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Effects of High-Intensity Interval Exercise Program (Tabata Exercise Program) on Body Composition, Lower Limb Muscle Strength, and Cardiorespiratory Functional Capacity: A Pilot Study*

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ABSTRACT

The purpose of this study is to analyze the effects of the Tabata exercise program on male college students' body composition, lower limb muscle strength, and cardiorespiratory functional capacity. For this study, eight male college students with an average age of 20.6 participated, and after applying the Tabata exercise program twice a week for 8 weeks, we did a comparative analysis by measuring body composition, lower limb muscle strength, endurance, and maximum oxygen uptake before and after the program. To analyze the differences between measurement values before and after the exercise, we used Wilcoxon's signed rank test among nonparametric statistical methods. Among the changes in body composition, there was a significant increase in skeletal muscle mass, but the change in weight was not significant. The study exhibited significant statistical increase in the skeletal muscle mass from 31.9 kg to 32.8 kg, and basal metabolism, which increased from 1583 kcal to 1613 kcal. Weight and body fat increased, but no significant statistical change was detected. In muscular strength, the left flexor showed a significant statistical increase, and in muscular endurance, both the right flexor/extensor and left flexor/extensor displayed significant statistical increases. There was also an increase in maximum oxygen uptake, but not much critical difference. These results indicate that the Tabata exercise program, which involves many lower limb movements, enhanced improvements in muscle mass, muscular strength, and muscular endurance when performed for 8 weeks.

1. Introduction

Despite the development of scientific techniques and improvement of living standards, many people cannot invest much time in caring for their health, and physical activity decreases while

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the rates of various adult diseases increase. This is known to be related to the prevalence of various adult diseases due to the decrease of physical activities from excessive workload and social competition.

The American College of Sports Medicine (ACSM) and Center for Control and Prevention recommend performing moderate-intensity physical activity for more than 150 minutes a week (ACSM, 2017). The moderate-intensity physical activities are effective only if performed for a long time, and some people may be burdened by time efficiency. According to the Korean Ministry of Health and Welfare, the biggest reason for ack of exercise for most people was “lack of time” (Ministry of Health and Welfare, 2013).

However, it was reported that high-intensity interval exercise has positive effects of enhancing weight decrease and improving physical strength even in the case of brief exercise time (Talanian et al., 2007).

In addition, the high-intensity interval exercise has positive effects in health promotion, consequently lowering the risk of cardiovascular disease and death rate (Duncan et al., 2005). After comparing high-intensity interval exercise and continuous running by setting the same total exercise amount, it was documented that high-intensity interval training relatively improves the ability of fat oxidation to a higher degree (Laursen & Jenkins, 2002). AEkström et al. (2017) proved the effect of high-intensity interval training as they reported significant improvement in exercise function in push-ups, kneeling push-ups, and standing long jumps after applying the Tabata exercise program to children from ages 7 to 9 for 6 weeks.

In high-intensity interval training, people experience an anaerobic process high in the body for a short period of time and go through an oxygen debt process. Therefore, to supplement insufficient oxygen in the body, the process of excess post-exercise oxygen consumption (EPOC) takes place even after exercise is completed, and this continues for maximum of 12 hours. The Tabata exercise is a whole-body exercise, and it increases metabolism (Emberts et al., 2013). The fact that energy is continuously consumed even after the completion of exercise, proves to be more effective in respect to the energy consumption of moderate and low intensity exercise.

The Tabata exercise program is an intermittent, high-intensity circuit training method that involves high-intensity exercise for 20 seconds followed by 10 seconds rest, repeated eight times during total of 4 minutes exercise. This program was developed and applied by Doctor Izumi Tabata in Japan for the purpose of training speed skating athletes (Tabata et al., 1996) and Dr. Tabata reported that 4 minutes long Tabata exercise program (170% of VO2 max) improves anaerobic ability in comparison to the aerobic ability of 60 minutes long moderate-intensity (70% of VO2max) endurance running.

This study aims to understand the improvement level of muscular strength and muscular endurance of the Tabata exercise program, which comprises 8 weeks of high-intensity circuit interval training, and to provide basic data for suggesting efficient exercise program for college students and general public who lack physical activity.

2. Materials and Methods

2.1 Subjects

For the subjects of this study, we recruited eight male students enrolled in college B, who did not have any abnormal movements when running. We explained the purpose and process of this study to all participants, received their agreement, and launched the study. The physical characteristics of the study participants are described in Table 1.

