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Effect of different exercise intensities after cessation of high-intensity training program on physical fitness, isokinetic muscle function and skeletal muscle metabolism: a synthesis of human and animal study

Department of Kinesiology

GRADUATE SCHOOL
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Abstract

Effect of different exercise intensities after cessation of high-intensity training program on physical fitness, isokinetic muscle function and skeletal muscle metabolism: a synthesis of human and animal study

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The purpose of this study was to investigate whether different exercise intensities during 4-week detraining period could maintain changes in body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function of obese adult female after 8 weeks of high-intensity training (HIT) and activate aerobic and anaerobic exercise-related signaling pathway in soleus muscle of obese rats. Study-Ⅰ was a human subject study and 21 obese women took part in this experiment excluding 11 subjects who did not meet the criteria, 19 subjects with COVID-19 infection, and 7 subjects with personal circumstances. All participants were divided into 4 groups; a non-training group (NTG), a low-intensity exercise group (LIG), and a moderated-intensity exercise group

(MIG) according to the exercise intensity during the 4-week detraining period after 8-week HIT. Body composition, cardiovascular risk factors, physical fitness, and isokinetic knee and trunk muscle functions of each group were compared and analyzed. The high-intensity training program was applied three times a week for 8 weeks, and exercise intensity was set at RPE 8~18 with short rest period of 10～30 seconds. And then during 4-week detraining period, the exercise intensity in LIG was RPE 8～10, and RPE 12～14 for MIG. To confirm the effect of exercise intervention during detraining period, body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function were measured before and after 8-week HIT, and after 4-week detraining. Significant differences between groups and periods were confirmed by two-way repeated measures ANOVA, and differences between groups were confirmed by one-way ANOVA, and Scheffe's post-hoc was performed. As a result of this study, body composition significantly decreased in waist circumference, hip circumference, and waist-height ratio in MIG, and had a positive effect on the improvement of muscular endurance, agility, and cardiorespiratory endurance. However, there was no positive effect on improvement of cardiovascular index and isokinetic muscle function in all groups. Therefore, the study-Ⅰ suggested important information that continuous moderate-intensity exercise is necessary during the detraining period to maintain the anti-obesity effect of the high-intensity training program performed for 8 weeks.

In the study-Ⅱ, we conducted animal study to confirm aerobic and anaerobic metabolism in skeletal muscle based on the results of the human study obtained from Study-Ⅰ. The purpose of study-Ⅱ was to examine whether low of moderate intensity of exercise during the detraining period could positively keep up activation of signaling pathway related with aerobic and anaerobic metabolism in the flexor pollicis longus and soleus muscles obtained by 8-week HIT. SD rats (6 weeks old, n=36) participated in HIT program for 8 weeks, and then during the detraining period, low or moderate intensity exercise was applied for 2 weeks. all rats were randomly assigned into 5 groups; the non-exercise group (NEG, n=6), the group that finished high-intensity exercise (EG, n=6), the resting group (CD2, n=6), the low-intensity exercise group

(LID2, n=6), and the moderated-intensity exercise group (MID2, n=6) during the detraining period. The high-intensity exercise program was treadmill exercise 3 times a week at a speed of 24m/min for 30 minutes a day for 8 weeks. For 2-week detraining, low-intensity treadmill exercise was performed at 8m/min and moderated-intensity treadmill exercise at 16m/min three times a week. Activation of muscle hypertrophy and mitochondrial biosynthesis-related signaling pathway in the flexor pollicis longus and soleus muscles were confirmed by Western blot analysis. Differences between groups were analyzed by one-way ANOVA, and Tukey was performed as a post-hoc. As a result of study 2, expression level of PI3K in the flexor pollicis longus muscle was higher in EG and LID2 than in NEG, and Akt and p-mTOR in MID2 and EG were increased significantly compared to those in NEG, CD2, and LID2. In addition, the phosphorylated level of AMPK in the soleus muscle was higher in CD2 and MID2 than in NEG, and FNDC5 in LID2 dynamically upregulated compared to those in EG and CD2. Therefore, study 2 suggested new evidence that moderate intensity exercise during detraining period might consistently maintain activation in muscle hypertrophy-related protein pathway after 8-week HIT, and low intensity exercise might continuously activate aerobic metabolism in skeletal muscle obtained by HIT.

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I. Introduction

1. Research significance

Detraining is defined as a phenomenon in which the physiological adaptation of the body through regular exercise is reduced over time due to factors such as exercise cessation, injury, or environmental change (Mujika & Padilla, 2000). Long-term detraining has been known to negatively change physiological metabolism including VO_2max, plasma volume, maximum cardiac output, left ventricular volume/thickness, and citrate synthase activity improved by regular exercise (Coyle et al., 1984; Houmard et al., 1993), and these changes rapidly decrease aerobic capacity by 4～25% (Mujika and Padilla, 2001).

In addition, in the field of skeletal muscle metabolism, it has been reported that the average cross-sectional area of fast-twitch fibers (FT) and maximum strength were decreased during prolonged periods of detraining, but the distribution of skeletal muscle fibers does not change (Bangsbo & Mizuno, 1988). Reduction of muscle size and strength after cessation of training is highly associated with intramuscular glycogen depletion and inhibition of myogenic differentiation-related protein cascades (Costill et al., 1985; Laforgia et al., 1999; Mujika & Padilla. 2000) as well as downregulation in lipid metabolism, insulin sensitivity, and muscle lipoprotein lipase activity (Coyle et al., 1984).

With these previous results, long-term detraining has negative effect on improved cardiovascular fitness, musculoskeletal metabolism, and hormone expression levels in endocrine system after regular high-intensity training (HIT, Houston et al., 1983). Many previous researchers have tried to suggest various exercise strategies to block the negative effect of detraining. Rietiens et al. (2001) verified that exercise training at 50% HRmax during 3-week detraining period could maintain maximal oxygen intake, endurance capacity, resting metabolic rate, and body weight in cyclists developed through

HIT. Tavares et al. (2017) confirmed that after both resistance exercise in 50% (once a week) or 43% (twice a week) of 1RM during 8-week detraining stage might keep up developed muscle mass and maximum strength after high-intensity resistance training for 8 weeks. In addition, García et al. (2009) suggested that the maximum oxygen intake (VO_2max) in elite kayakers was decreased by 10.1% during 5-week detraining, whereas performing low-intensity exercise during this period downregulated VO_2max by only 4.8%.

But, contrary to the results of previous studies, there is a research paper that light moderate-intensity exercise (<6.0 METS) for 35 to 42 days after training was stopped rather increased percent body fat (%BF) and body weight (Ormsbee & Arciero, 2012). Also, Fatouros et al. (2006) emphasized that only moderate exercise of 60% or more is important to suppress the weakening effect of muscle strength and flexibility during the detraining period.

Taken together, the above findings provide reliable information that performing exercise during the detraining period continues to improve physical strength and body composition after HIT for a long time. However, the mechanical effect of exercise intensity in patients with obesity during detraining period remains controversial to date.

Skeletal muscle which accounts for 50% of body weight, regulates basic functions including movement and breathing. Sustaining a certain level of skeletal muscle mass is an important factor that has a good effect on health and quality of life (Bottinelli & Reggiani, 2000). In general, resistance exercise has been known to increase skeletal muscle mass via activation of protein biosynthesis in muscle cells (Bruton, 2002; Murach et al., 2020), but long-term training cessation leads to a reduction in skeletal muscle mass, known as muscle atrophy, suggesting that the quantitative increase or decrease in skeletal muscle mass clearly regulates a balance between protein synthesis and degradation (Fernandes et al. al., 2012). Therefore, it is necessary to accurately understand the protein signaling pathways in skeletal muscle that appears during detraining.

