RPE 14–18)	30-sec exercise; 15 sec rest/set 3 sets	3–4
Cool-down	• Stretching		5 min	

HRR, heart rate reserve; RPE, rating of perceived exertion.

were conducted 72 hr after the last round of exercise.

Body composition

The height (cm) and weight (kg) of each subject was measured using an automated analyzer (DS-102, Jenix, Seoul, Korea), and the body mass index (BMI) was then calculated using the formula "BMI = weight (kg)/height (m)^2." To measure the body fat percentage (BF%), a body composition analyzer (Inbody 720, Inbody, Seoul, Korea) was used. A measuring tape was used to measure the waist circumference (WC) from the lowest part of the rib cage to the center of the iliac crest.

Blood testing

Blood tests were performed on all subjects after 12 hr of fasting. The blood was drawn at the same time under the same conditions before and after the exercise. A disposable needle was used to draw 5 mL of venous blood from the anterior cardinal vein. The blood was stored in serum separating tubes for serum and centrifuged for 10 min at 3,000 rpm; 200 μL of the serum was stored in a sample tube. The irisin and FGF-21 levels were assessed using the enzyme linked immunosorbent assay (ELISA) method with the irisin ELISA kit (BioVendor, Brno, Czech Republic) and FGF-21 Quantikine ELISA kit (R&D System, Minneapolis, MN, USA), respectively.

Physical fitness measurements

The physical fitness in this study was estimated based on the muscular strength, muscular endurance, flexibility, and cardiorespiratory fitness. For muscular strength, a digital hand dynamometer (DW-781, Daewoosports Industry, Seoul, Korea) was used to assess the handgrip strength. The subjects were asked to hold the handle of the dynamometer using the second joints of all fingers except the thumb and pull the handle as hard as they could for 5 sec after adjusting the width of the joints to 90°, while the angle between the body and the stretched arm was maintained at 15°. Two consecutive measurements were recorded, and the maximum value was recorded to the precision of 0.1 kg. The muscular endurance was assessed by performing the sit-up test for 1 min, and the number of sit-ups performed was recorded. In this test, the subjects were asked to lie down with their hands clasped and supporting the head, lift the upper body up till both the elbows touched the knees, and then descend till both the shoulders touched the floor, without using momentum. For flexibility, the sit-and-reach test was used. In this test, the subjects had to sit with stretched knees and upright feet that touched the entire vertical surface of the measuring tool (DW-782, Daewoosports Industry). They then brought their arms together to let the tips of the fingers push the measuring ruler as far as possible and maintain the position for 3 sec while the distance was recorded. Two measurements were recorded, and the maximum value was recorded to the precision of 0.1 cm. The cardiorespiratory fitness was assessed by a 1,200-m running test. The subjects ran on a 1,200-m field track at their maximum speed, and the total elapsed time was recorded to the precision of 0.01 sec.

Statistical analysis

All measured data were represented as means and standard deviations. To analyze the effect of the exercises, a paired sample t-test was performed on the pre- and postexercise values. All statistical processing was performed using IBM SPSS Statistics ver. 25.0 (IBM Co., Armonk, NY, USA), and the significance level (α) was set at $P \leq 0.05$.

Table 3. Changes in the obesity indexes after 4 weeks of high-intensity circuit training

Variable	Before exercise	After exercise	Δ Score	*P*-value
Weight (kg)	63.48 ± 9.01	61.50 ± 9.10	-1.98 ± 0.54	0.001
BMI (kg/m^2)	25.14 ± 2.51	24.24 ± 2.60	-0.90 ± 0.35	0.001
Body fat (%)	30.46 ± 3.95	29.26 ± 3.65	-1.20 ± 0.96	0.003
LBM (kg)	42.89 ± 4.80	42.65 ± 5.08	-1.01 ± 1.24	0.320
WC (cm)	76.89 ± 7.77	75.15 ± 7.75	-1.74 ± 1.39	0.003

Values are presented as mean ± standard deviation.
BMI, body mass index; LBM, lean body mass; WC, waist circumference.
Δ score represents the difference between the score after and before the exercise program.