Table 1. Participants' Physical Characteristics

Item	Average (Mean)	Standard Deviation (SD)
Age (yrs.)	20.6	1.24
Height (cm)	172.7	7.43
Weight (kg)	66.2	9.62
Skeletal Muscle Mass (kg)	31.9	5.58
Amount of Body Fat (kg)	10.0	4.33

2.2 Method and Procedure

2.2.1 Measurement Tools

The measurement tools used in this study are listed in Table 2.

Table 2. Experiment Tools

Tool	Model	Manufacturer
Measurement of Height and Weight	Fat Monitor (BSM330)	Biospace (Korea)
Breathing Gas Analyzer (treadmill)	TrueOne2400	Parvo Medics (USA)
Isokinetic Device	Humac	CSMI USA

2.2.2 Physical Test

For a physical Test performed to understand the test subjects' physical characteristics, we used an automatic measuring instrument (Biospace, Korea) for height and weight. To measure physical characteristics, the subjects stepped on the foothold of a measurement device. Height was measured in the unit of 0.5 cm and weight was measured in the unit of 0.1 kg.

2.3 Tabata Exercise Program

This is an exercise method developed by exercise physiologist Izumi Tabata in 1996. One set of high-intensity exercise is performed for 20 seconds followed by resting for 10 seconds, which is repeated for a total of eight sets and exercise for 4 minutes. The movements must be repeated as quickly as

possible. The Tabata exercise program is performed by composing eight movements as in Table 3.

2.4 Isokinetic Muscle Functional Test

To evaluate the level of improvement of participants' lower limb muscle function, we used CSMI made by Humac, which is an isokinetic muscle function measurement device, and we fixed the torso with a belt attached to the back of a chair. After adjusting the chair's height to be fit at thigh length, the lateral femoral condyle's distal and dynamometer axis were matched. Range of motion (ROM) of the knee joint was measured and the tibia part was fixed. The femoral region was fixed by using a fixed band designed only for the knee joint to be used during flexion and extension. For the study protocol, muscular functioning of the flexor and extensor was evaluated by repeating motions five times at an angular speed of 60°/sec and 10 times at an angular speed of 180°/sec. Muscle function test of the knee joint's flexor and extensor before and after Tabata exercise was evaluated for two rounds. Muscular strength evaluated the peak torque value and muscular endurance evaluated the work done value, and these were used for analysis.

2.5 Respiratory Gas Analyzer Test

A respiratory gas analyzer (treadmill) was used to evaluate the improvement level of participants' cardiorespiratory functional capacity. Participants wore a mask and stepped on the treadmill and adjusted to the exercise test device by walking lightly. Employing the Bruce protocol as the exercise intensity increases in stages by a slope of 2% and speed of 0.8 mph every 3 minutes from the first treadmill's slope of 10% and speed of 1.7 mph, the respiratory exchange ratio (RER) value was monitored and VO2 max was measured for analysis.

2.6 Statistical Analyses

Average and standard deviation were derived for all measurement results, and to investigate the difference between before and after applying the Tabata exercise program, the SPSS v23.0 statistics program was used. For the statistical method, Wilcoxon`s signed rank test among nonparametric statistical methods was used. The statistically significant level was set as α =0.05.

3. Results

Applying the high-intensity interval training of Tabata exercise program for 8 weeks, this study analyzed the improvement level of muscular strength, muscular endurance, and cardiorespiratory functional capacity in college students.

3.1 Changes in Body Composition

Table 4 presents changes in body composition, and there was significant statistical increase in

skeletal muscle mass from 31.9 kg to 32.8 kg and basal metabolism from 1583 kcal to 1613 kcal. Weight and body fat increased, but there was no significant statistical difference.

3.2 Changes in Muscular Strength and Muscular Endurance

Table 5 presents changes in muscular strength and muscular endurance, and for muscular strength, there was significant difference in the left flexor, and for muscular endurance in both the right flexor/extensor and left flexor/extensor.

3.3 Changes in Maximum Oxygen Uptake

Maximum oxygen uptake increased from 45.967 ㎖/kg/min to 46.3 ㎖/kg/min, but there was no significant statistical difference.