Resistance exercise results in hypertrophy and functional improvement of skeletal muscle by activating the anabolic signaling pathway including PI3K (Phosphoinositide 3-kinases), Akt (Protein kinase B), mTOR (mechanistic target of rapamycin), MAPK (mitogen-activated protein kinase), and CaMK (Ca2+/calmodulin)-dependent protein kinase (Fernandes et al., 2012). The Akt-mTOR signaling pathway is a specific indicator regulating skeletal muscle hypertrophy, and oxidative phosphorylation of Akt upregulates the activity of mTOR protein, which facilitates proliferation and differentiation of satellite cell in skeletal muscle (Wang & Proud, 2006). Similar to Akt-mTOR cascades, IGF-1 (insulin-like growth factor-1) also stimulates the synthesis rate in differentiated muscle fiber after regular resistance training (Yang & Goldspink, 2002). According to a previous animal study confirming alternation in the signal transduction pathway in skeletal muscle after resistance exercise, it has been reported that the active pathway of mTOR was dramatically increased after resistance exercise but recovered to the pre-exercise state 12 days after training was stopped (Ogasawara et al., 2013).

Endurance exercise accelerates the signaling pathways of cAMP (cyclic adenosine monophosphate), CaMK, AMP-activated protein kinase (AMPK), and p38-MAPK (p38 mitogen-activated protein kinase), which are involved in transcriptional regulation of mitochondrial biogenesis in muscle. Along with this, PGC1-α is a key regulator of mitochondrial biogenesis and induces the expression of various proteins of gene transcription factors such as PPARα (peroxisome proliferator-activated receptors) and ERR α (estrogen-related receptor alpha) (Nicholas et al., 2014). In previous study, Craig et al. (2015) reported that regular endurance exercise could cause increases in specific oxidative capacity in satellite cells through activating mitochondrial biogenesis and fatty acid utilization, which was modulated by cAMP-AMPK cascades and PPARα signaling pathway.

Summarizing previous studies related to detraining, protein signaling pathways activated by high-intensity aerobic or anaerobic exercises for a long time was downregulated over time during detraining period, but it was confirmed that exercise performance during the detraining period had a positive effect on aerobic and anaerobic physiological changes induced by HIT. However, studies on the role of exercise intensity on obesity-related factors and physical fitness during detraining period are not enough.

Therefore, the purpose of this study was to investigate whether different exercise intensities during 4-week detraining period could maintain changes in body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function of obese adult female after 8 weeks of high-intensity training (HIT) and activate hypertrophy and mitochondria biogenesis-related protein signaling pathway in soleus muscle of rats after HIT.

2. Research purpose

The objectives of this study were as follows:

1. The effect of exercise intensity (low or moderate) performed during the detraining period (4 weeks) after high-intensity training (8 weeks) on obese adult women was investigated on body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function.

2. The mechanism of changes in proteins related to muscle hypertrophy and mitochondrial biosynthesis was verified by the exercise intensity (low or moderate) performed during the detraining period (2 weeks) after high-intensity exercise (8 weeks) in rats.

3. Research hypothesis

The research hypothesis addressed in this dissertation were as follows:

Study Ⅰ

1) Depending on the exercise intensity (low or moderate) performed during the detraining period (4 weeks), there will be differences in body composition, waist-height ratio, and waist-hip circumference ratio of obese adult women.

2) Depending on the exercise intensity (low or moderate) performed during the detraining period (4 weeks), there will be differences in cardiovascular risk factors in

obese adult women.

3) Depending on the exercise intensity (low or moderate) performed during the detraining period (4 weeks), there will be a difference in physical fitness of obese adult women.

4) Depending on the exercise intensity (low or medium) performed during the detraining period (4 weeks), there will be a difference in isokinetic muscle function (knee/trunk extension, flexion) of obese adult women.

Study Ⅱ

1) Depending on the exercise intensity (low or moderate) performed during the detraining period (2 weeks), there will be differences in hypertrophy-related proteins (PI3K, p-ERK, p-Akt, p-mTOR) in the flexor pollicis longus of SD-type rats.

2) Depending on the exercise intensity (low or moderate) performed during the detraining period (4 weeks), there will be differences in mitochondrial biosynthesis-related proteins (p-AMPK, PGC1-α, FNDC5) in SD-type rat soleus muscles.

4. Research Limitations

The research limitations of this study were as follows:

Study Ⅰ

The research limitations of this study were as follows:

1) The participant of the study was limited to a specific area.

2) The psychological factors of the study participants could not be controlled.

3) The diet, sleep time, and physiological phenomena of the study participants were not completely controlled.

Study Ⅱ

1) The genetic factors between humans and study subjects could not be controlled.

2) Physiological phenomena of the subjects could not be completely controlled.

5. Operational definitions

The following definitions and explanations of the terms were established for use in this study:

1) Detraining

It is a phenomenon in which the physiological and functional abilities of the body improved by exercise are partially or completely lost due to suspension of training or decrease in exercise amount.

2) Muscle function

The function of a muscle, including muscle strength, muscular endurance, and muscle power exerted by a contracting muscle.

3) Skeletal muscle metabolism

Skeletal muscle metabolism is all chemical reactions, including the transport of substances between cells within skeletal muscles, and skeletal muscle metabolism includes immune cells and muscle cells and is regulated by various signaling pathways activated or suppressed by nutrition, hormones, inflammation, and nerve stimulation.

4) Muscle hypertrophy

The enlargement of skeletal muscles through an increase in muscle size, leading to a certain increase in muscle strength.

5) Mitochondrial biogenesis

An increase in the number and size of mitochondria, and mitochondrial biogenesis in skeletal muscle occurs mainly through the stimulation through aerobic exercise.

6) Mechanistic target of rapamycin (mTOR)

A down-stream molecule of insulin-like growth factor 1 (IGF-1), a protein that induces cell growth and muscle synthesis, and plays an important role in muscle strength and hypertrophy.

7) AMP-activated protein kinase (AMPK)

An enzyme that acts as a sensor in maintaining intracellular energy homeostasis and is closely related to the regulation of energy metabolism through fatty acid oxidation and glycolysis.

8) Peroxisome proliferator-activated receptor-gamma coactivator-1 alpha (PGC1-α)

A transcription factor associated with the regulation of mitochondrial function and cellular energy metabolism and is closely related to the maintenance or increase of mitochondrial biogenesis in skeletal muscle.

9) Fibronectin type III domain-containing protein 5 (FNDC5)

A hormone derived from skeletal muscle that changes white fat into brown fat and induces heat production to increase body energy consumption. It is known as a potential therapeutic agent for obesity and related diseases.

II. Literature review

1. Physiological changes due to detraining

Detraining is defined as a phenomenon in which the physiological and functional abilities of the body improved by exercise are partially or completely lost due to the cessation of exercise or decrease in exercise amount (Mujika & Padilla, 2000). These training suspensions show different characteristics depending on the duration of exercise suspension or the degree of reduction in exercise volume.

In the case of changes in cardiorespiratory function due to training suspension, maximum oxygen intake (VO_2max) decreases by 4-14% within 4 weeks of training suspension, and the higher the increase in maximum oxygen intake due to training, the greater the loss rate due to training suspension (Coyle et al., 1984; Martinet et al., 1986; Moore et al., 1986; Houmard et al., 1996). In addition, total blood volume and plasma volume decrease by 5 to 12%, and heart rate during exercise increases by about 5 to 10% at submaximal exercise and maximum exercise intensity but stabilizes after 2 to 3 weeks of stopping training. However, the resting heart rate did not change even after 10 days of cessation of training. Stroke volume decreases by 1 to 17% after 12 to 21 days of training cessation, and maximum stroke volume further decreases by 8% after 21 days. After 3 weeks of training cessation, left ventricular wall thickness decreased by 25% and left ventricular mass decreased by 19.5% (Thompson et al., 1984; Coyle et al., 1986; Houmard et al., 1992).