Table 4. Changes in irisin and fibroblast growth factor-21 after 4 weeks of high-intensity circuit training

Variable	Before exercise	After exercise	Δ Score	*P*-value
Irisin (μg/mL)	3.50 ± 0.77	4.03 ± 1.18	0.53 ± 1.15	0.180
FGF-21 (pg/mL)	283.06 (115.58–415.44)	194.41 (76.50–428.07)	-107.84 ± 237.55	0.182

Values are presented as mean ± standard deviation or mean (interquartile range).
FGF-21, fibroblast growth factor-21.
Δ score represents the difference between the score after and before the exercise program.

Table 5. Changes physical fitness after 4 weeks of high-strength circuit training

Variable	Before exercise	After exercise	Δ Score	*P*-value
Handgrip strength (kg)	26.51 ± 5.21	27.52 ± 4.54	1.01 ± 1.24	0.030
Sit-up (repetition)	28.4 ± 7.93	31.10 ± 6.93	2.70 ± 3.16	0.024
Sit-and-reach test (cm)	13.23 ± 7.38	14.60 ± 6.46	1.37 ± 2.46	0.113
1,200-m running test (sec)	433.56 ± 50.64	423.70 ± 52.10	–9.86 ± 6.35	0.001

Values are presented as mean ± standard deviation.
Δ score represents the difference between the score after and before the exercise program.

RESULTS

Change in physique and body composition

The changes in the body composition after the 4-week high-intensity CT are shown in Table 3. The postexercise weight showed a significant decrease by approximately 2 kg ($P < 0.001$), and the obesity indices of WC and BF% decreased significantly by approximately 1.74 cm ($P = 0.003$) and 1.2% ($P = 0.003$), respectively. The muscle mass showed no significant difference between the pre- and postexercise measurements.

Changes in the irisin and FGF-21 levels

The changes in the irisin and FGF-21 browning factors after the 4-week high-intensity CT are shown in Table 4. After CT, the irisin levels increased by approximately 0.53 ± 1.15 μg/mL and the FGF-21 levels decreased by approximately 107.84 ± 237.55 pg/mL, but neither showed a significance difference.

Changes in physical fitness

The changes in the physical fitness after the 4-week high-intensity CT are shown in Table 5. There was significant improvement in the handgrip strength test conducted for the muscular strength ($P = 0.030$), 1-min sit-up test for the muscular endurance ($P = 0.024$), and 1,200-m running test for the cardiorespiratory fitness ($P < 0.001$). However, no significant difference was found in the sit-and-reach test, the flexibility indicator.

DISCUSSION

This study aimed to verify the effect of a 4-week high-intensity CT exercise program on the physical fitness, obesity indices, and browning factor levels in inactive female college students. The results showed that the obesity indices significantly decreased after 4-week high-intensity CT, with significant improvements in the physical fitness indicators of muscular strength, muscular endurance, and cardiorespiratory fitness. For the browning factors, the

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irisin levels increased but FGF-21 levels decreased, with no statistical significance.