3.4 Figures, Tables and Schemes

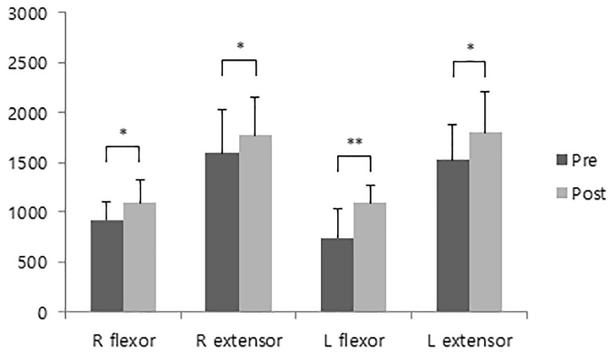

Fig. 1. Changes in muscular Endurance before and after exercise

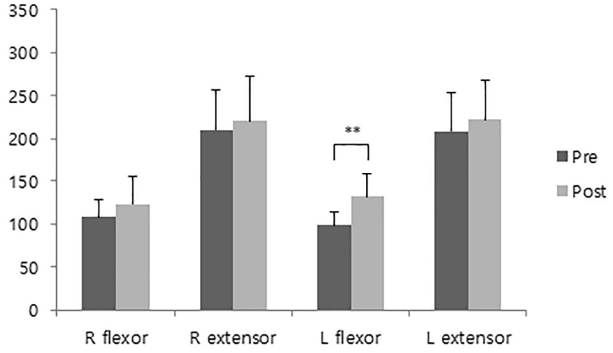

Fig. 2. Changes in muscular strength before and after exercise

Table 3. Tabata Exercise Program

No.	Exercise Type	Time
1	Jumping jacks	20 s
	10 s rest	
2	Mountain climber	20 s
	10 s rest	
3	Air squats	20 s
	10 s rest	
4	Air bike	20 s
	10 s rest	
5	High knees	20 s
	10 s rest	
6	Lunges	20 s
	10 s rest	
7	Burpee test	20 s
	10s rest	
8	Push-ups	20 s
	10 s rest	

Table 4. Changes in Body Composition

Body weight			Skeletal muscle mass			Fat mass			Basal metabolism		
Pre	Post	Z-value	Pre	Post	Z-value	Pre	Post	Z-value	Pre	Post	Z-value
66.2 ±9.62	68.3 ±10.41	-1.955	31.9 ±5.58	32.8 ±5.85	-2.431*	10.0 ±4.33	10.7 ±3.96	-1.008	1583.0 ±194.11	1613.0 ±201.65	-2.192*

Values are mean ± S.D., * p<.05, ** p<.01, *** p<.001 by Wilcoxon's signed rank test

Table 5. Changes in Muscular Strength and Muscular Endurance

R-flexor muscular strength			R-extensor muscular strength			L-flexor muscular strength			L-extensor muscular strength		
Pre	Post	Z-value	Pre	Post	Z-value	Pre	Post	Z-value	Pre	Post	Z-value
107.6 ±20.04	122.6 ±32.05	-1.362	209.9 ±46.75	220.3 ±51.93	-0.98	98.3 ±15.03	131.6 ±26.74	-2.666**	208.4 ±44.32	221.9 ±45.76	-1.362

R-flexor muscular endurance			R-extensor muscular endurance			L-flexor muscular endurance			L-extensor muscular endurance		
Pre	Post	Z-value	Pre	Post	Z-value	Pre	Post	Z-value	Pre	Post	Z-value
916.0 ±188.61	1087.1 ±235.48	-2.521*	1592.8 ±441.11	1777.0 ±381.69	-2.016*	743.9 ±285.95	1091.7 ±177.47	-2.666**	1525.9 ±356.29	1801.6 ±411.06	-2.073*

Values are mean ± S.D., * p<.05, ** p<.01, *** p<.001 by Wilcoxon's signed rank test

4. Discussion

This study examined changes in body composition, muscular strength and muscular endurance, and maximum oxygen uptake amount of eight male college students who performed the Tabata exercise program for 8 weeks.

The Tabata exercise program is a high-intensity program performed for a short period of time, hence it has time efficiency (Foster et al., 2015). It was also found that the Tabata exercise program is one of the effective methods among high intensity/intermittent exercise training methods (Tabata, 2019).

4.1 Changes in body composition

After the Tabata training, there were changes in body composition including, increase in weight by 2.1 kg, increase in skeletal muscle mass by 0.9 kg, and increase in body fat amount by 0.7 kg.

In addition, when 10 obese middle-aged women at borderline performed the Tabata exercise program for 8 weeks, it was reported that their weights decreased, and their body fat percentage decreased by significant statistical amount. The study on the relationship between high-intensity interval training and body composition after performing 20 minutes exercise 3 times a week for 12 weeks in the case of young overweight males, it showed that their weight, BMI, body fat percentage, and body fat volume significantly decreased (Heydari et al., 2012).