In terms of energy metabolism, training suspension means an increase in dependence on carbohydrate metabolism as an energy source for muscle movement, which leads to an increase in the respiratory exchange ratio (RER) (Coyle et al., 1984; Moore eats al., 1987). Sensitivity to glucose uptake rapidly decreases in the absence of physical activity, resulting in a decrease in lipase activity and GLUT-4 content by 17～33% after 6-10 days (Houmard et al., 1992). The inactivation of these hormones induces a rapid decrease in lipoprotein lipase activity in muscle, significantly increases postprandial lipidemia, decreases high-density lipoprotein cholesterol, and increases low-density cholesterol. density lipoprotein cholesterol) (Thompson et al., 1984; Simsolo et al., 1993). In addition, the oxidative capacity of the muscle is reduced, and the lactate threshold is reduced by up to 50% in one week (Costill et al., 1985). Glycogen is negatively affected even by as little as a week of detraining due to the conversion of glucose to glycogen in muscle and a rapid decrease in glycogen synthase activity (Moore et al., 1987; Madsen et al., 1993; Vukovich). et al., 1996).

In terms of enzymatic activity, detraining for less than 4 weeks leads to a 25～45% reduction in citrate synthase, and reduced muscle oxidative capacity is associated with β -hydroxy acid-CoA dehydrogenase. CoA dehydrogenase, malate dehydrogenase, and succinate dehydrogenase are reduced by 12～27%. In addition, the lipoprotein lipase activity of skeletal muscle decreased by 45～75%, but increased by 86% at the adipose tissue level, favoring the accumulation of adipose tissue (Coyle et al., 1985; Moore et al., 1987; Bangsbo et al., 1987; Houmard et al., 1992; McCoy et al 1994). Glycogen synthase activity decreases by 42% after only 5 days without training (Mikines et al., 1989) However, it has been reported that aerobic function due to detraining decreases within 2 weeks, whereas anaerobic capacity does not significantly decrease within 4 weeks (Sysler & Stull., 1970; Hortobagyi et al., 1993).

To minimize the negative effects of detraining or maintain the effects of initial exercise for a long time, various studies are being conducted, such as aerobic and anaerobic complex exercise programs, exercise duration, and exercise intensity changes.

However, a clear method has not been suggested.

2. Strategies to prevent the negative effects of training withdrawal

Muscle mass improved by exercise can lead to muscle loss due to long-term detraining (Bickel et al., 2011). Although some studies have reported that muscle strength is maintained for months or years (Houston et al., 1983; Smith et al., 2003; Ogasawara et al., 2013; Mujika and Padilla, 2000), the subjects were adolescents and the elderly. One study reported significant loss of muscle strength after only 6 weeks of training cessation. In other words, muscle strength improved by short-term exercise decreases as rapidly as the exercise period (Coratela and Schena, 2016; Kalapotharakos et al., 2007). However, stopping training does not lead to muscle loss in a short time.

Tapering is used as a strategy to effectively maintain and increase previous strength and muscle mass by taking a period of rest after exercise or adjusting exercise intensity and frequency (Mujika et al., 2004; Murach and Bagley, 2015; Pritchard et al., 2015). In other words, methods are proposed to offset the negative elements of detraining and lead to positive effects by effectively arranging exercise intensity, frequency, amount, and period.

According to previous studies, beginners who have recently started exercising can maintain muscle strength even if the amount of exercise is reduced from 1/3 to 1/9 of the previous exercise amount. (Bickel et al., 2011), Resuming exercise after detraining can improve your strength more quickly than before (Ogasawara et al., 2013). If you continue to exercise once a week, you can maintain the effect of exercise for more than 8 to 12 weeks (Rønnstad et al., 2011; Tavares et al., 2017), and maintain muscle strength and neuromuscular strength for a long period of time through eccentric exercise and cross exercise (Mujika and Padilla, 2000; Coratella and Schena, 2016). In the case of events requiring endurance, players are advised to continue training even during breaks or injuries (Joo, 2016; Maldonado-Martin, 2017). Sports injuries such as ankle sprains or Achilles tendinitis require alternative training methods such as water running, cycling, rowing, reduced exercise frequency (Rietjens et al., 2001; García-Pallarés et al., 2009), Resistance exercise can improve aerobic capacity (Aagaard and Andersen, 2010; Sunde et al., 2010). In addition, it was suggested that intermittent high-intensity training is positive in maintaining physiological adaptation due to previous training (Mujika and Padilla, 2000).

3. Obesity and exercise

Exercise to improve obesity requires enough exercise to reduce body fat. In general, the amount of exercise depends on its duration and intensity. That is, since exercise affects the amount of energy consumption in the body, it is necessary to determine the minimum level of physical activity to improve obesity.

According to the American College of Sports Medicine (ACSM), 225 to 420 minutes of exercise per week are recommended to change the body through exercise. In addition, it was estimated that if you maintain exercise for 250 minutes every week, you can lose 5 kg in 6 months (Donnelly et al., 2009). For effective obesity improvement, moderate-intensity exercise is necessary, and moderate-intensity exercise is to maintain 3~6 METs (Metabolic equivalents task) or 64~76% of the maximum heart rate (Garber et al., 2011). In addition, even if the amount of daily exercise is divided into several short units, it is as effective for weight management as performing the same total amount of exercise in one batch (Fogelholm et al., 2006). Dunn (2009) reported that cardiovascular disease (CVD) can be improved only with changes in daily life habits, and that obesity can be improved through regular exercise and increased physical activity in daily life.

Apart from the amount of exercise in the treatment of obesity, the type of exercise also needs sufficient consideration. First, aerobic exercise is easy to apply to obese people and is a popular and effective form of exercise for weight loss due to its high efficiency in terms of energy consumption. In recent studies, studies on weight management programs that combine aerobic exercise with resistance exercise or intermittent exercise have been actively conducted to provide positive information for health and weight management of obese people. Resistance exercise stimulates the breakdown of body fat similarly to aerobic exercise, but unlike aerobic exercise, it requires less energy consumption than aerobic exercise because it requires a longer rest period. However, resistance exercise leads to an increase in lean mass, and muscle hypertrophy can have a positive effect on changes in body weight by increasing basal metabolic rate. However, resistance exercise for obese people requires caution as there is a risk of musculoskeletal injury (Sword, 2012).

III. Study Ⅰ: Effects of different exercise intensities during detraining period on body composition, cardiovascular risk factor, physical fitness, and isokinetic muscle function in obese adult women after 8-weeks high-intensity training.

1. Research significance

Obesity is a condition in which the size and amount of fat cells in the body are excessively increased, and this is caused by various factors such as eating habits, lack of sleep, physical activity, medications, genetics, and family history.

Excessive accumulation of fat acts as a cause of metabolic diseases such as heart disease, stroke, depression, diabetes, and musculoskeletal disorders (Expert panel member, et al., 2014). Although dietary, exercise, and drug approaches have been suggested as therapeutic strategy for preventing and improving obesity, the importance of exercise therapy is being emphasized in terms of economy and effectiveness (Mclnnis, 2000).

Regular physical exercise leads to weight loss by reducing body fat, and 5～10% weight loss in obese people improves obesity-related health problems by affecting fasting blood sugar, glycosylated hemoglobin, systolic and diastolic blood pressure, and blood lipid. (Coyle et al., 1986; Coyle et al., 1984). In previous clinical trials, high-intensity physical exercise increases skeletal muscle mass, and results in body weight loss through enhancement of basic metabolism index (BMI) (Oppert et al., 2021). However, according to a study by Mackie et al. (2017), 80% of those who intentionally lost more than 10% of body weight reported a yo-yo phenomenon within one year (Vidal, 2002; Wing & Phelan, 2005).

In order to solve this problem, continuous exercise performance is very important, but it may be difficult to perform regular exercise according to sports injury and environmental change. Mujika & Padilla (2000) define detraining as a phenomenon in which exercise is stopped or the amount of exercise is reduced after long-term exercise.