Previous studies on irisin have reported that the postexercise level of irisin varies depending on the exercise type and intensity and the short-term or long-term duration. In a study conducted on healthy male adults in their 20s, the comparison between high-intensity and low-intensity aerobic exercises inducing the same calorie burn showed that the level of irisin in blood increased by 23% within 19 hr after performing the high-intensity exercises (Tsuchiya et al., 2014). In a study conducted on obese female adolescents, the comparison between short-term moderate- to high-intensity aerobic exercises and high-intensity exercises performed in intervals showed that the level of irisin in muscular tissues increased significantly after the latter (Archundia-Herrera et al., 2017). Furthermore, a study conducted on healthy male adults reported that after 20 days of high-intensity interval training, the level of irisin mRNA increased (Eaton et al., 2018). Unlike previous studies, our study did not observe a significant change in the irisin levels of inactive female college students performing a 4-week high-intensity CT program, despite showing an increasing trend. Similar results have frequently been reported by studies investigating the effect of training. A review of the relationship between irisin and exercise showed that though the irisin level generally increases after short-term exercises, it does not change after long-term exercises. Similarly, Norheim et al. (2014) reported that the level of irisin in blood after a short-term aerobic exercise significantly increased by approximately 1.2-fold, whereas a 12-week training program in identical subjects did not induce a significant change. In a study by Hecksteden et al. (2013), the group performing aerobic and resistance exercises for 26 weeks showed no significant changes in the irisin level as compared to the control group. In a study conducted on healthy adults of the same age group as in this study, the irisin levels did not show any significant changes after short-term or 3-week long high-intensity resistance training exercises (Fernandez-del-Valle et al., 2018). A review of the irisin level after a short-term exercise reported that the level increased by approximately 15% on an average (Fox et al., 2018), but a review of the irisin level after a long-term exercise reported no change after the exercise (Qiu et al., 2015). These findings could be due to the rapid half-life of irisin (Hecksteden et al., 2013); the results of our study are also likely to be similarly influenced, as the blood test was performed 72 hr after exercise to avoid the temporary exercise effects and because the blood was refrigerated until the test rather than being tested immediately. Moreover, the irisin level follows a circadian rhythm, such that the lowest level is generally observed at 6 a.m. and the highest level at 9 p.m. (Anastasilakis et al., 2014). The blood collection in this study was performed in the morning for the fasting blood samples. Therefore, future studies investigating the effect of exercise on the irisin level should consider the time of measurement of the irisin level in the study design.

FGF-21, another browning factor like irisin, is known to be produced by various tissues such as the muscular tissue (Fon Tacer et al., 2010). It not only plays a physiological role in the regulation of glucose and lipid metabolism and the browning of the white adipose tissues, but also in the increase in energy consumption (Fisher et al., 2012; Kharitonenkov et al., 2005; Lee et al., 2013). However, compared to irisin, studies on the effect of exercise on FGF-21 are lacking, and the existing studies present inconsistent results. A previous study analyzing the effect of 60 min of high-intensity cycle ergometer exercise in healthy adults in their 20s reported that the postexercise levels of FGF-21 showed a significant increase (Tanimura et al., 2016). Likewise, in a study by Cuevas-Ramos et al. (2012), a 2-week treadmill exercise reportedly increased the FGF-21 levels significantly in healthy female adults, whereas the overweight individuals showed no change. In this study, the FGF-21 levels after the 4-week high-intensity CT showed an increasing trend, but without statistical significance. These findings coincided with those of the study by Taniguchi et al. (2016), in which a 5-week cycle exercise (3 times a week) was performed. Thus, the relationship between exercise and FGF-21 remains unclear. Nevertheless, a possible cause of the decrease in the FGF-21 levels after exercise could be the influence of insulin and the decrease in the liver lipids. In the study by Taniguchi et al. (2016), the fall in the postexercise level of FGF-21 was reported to have been caused by the fall in the liver lipids, while Cuevas-Ramos et al. (2012) suggested a possible influence of increased insulin after exercise on FGF-21 production. However, the evidence is insufficient, and further studies should be conducted to clearly identify the mechanisms causing the change in the level of FGF-21 after exercise.

This study has several limitations. First, the effect of high-intensity CT was tested after 4 weeks, and further studies should be conducted to evaluate its long-term effect. Second, in the absence of the control group, the dietary intake could not be completely controlled. Nonetheless, it was found that the level of irisin was not influenced by the dietary intake or nutrient composition in a previous study analyzing the determinants of the irisin level (Anastasilakis et al., 2014). Third, objective monitoring of the physical activities performed other than the CT could not be conducted. However, the subjects in this study were asked to retain a dietary intake pattern similar to that followed before the study and not perform any other exercises other than the CT program in this study. The subjects were also interviewed on the current dietary intake and exercise during each session of the CT program.

Despite a relatively short duration of exercise in this study, there were significant improvements in the physical composition and physical fitness, with an increasing trend of the irisin level, which is an adipose tissue browning factor. While the effect of exercise on the browning factors could not be clearly identified against the initial hypothesis, this study may have been significant in providing the evidence for exercise-based health management in a relatively inactive group of female college students.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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