As exercise increases skeletal muscle mass and brings positive changes in body composition, it was reported that high-intensity interval training also stimulates mitochondrial enzyme expression and increase in the oxidation of body fat, which is effective for weight control (Talanian et al., 2007). Also, it is known that exercise increases energy consumption at rest; in particular, while high-intensity interval training increases the excessive oxygen uptake amount after exercise, it significantly increases energy consumption when at rest for 22 hours after exercise, and it has been shown that it decreases the respiration rate (Paoli et al., 2012).

After the course of comprehensive examination of this study and previous studies, it is regarded that the significant change in basal metabolism is due to significant change in skeletal muscle mass, thus it could be considered that the Tabata exercise program has a positive influence on changes in body composition.

4.2 Changes in muscular strength and muscular endurance

Before and after Tabata training in this study, the isokinetic muscular strength of the knee joint at 60°/sec angular speed for each right and left extension increased about 5.0% and 6.4%, respectively, and each right and left flexion increased about 13.9% and 33.7%.

At 180°/sec angular speed, muscular endurance for each right and left extension increased about 11.5% and 18.0%, and each right and left flexion increased about 18.6% and 46.7%.

Circuit weight training statistically increased muscular strength and muscular endurance at a significant level.

In a comparative study on continuous high-intensity training and Tabata high-intensity interval training performed by 68 young people, it was reported that the Tabata exercise group displayed significant impact in the measurement of muscular endurance with push-ups after 4 weeks, and the effect continued even after 2 months (Islam et al., 2019).

By combining these results, we can confirm that it is similar to previous studies that presented positive changes in muscular strength and muscular endurance with high-intensity interval training. The reason for remarkable effect on muscular endurance is postulated to be the increase in mitochondria in muscles after high-intensity interval training (Jacobs et al., 2013).

4.3 Changes in cardiopulmonary function

For changes in maximum oxygen uptake amount (VO2max) before and after the training, the amount increased by 0.8%, but it was not statistically significant.

Miyamoto-Mikami et al.(2018) applied the Tabata exercise program for 6 weeks with 17 males, and reported that the maximum oxygen uptake amount (VO2max) significantly increased. Tjønna et al.(2013) performed high-intensity interval training three times a week for 10 weeks with overweight middle-aged and reported that the maximum oxygen uptake amount (VO2max) increased by 13%. Helgerud et al.(2007) performed an exercise three times a week for 8 weeks with 40 young males, and reported that the maximum oxygen uptake amount (VO2max) increased more significantly in the high-intensity interval training group than in the moderate-intensity continuous training group.

In addition, Emberts et al. (2013) applied four sets of the Tabata exercise program to 16 males and females (eight each), and the average heart rate was measured at 86% of the maximum heart rate, and the average oxygen uptake amount was measured at 74% of the maximum oxygen uptake amount. It also indicated that the program had significant intensity to improve cardiopulmonary endurance. Furthermore, rated perceived exertion (RPE) was 15.4, which is the “hard” intensity level, and even after comparing it with medium-low intensity exercise performed for 4 minutes, it demonstrated that energy consumption with the Tabata exercise was high.

In case of the mechanism related to the increase in cardiopulmonary strength, if skeletal muscle contractility improves, the returning amount of venous blood increases, which then induces an increase in one-time heart outflow. This exhibits the effect of improving cardiopulmonary endurance (Joyner et al., 2008). Besides, the more positive influence of high-intensity intermittent exercise on cardiorespiratory fitness compared to the high-intensity continuous exercise are as follows: 1) PGC-1α , which influences the invigoration of mitochondria increases; 2) it induces the ability improvement of mitochondria by improving the absorption of Ca ions between muscular fiber and sarcoplasmic reticulum; and 3) this increases the one-time outflow of the left ventricle (Wisløff et al., 2007; Rognmo et al., 2008).

The Tabata exercise is a high-intensity exercise performed for 20 seconds, exhibiting instant effect after short period of time, thus this exercise can reduce tedious activities, and utilize time more effectively before actual training session.

5. Conclusions

This study analyzed the effects of the Tabata exercise program on body composition, muscular strength, muscular endurance, and cardiopulmonary function of male college students for 8 weeks, and the results are summarized as follows.

First, there was a significant increase in the skeletal muscle mass of body composition.

Second, there was a significant increase in muscular strength in the flexor of the left knee joint.

Third, there was a significant increase in muscular endurance in both the left and right knee joint flexor and extensor.

Fourth, there was no significant increase in cardiorespiratory functional capacity.

With these results, it is concluded that performing the Tabata exercise program for 8 weeks has a positive effect on increase of the muscle mass and improvement of muscular strength and muscular endurance.

Conflicts of Interest

The authors declare that they have no conflicts of interest

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