Looking at previous studies related to detraining, maximum oxygen intake (VO_2max), an indicator of cardiopulmonary capacity, was decreased by 4～14% within 4-week detraining period, and total blood and plasma volume were declined by 5～12% (Coyle et al., 1984; Martinet et al., 1986) as well as lipoprotein lipase activity and GLUT-4 protein content in skeletal muscle were reduced by 17～33% during 6～10 days of detraining (Coyle et al., 1984; Moore eats al., 1987; Houmard et al., 1992). In addition, McCoy et al. (1994) suggested that lipoprotein activity in skeletal muscle was decreased by 45～75%, while the body fat accumulation was increased by 86% (Moore et al., 1987; Bangsbo et al. al., 1987; Houmard et al., 1992).

With these previous data, we can confirm that aerobic exercise functions are rapidly decreased within 2 weeks of detraining, and anaerobic exercise capacity is maintained for more than 4 weeks of detraining.

As such, most obesity-related detraining studies focus only on the change in exercise effect during detraining after regular exercise, but studies on weight loss and physical fitness maintenance in obese people by subdividing the intensity of exercise performed during the detraining period is not enough. Therefore, the purpose of this study was to examine whether different exercise intensities during detraining period could maintain the improved body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function in obese adult women after HIT.

2. Research purpose

The effect of exercise intensity (low or moderate) performed during the detraining period (4 weeks) after high-intensity training (8 weeks) on obese adult women was investigated on body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function.

3. Materials and Methods

1) Research participants

To determine the optimal sample size before recruiting subjects for this study, the minimum sample size (Effect size=0.35, Power=0.97, size=40) was derived using G×Power 3.1 (Faul et al., 2009). The subjects of this study were adult women in their 20s and 30s (n=56) who had no cardiovascular or musculoskeletal diseases for the past 6 months. Participants in this study were adult women in their 20s and 30s (n=56) who had no cardiovascular or musculoskeletal disorders for the past 6 months. Of these, 45 people participated, excluding those with a body fat percentage of less than 30% (n=6) and over 50% (n=5) (Kong et al., 2016). During 8 weeks of high-intensity training, exercise was stopped due to COVID-19 infection (n=16) and personal reasons (n=5), and the final 21 participants completed high-intensity training. 21 participants were randomly assigned and divided into non-training group (NTG, n=7), low-intensity exercise group (LIG, n=7), and moderate-intensity exercise group (MIG, n=7), and detraining During the period (4 weeks), 1 NTG and 1 LIG dropped out, so 19 participants completed detraining. The study participants provided written consent, and the study design was approved by the institutional review board of the Jeju National University (JJNU-IRB-2022-022). The characteristics of the study participants are provided in <Table 1>. The characteristics of detraining participants are provided in <Table 2>.

Table 1. Characteristics of participants (n=19)

Variables	Mean±SD
Age (yr)	21.11±1.88
Height (㎝)	162.22±6.16
Weight (㎏)	64.81±6.28
Skeletal muscle mass (SMM, ㎏)	22.04±2.14
Fat free mass (FFM, ㎏)	40.82±4.37
Body fat mass (BFM, ㎏)	23.99±4.29
Body mass index (BMI, ㎏/㎡)	24.81±2.61
Percent body fat (%BF)	39.91±4.48
Waist circumference (WC, ㎝)	81.80±6.01
Hip circumference (HC, ㎝)	99.53±2.74
Waist to height ratio (WHtR, %)	.51±.04
Waist to hip ratio (WHR, %)	.82±.04

Table 2. Characteristics of detraining participants (n=19)

Variables	NTG(n=6)	LIG(n=6)	MIG(n=7)	Total	*F*	*p*
Age (yr)	20.33±1.75	22.17±1.17	20.86±2.27	21.11±1.88	1.624	.228
Height (㎝)	162.8±6.41	162.5±0.94	161.47±7.62	162.22±6.16	.076	.927
Weight (㎏)	62.35±7.95	62.07±4.19	63.44±6.02	62.66±5.91	.090	.915
SMM (㎏)	21.20±2.70	21.10±1.43	21.57±2.05	21.31±2.01	.090	.914
FFM (㎏)	38.99±4.83	40.08±3.56	40.36±4.41	39.84±4.10	.176	.840
BFM (㎏)	23.36±4.97	21.99±1.82	23.09±4.59	22.82±3.89	.192	.827
BMI (㎏/㎡)	24.55±1.57	23.67±1.95	22.91±2.87	23.67±2.23	1.504	.252
%BF	37.28±4.84	35.47±2.54	36.27±5.28	36.34±4.26	.250	.782
WC (㎝)	80.67±5.33	76.05±4.47	80.04±6.19	78.98±5.52	1.298	.300
HC (㎝)	98.57±3.49	96.15±3.16	98.50±1.56	97.78±2.87	1.488	.255
WHtR	.50±0.02	.47±0.03	.50±0.05	.49±0.04	1.171	.335
WHR	.82±0.04	.79±0.03	.81±0.06	.81±0.05	.555	.585

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group; SMM, skeleton muscle mass; FFM, fat free mass; BFM, body fat mass; BMI, body mass index; %BF, percent body fat; WC, waist circumference; HC, hip circumference; WHtR, waist to height ratio; WHR, waist to hip ratio

2) Experimental design

The experimental design of this study was to investigate the effects of exercise performed during the detraining period (4 weeks) on body composition, cardiovascular risk factors, physical strength, and isokinetic muscle function according to exercise intensity in obese adult women. The overall experimental design of this study is shown in <Figure 1>.

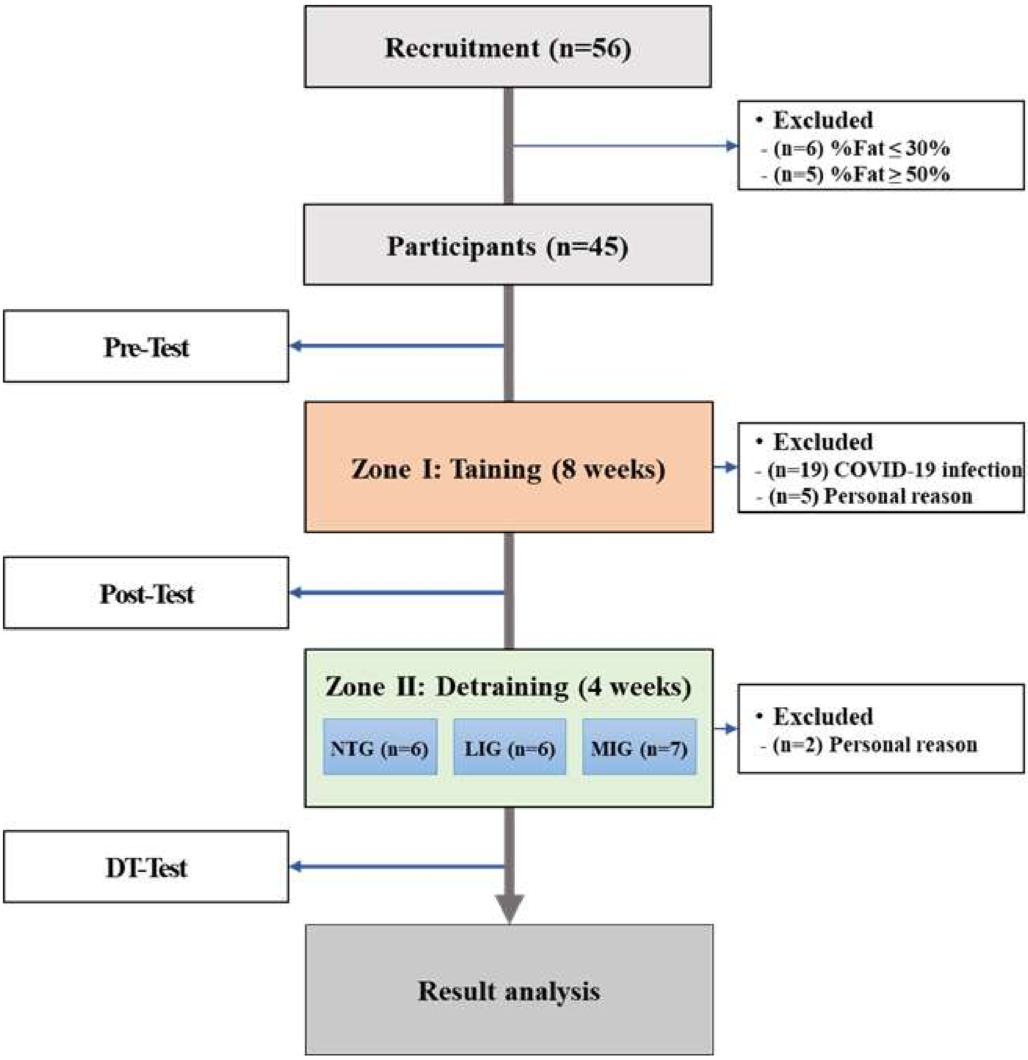

Figure 1. The experimental study design for study Ⅰ

NTG: non-training group, LIG: Low-intensity exercise group, MIG: Moderate-intensity exercise group

3) Exercise program

The exercise program of this study was divided into Zone I and Zone II. Zone I applied the principle of progressive load, 3 times a week for 8 weeks, Rating of perceived exertion (RPE; Borg Scale) 8～18, exercise-rest ratio 1:1～3, exercise time 10～30 seconds. Zone II was performed three times a week during the detraining period (4 weeks) by applying different exercise intensities for each group. LIG was applied with RPE 8～10, exercise-rest ratio 1:3, exercise time 20～30 seconds, and MIG was applied with RPE 12～14, exercise-rest ratio 1:2, exercise time 20～30 seconds (Reljic et al., 2021). The exercise program of this study is shown in <Table 3>.

Table 3. Exercise program of Zone Ⅰ and Zone Ⅱ

Session	Exercise	Intensity		Time	Frequency
Warm-up	Dynamic stretching			5 min	
	Running			5 min	
Main-exercise	Squats Butt kicks High knee Scissors jump Jumping jacks Jump squats	**Zone Ⅰ**	RPE: 8～12 (2 Weeks)	exercise: 10～30(sec) rest: 20～90(sec) bouts: 3～6 reset: 120(sec)	3 days a week
			RPE: 12～18 (6 Weeks)	exercise: 20～30(sec) rest: 20～90(sec) bouts: 3～6 reset: 120(sec)	
		Zone Ⅱ	Low RPE: 8～10 (4 Weeks)	exercise: 0～30(sec) rest: 60～90(sec) bouts: 3～6 reset: 120(sec)	
			Moderate RPE: 12～14 (4 Weeks)	exercise: 10～30(sec) rest: 20～60(sec) bouts: 3～6 reset: 120(sec)	
Cool-down	static stretching			5 min	

4) Body composition

To measure physique and body composition, participants visited the laboratory at 9 am in an 8-hour fasting state and were measured. After changing into light clothes, height and weight were measured using an automatic height and weight scale (DS-103M, Dong San Jenix, Seoul, Korea) without shoes on. For body composition, skeletal muscle mass (SMM), fat free mass (FFM), body fat mass (BFM), body mass index (BMI), and body fat percentage (%BF) were measured before participation in exercise (0 weeks), after high-intensity training (8 weeks), and after detraining (12 weeks) using a body composition analyzer (Inbody 770, Seoul, Korea).

5) Cardiovascular risk factors

Cardiovascular risk factors were measured before participating in exercise (week 0), after high-intensity training (week 8), and after detraining (week 12) after visiting the laboratory at 9:00 am while fasting for at least 8 hours.

(1) Fasting glucose

For fasting blood glucose measurement, blood was collected from the capillaries of the index finger using a disposable lancet (Accu-Chek® Softclix, Roche, Mannheim, Germany and analyzed using a blood glucose meter and test strips (Accu-Chek® Guide, Roche, Mannheim, Germany).

(2) Blood lipid

The normal standard for fasting blood sugar is less than 99mg/dL, 100 to 125mg/dL is impaired fasting glucose, and 126mg/dL or more is diagnosed as diabetes.

6) Physical fitness

Basic physical strength was measured using the measurement items and tools in <Table 4> before, and after 8 weeks of high-intensity training, and after 4 weeks of detraining.

Table 4. Physical fitness

Physical fitness	Physical fitness Items	Measuring Instruments	Apparatus
Muscular strength	Grip strength (㎏)	Digital dynamometer	T.K.K.-5101, TAKEI, Japan
	Back strength (㎏)	Digital back-dynamometer	T.K.K.-5402, TAKEI, Japan
Muscular endurance	Sit-up (N/60sec)	Sit-up board	T.K.K.-5505, TAKEI, Japan
Flexibility	Sit and reach (㎝)	Long-seat anteflexion mater	T.K.K.-5412, TAKEI, Japan
	Trunk lift (㎝)	Digital backward-flex meter	T.K.K.-5404, TAKEI, Japan
Cardiorespiratory endurance	Harvard step test	Step box (45㎝)	Step box, Iwanna, China
		Electronic metronome	SMT-1000, SAMICK, Korea

N, Number of times

(1) Muscular strength

Muscular strength (grip strength, back strength) was measured before participation in exercise (0 weeks), after high-intensity training (8 weeks), and after detraining (12 weeks).

① A digital grip dynamometer (T.K.K.-5101, TAKEI, Japan) was used for grip strength. The width of the grip dynamometer was adjusted so that the second joint of the finger of the dominant hand formed a right angle with both feet shoulder-width apart. After holding the grip dynamometer, the distance between the body and the arm was straightened at about 15°, and the maximum force was applied to pull the handle for 2 to 3 seconds to measure it. The measurement was performed twice, and the maximum value was recorded in units of 0.1 kg.

② Back strength was measured using a back strength meter (T.K.K. 5402, TAKEI, Japan). Participants were asked to stand on the back dynamometer footrest with both feet apart about 15cm, then bend the upper body about 30 degrees and hold the handle of the back dynamometer. Participants were asked to pull the handle with maximum force for 3 seconds while raising their upper body. The measurement was carried out twice and the maximum value was recorded in units of 0.1 kg.

(2) Muscular endurance

Muscular endurance was measured before participating in sit-ups (0 weeks), after high-intensity training (8 weeks), and after detraining (12 weeks). Muscular endurance was measured using a sit-up measuring instrument (T.K.K.-5505, TAKEI, Japan). Participants were asked to lie down with their hands behind their heads and their knees bent at about 90 degrees on the measuring instrument. At the start signal, bend the upper body forward so that both elbows touch both knees, and then repeat the motion of lying down again. Record the maximum number of repetitions performed in 60 seconds.

(3) Flexibility

Flexibility (trunk flexion, trunk back extension) was measured before participation in exercise (0 weeks), after high-intensity training (8 weeks), and after detraining (12 weeks). For the measurement of flexibility, a trunk flexion measuring instrument (T.K.K. 5111, Takei, Japan) was used. Participants were asked to sit on the measuring instrument with the distance between their feet not exceeding 5 cm. Place the tips of both hands on the electronic measuring instrument, bend the waist, and push the electronic measuring instrument as far as possible to maintain the posture for 3 seconds. After measuring a total of two times, the maximum distance was recorded in units of 0.1 ㎝.

A trunk back flexion measuring instrument (T.K.K. 5404, Takei, Japan) was used. The participant was asked to lie down and hold both hands behind the waist. The assistant fixed the subject's knees and thighs by pressing them from behind. The participant performed the exercise twice by completely lifting the upper body including the chin and head and maintaining the posture for 3 seconds. The maximum height of the chin was recorded in units of 0.1㎝.

(4) Cardiorespiratory endurance

To evaluate the cardiorespiratory capacity of obese adult women, the physical efficiency index (PEI) was measured before participating in exercise (0 weeks), after high-intensity training (8 weeks), and after detraining (12 weeks) through the Harvard Step test.

For cardiorespiratory endurance measurement, the PEI was calculated through the Harvard step test. The Harvard step test performed an elevation exercise using a metronome for 3 minutes in a 45㎝ high box (Aerobic step box, Iwanna, China) at a speed of 120 bpm while wearing simple clothes. After measuring the heart rate between 1 minute and 1 minute and 30 seconds, 2 minutes and 2 minutes and 30 seconds, and 3 minutes and 3 minutes and 30 seconds from the end of exercise, PEI was calculated and recorded.

The PEI calculation formula is as follows.

<PEI = (Total of heart rate of 180 seconds/2×3 times) × 100>

7) Knee and Trunk muscle function

Knee and trunk muscle functions (isokinetic muscle function, Lower extremity muscle function) were measured before participation in exercise (0 weeks), after high-intensity training (8 weeks), and after detraining (12 weeks).

(1) Knee isokinetic muscle function

Knee isokinetic muscle function was measured using HUMAC NORM (Humac Norm 776, CSMI, Boston, USA). To minimize the involvement of other muscle groups during measurement, the chest and femur regions were fixed with belts. Preliminary operations were performed three or more times prior to the main measurement, and the measurement method was fully understood. At the time of measurement, the load speed was measured at 60°/sec and 240°/sec to measure the strength and endurance of the extensor and flexor muscles of the knee.

(2) Trunk isokinetic muscle function

Isokinetic muscle function of the trunk was measured using HUMAC NORM (Humac Norm 776, CSMI, Boston, USA). To minimize the intervention of other muscles during measurement, the back, chest, waist, and thighs were fixed with fixing devices. Before the main measurement, three or more preliminary operations were performed, and the measurement method was fully understood. At the time of measurement, the load speed was set at 30°/sec to measure the muscle strength of the waist.

(3) Lower extremity muscle function

① For vertical jump measurement, the maximum height (㎝) was recorded by repeating the measurement twice by jumping up as high as possible without rolling the feet after standing on the digital vertical jump (DW 771A, SKARO, Korea). Fatigue was minimized by taking a break for about 2 minutes after each measurement.

② For the sit to stand test, subjects sat on a chair (height: 43.2 ㎝), crossed their arms at chest level, raised their hands on their shoulders, and then sat down and stood up for 30 seconds until their knees were fully extended. Starting from a sitting position, standing up was counted once, and the maximum number of repetitions was recorded (Martinez et al., 2019).

4. Statistical analysis

For the measured data in this study, the normality test was confirmed through the skewness and kurtosis of all variables using the SPSS for windows (Version 22.0) statistical program. The mean and standard deviation of all variables were calculated through descriptive statistics. The detailed statistical processing method to identify the interaction between groups and periods and differences between groups is as follows.

① A paired sample t-test was conducted to confirm the effect of exercise before participation in exercise (0 weeks) and after high-intensity training (8 weeks)

② Two-way repeated measures ANOVA was performed to verify the effect of interaction between groups and periods of all variables.

③ Variables showing significant differences between groups at 8 weeks were controlled for prior variables using analysis of covariance (ANCOVA).

④ To compare the differences between groups, one-way ANOVA was performed, followed by the Scheffe post-hoc test.

⑤ The significance level was set at $P<0.05$.

5. Results

The results of this study, which confirmed the effects of exercise intensity (low or moderate intensity) performed during the detraining period on body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function in obese adult women, are as follows.

1) Effects of 8 weeks of high-intensity training

(1) Body composition

The results of changes in body composition before and after 8 weeks of high-intensity training are presented in <Table 5>.

Table 5. Comparison of changes in body composition after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
Weight (kg)	64.81±6.28	62.66±5.91	63.74±6.10	11.071	.001
SMM (kg)	22.04±2.14	21.31±2.01	21.67±2.07	11.128	.001
FFM (kg)	40.82±4.37	39.84±4.10	40.33±4.24	3.434	.003
BFM (kg)	23.99±4.29	22.82±3.89	23.41±4.09	3.861	.001
BMI (kg/m²)	24.81±2.61	23.98±2.39	24.40±2.50	10.276	.001
%BF	36.91±4.48	36.34±4.26	36.62±4.37	1.324	.202
WC (cm)	81.80±6.01	78.98±5.52	80.39±5.76	7.500	.001
HC (cm)	99.53±2.74	97.78±2.87	98.66±2.81	5.100	.001
WHtR	.51±.04	.49±.04	.50±.04	5.895	.001
WHR	.82±.04	.81±.05	.81±.04	3.059	.007

SMM, skeleton muscle mass; FFM, fat free mass; BFM, body fat mass; BMI, body mass index; %BF, percent body fat; WC, waist circumference; HC, hip circumference; WHtR, waist to height ratio; WHR, waist to hip ratio

As a result of a paired-sample t-test to confirm changes in body composition before and after high-intensity training, the mean change in body weight (t=11.071, p=.001) was 2.15±.85 (㎏), SMM (t=11.128, p=.001) was .73±.29 (㎏), FFM (t=3.434, p=.003) was .98±1.25 (㎏), BFM (t=3.861, p=.001) was 1.16±1.32 (㎏), and BMI (t=10.276, p=.001) was significantly decreased to .83±.35 (㎏).

In contrast, the mean change in WC (t=7.500, p=.001) was 2.82±1.64 (㎝), HC (t=5.100, p=.001) was 1.75±1.50 (㎝), WHtR (t=5.895, p=.001) was .02±.01 (%), and WHR (t=3.059, p=.007) was .01±.02 (%) significantly decreased. On the other hand, there was no significant difference in %BF (t=1.324, p=.202).

It was confirmed that changes in body composition due to high-intensity training for 8 weeks were significantly reduced in weight, SMM, FFM, BFM, BMI, WC, HC, WHtR, and WHR, except for %BF.

(2) Cardiovascular risk factors

The results of changes in cardiovascular disease risk factors before and after 8 weeks of high-intensity training are presented in <Table 6>.

Table 6. Comparison of changes in cardiovascular disease risk factors after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
SBP (㎜Hg)	117.32±9.51	113.95±8.61	115.63±9.06	1.357	.192
DBP (㎜Hg)	72.95±8.20	71.68±6.38	72.32±7.29	.776	.448
TC (㎎/㎗)	207.84±35.57	197.21±30.64	202.53±33.10	1.385	.183
TG (㎎/㎗)	137.95±33.49	143.63±31.88	140.79±32.69	-.821	.422
HDL (㎎/㎗)	63.84±17.94	61.11±15.91	62.47±16.93	1.403	.178
LDL (㎎/㎗)	113.16±31.26	104.63±30.30	108.89±30.78	1.080	.294
FBG (㎎/㎗)	94.37±6.99	93.68±8.72	94.03±7.86	.553	.587

SBP, *systolic blood pressure;* DBP, *diastolic blood pressure;* TC, *total cholesterol;* TG, *triglycerides;* HDL, *high density cholesterol;* LDL, *low density cholesterol;* FBG, *fasting blood glucose*

As a result of a paired-sample t-test to confirm changes in cardiovascular disease risk factors before and after high-intensity training, SBP (t=1.357, p=.192), DBP (t=.776, p=.448), TC (t=1.385, p=.183), TG (t=-.821, p=.422), HDL (t=1.403, p=.178), LDL (t=1.080, p=.294) and FBG (t=.553, p=.587) did not show a significant difference.

There were no significant changes in cardiovascular disease risk factors due to 8 weeks of high-intensity training.

(3) Physical fitness

The results of changes in physical fitness before and after 8 weeks of high-intensity training are presented in <Table 7>.

Table 7. Comparison of changes in physical fitness following after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
GS (㎏)	26.07±5.72	28.17±6.57	27.12±6.15	-3.814	.001
BS (㎏)	55.80±15.12	69.65±16.02	62.73±15.57	-7.586	.001
TF (㎝)	14.44±8.53	18.26±9.29	16.35±8.91	-2.591	.018
TE (㎝)	42.17±8.91	45.83±8.61	44.00±8.76	-1.912	.072
SU (rep)	15.26±9.29	21.26±8.81	18.26±9.05	-5.948	.001
PEI (%)	47.50±3.87	49.97±4.14	48.74±4.00	-3.479	.003
VJ (㎝)	23.21±3.41	26.47±3.69	24.84±3.55	-5.815	.001
STS (rep)	33.00±5.73	34.89±7.87	33.95±6.80	-1.511	.148

GS, *grip strength;* BS, *back strength;* TF, *trunk flexion;* TE, *trunk back extension;* SU, *sit-up;* PEI, *physical efficiency index;* VJ, *vertical jump;* STS, *sit-to-stand*

As a result of a paired-sample t-test to confirm the change in physical fitness before and after high-intensity training, the mean change in GS (t=-3.814, p=.001) was 2.09±2.39 (㎏), BS (t=-7.586, p=.001) was 13.85±7.96 (㎏), TF (t=-2.591, p=.018) was 3.82±6.43 (㎝), SU (t=-4.216, p=.001) was 6.00±4.40 (rep), and PEI (t=-3.884, p=.001) was 2.47±3.09 (%), VJ (t=-5.655, p=.001) was 3.26±2.45 (㎝), which increased significantly, in contrast was significant the mean change in TE (t=-1.912, p=.072) and STS (t=-21.511, p=.148) no difference appeared.

As for the changes in physical fitness due to high-intensity training for 8 weeks, GS, BS, TF, SU, PEI, and VJ in place were significantly improved than the pre-value.

(4) Isokinetic muscle function

① Knee isokinetic strength

The results of changes in knee isokinetic strength before and after 8 weeks of high-intensity training are presented in <Table 8>.

Table 8. Comparison of changes in knee peak torque 60°/sec after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
Right extensors (Nm)	89.47±28.74	102.58±22.09	96.03±25.42	-2.993	.008
Right extensors (%BW)	140.63±42.41	161.68±28.17	151.16±35.29	-3.013	.007
Left extensors (Nm)	93.11±21.02	106.63±25.87	99.87±23.45	-2.870	.010
Left extensors (%BW)	147.68±31.09	167.32±31.44	157.50±31.27	-2.862	.010
BBRE (%)	13.37±9.78	7.79±6.86	10.58±8.32	1.989	.062
Right flexors (Nm)	41.68±16.61	52.37±14.92	47.03±15.76	-4.192	.001
Right flexors (%BW)	63.53±24.81	82.26±20.57	72.89±22.69	-4.371	.001
Left flexors (Nm)	43.00±16.01	51.37±14.84	47.18±15.43	-2.457	.024
Left flexors (%BW)	67.84±23.09	80.47±19.33	74.16±21.21	-2.554	.020
BBRF (%)	16.00±15.11	8.42±8.58	12.21±11.84	1.785	.091
Right H:Q Ratio	45.95±8.13	51.05±10.14	48.50±9.13	-2.391	.028
Left H:Q Ratio	45.79±13.08	48.53±9.18	47.16±11.13	-1.009	.326

Nm, *newton meter;* % BW, *percent body weight*; BBRE, *bilateral balance ratio for extensor*, BBRF, *bilateral balance ratio for flexor;* H:Q, *hamstring :quadriceps*

As a result of a paired-sample t-test to confirm the change in maximal muscle strength of the knee before and after high-intensity training, the mean change in the absolute value of maximal muscle strength in the right extensor (t=-2.993, p=.008) was 13.11±19.08 (Nm), relative value (t=-3.013, p=.007) was 21.05±30.46 (%BW), the mean change of left extensor maximal muscle strength absolute value (t=-2.870, p=.010) was 13.53±20.55 (Nm), relative value (t=-2.862, p=.010) was 19.63±29.90 (%BW), showing significant differences. but there was no significant difference in BBRE (t=1.989, p=.062).

Also, the mean change in the absolute value of the maximum right flexor muscle strength (t=-4.192, p=.001) was 10.68±11.11 (Nm), relative value (t=-4.371, p=.001) was 18.74±18.69 (%BW), and the mean change of the absolute value of the maximum left flexor muscle strength (t=-2.457, p=.024) was 8.37±14.84 (Nm), relative value (t=-2.554, p=.020) was 12.63±21.56 (%BW), showing a significant difference, but there was no significant difference with BBRF (t=1.785, p=.091). On the other hand, a significant difference was found in the mean change of 5.11±9.31 (%) in the right H:Q ratio (t=-2.391, p=.028), but there was no significant difference in the left H:Q ratio (t=-1.009, p=.326).

The change in isokinetic muscle strength of the knee due to high-intensity training for 8 weeks was the absolute value and relative value of the maximum muscle strength of the right extensor muscle, and the absolute value and relative value of the maximum muscle strength of the left extensor muscle, and the absolute value and relative value of the maximum muscle strength of the right flexor muscle, and the absolute value of the maximum muscle strength of the left flexor muscle, and right H:Q ratio were significantly improved than the prior value.

② Knee isokinetic endurance

The results of changes in knee isokinetic muscular endurance before and after 8 weeks of high-intensity training are presented in <Table 9>.

Table 9. Comparison of changes in knee average power 240°/sec after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
Right extensors (Nm)	87.68±26.79	106.74±25.13	97.21±25.96	-3.056	.007
Right extensors (%BW)	200.32±202.74	168.05±31.83	184.18±117.29	.684	.503
Left extensors (Nm)	91.16±21.07	109.68±21.53	100.42±21.30	-3.906	.001
Left extensors (%BW)	144.47±31.94	171.84±22.42	158.16±27.18	-3.950	.001
Right flexors (Nm)	47.79±18.03	60.58±18.86	54.18±18.44	-2.926	.009
Right flexors (%BW)	75.95±26.68	95.42±26.19	85.68±26.43	-2.934	.009
Left flexors (Nm)	52.63±15.99	65.63±13.23	59.13±14.61	-3.825	.001
Left flexors (%BW)	83.84±24.63	102.11±22.80	92.97±23.71	-3.650	.002

Nm, newton meter; %BW, percent body weight

As a result of a paired-sample t-test to confirm the change in average power of the knee before and after high-intensity training, the mean change in the absolute value of the average power of the right extensor muscle (t=-3.056, p=.007) was 19.05±27.18 (Nm), the mean change of left extensor average power absolute value (t=-3.906, p=.001) was 18.53±20.68 (Nm), relative value (t=-3.950, p=.001) was 27.37±30.20 (%BW), the mean change of right flexor average power absolute value (t=-2.926, p=.009) was 12.79±19.05 (Nm), relative value (t=-2.934, p=.009) was 19.47±28.94 (%BW), and the mean change of left flexor muscle average power absolute value (t=-3.825, p=.001) was 13.00±14.81 (Nm), relative value (t=-3.650, p=.002) showed a significant difference at 18.26±21.81 (%BW), but the right extensor average power relative value (t=.684, p=.503) did not show a significant difference.

As a result of a paired-sample t-test to confirm the change in average power of the knee before and after high-intensity training, the mean change in the absolute value of the average power of the right extensor muscle (*t*=-3.056, *p*=.007) was 19.05±27.18 (Nm), the mean change of left extensor average power absolute value (*t*=-3.906, *p*=.001) was 18.53±20.68 (Nm), relative value (*t*=-3.950, *p*=.001) was 27.37±30.20 (%BW), the mean change of right flexor average power absolute value (*t*=-2.926, *p*=.009) was 12.79±19.05 (Nm), relative value (*t*=-2.934, *p*=.009) was 19.47±28.94 (%BW), and the mean change of left flexor muscle average power absolute value (*t*=-3.825, *p*=.001) was 13.00±14.81 (Nm), relative value (*t*=-3.650, *p*=.002) showed a significant difference at 18.26±21.81 (%BW), but the right extensor average power relative value (*t*=.684, *p*=.503) did not show a significant difference.

The change in isokinetic muscular endurance of the knee due to 8 weeks of high-intensity training was the absolute value and relative value of the average power of the right extensor muscle, the absolute value and relative value of the average power of the left extensor muscle, the absolute value and relative value of the average power of the right flexor muscle, the average power absolute value and relative value of the left flexor muscle, the average power relative values of left flexor muscles were significantly improved compared to the prior values.

③ Knee fatigue index

The results of changes in knee fatigue index before and after 8 weeks of high-intensity training are presented in <Table 10>.

Table 10. Comparison of changes in knee fatigue index 240˚/sec after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
Right extensors (%)	-12.42±20.74	-1.95±13.36	-7.18±17.05	-2.327	.032
Left extensors (%)	-5.32±13.32	7.58±9.81	1.13±11.56	-4.751	.001
Right flexors (%)	-1.42±31.76	5.16±25.98	1.87±28.87	-.713	.485
Left flexors (%)	-1.42±18.77	8.21±14.61	3.39±16.69	-1.780	.092

As a result of a paired-sample t-test to confirm the change in knee fatigue index before and after high-intensity training, the mean change in the right extensor muscle (t=-2.327, p=.032) was 10.47±19.62 (%), and the left extensor muscle (t=-4.751, p=.001) showed a significant difference at 12.89±11.83 (%). On the other hand, there was no significant difference in right flexor muscles (t=-.713, p=.485) and left flexor muscles (t=-1.780, p=.092).

Due to the high-intensity training for 8 weeks, the change in the fatigue index of the knee was improved in the right and left extensor muscles compared to the previous value.

④ Trunk isokinetic strength

The results of changes in trunk isokinetic strength before and after 8 weeks of high-intensity training are presented in <Table 11>.

Table 11. Comparison of changes in trunk peak torque 30°/sec after exercise (n=19)

Variable	Pre	Post	Total	*t*	*p*
Extensors (Nm)	101.79±29.68	97.53±26.06	99.66±27.87	1.092	.289
Extensors (%BW)	160.42±41.87	154.42±38.52	157.42±40.20	.971	.345
Flexors (Nm)	165.42±52.36	177.79±41.64	171.61±47.00	-1.894	.074
Flexors (%BW)	257.32±69.65	279.63±54.02	268.47±61.83	-2.154	.045
H:Q Ratio	63.79±18.86	55.74±15.19	59.76±17.03	2.442	.025

Nm, newton meter; %BW, percent body weight; H:Q, hamstring :quadriceps

As a result of conducting a paired-sample t-test to confirm the change in maximum muscle strength of the trunk before and after high-intensity training, the mean change in extensor relative value (*t*=-2.154, *p*=.045) was －22.32±45.16 (%BW), a significant difference was found in the mean change of 8.05±14.37 (%) of trunk H:Q ratio (*t*=2.442, *p*=.025). On the other hand, the mean change in flexor absolute value (*t*=-2.197, *p*=.040) was 14.48±30.19 (Nm), relative value (*t*=-2.404, *p*=.026) was 23.10±44.02 (%BW) was significantly improved. In addition, there were no significant differences in the absolute values of extensor muscle (*t*=1.092, *p*=.289), relative values (*t*=.971, *p*=.345), and flexor absolute values (*t*=-1.894, *p*=.074).

Due to 8 weeks of high-intensity training, changes in isokinetic muscle strength of the trunk improved relative values of flexors and trunk H:Q ratio compared to the previous values.

2) Effects of exercise during 4 weeks of detraining

(1) Body composition

① Body weight

<Table 12>, <Table 13>, and <Figure 2> present the results of changes in body weight in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 12. Descriptive statistics and one-way ANOVA results of body weight (kg)

Group	Pre	Post	Total
NTG[a]	62.35±7.95	65.27±7.85	63.81±7.90
LIG[b]	62.07±4.19	62.40±4.46	62.23±4.33
MIG[c]	63.44±6.02	58.59±5.63	61.01±5.83
Total	62.66±5.91	61.90±6.43	62.28±6.17
F	.090	1.959	
p	.915	.173	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 13. The result of two-way repeated measures ANOVA for body weight

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	50.484	2	25.242	.333	.722	.040	.094
Error	1212.968	16	75.810				
Within Subject							
Period	2.712	1	2.712	7.045	.017	.306	.703
Group×Period	102.893	2	51.446	133.640	.001	.944	1.000
Error	6.159	16	.385				

<Table 12> shows the mean and standard deviation of the change in body weight by measurement period according to exercise intensity during 4 weeks of detraining. <Table 13> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in body weight change.

In <Table 13>, there was no significant difference between the groups (F=.333, p=.722), but a significant difference was found in the measurement period within the group (F=7.045, p=.017). In addition, there was a significant difference in the interaction effect between groups and the measurement period (F=133.640, p=.001).

As a result of one-way ANOVA to confirm the difference between groups according to the measurement period, before applying detraining (F=.090 p=.915) and after 4 weeks of detraining (F=1.959, p=.173) did not show a significant difference.

As a result of conducting a paired-sample t-test to confirm the change within the group, the mean change in NTG weight was 2.92±.68 (㎏), showing a significant difference (t=-10.561, p=.001). The mean change in body weight of LIG was .33±.60 (㎏), showing a no significant difference (t=-1.356, p=.233). On the other hand, the mean change in body weight of MIG was 4.86±1.17 (㎏), showing a significantly difference (t=10.981, p=.001).

Summarizing the changes in body weight, there was no significant difference in the prior values of body weight between the groups in <Figure 2>. After detraining, NTG increased from the pre-value, but MIG decreased from the pre-value.

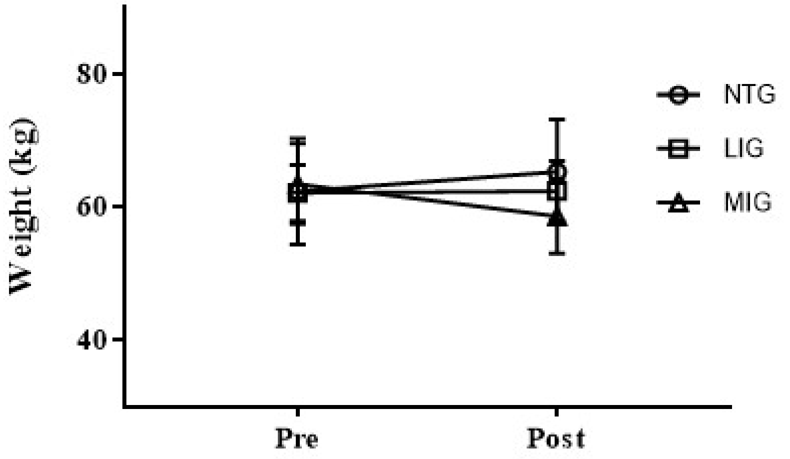

Figure 2. Change of body weight after exercise

NTG, non-texercise group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

② Skeletal muscle mass (SMM)

<Table 14>, <Table 15>, and <Figure 3> present the results of changes in skeletal muscle mass in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 14. Descriptive statistics and one-way ANOVA results of skeletal muscle mass (kg)

Variables	Pre	Post	Total
NTG[a]	21.20±2.70	22.19±2.67	21.70±2.69
LIG[b]	21.10±1.43	21.22±1.52	21.16±1.47
MIG[c]	21.57±2.05	19.92±1.92	20.75±1.98
Total	21.31±2.01	21.05±2.19	21.18±2.10
F	.090	1.955	
p	.914	.174	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 15. The result of two-way repeated measures ANOVA for skeletal muscle mass

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	5.819	2	2.909	.332	.723	.040	.094
Error	140.346	16	8.772				
Within Subject							
Period	.317	1	.317	7.214	.016	.311	.713
Group×Period	11.896	2	5.948	135.326	.001	.944	1.000
Error	.703	16	.044				

<Table 14> shows the mean and standard deviation of the change in SMM by measurement period according to exercise intensity during 4 weeks of detraining. <Table 15> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in changes in SMM.

In <Table 15>, there was no significant difference between the groups (*F*=.332, *p*=.723), and there was also a significant difference in the measurement period within the group (*F*=7.045, *p*=.017). In addition, there was a significant difference in the interaction effect between groups and the measurement period (*F*=133.640, *p*=.001).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, before applying detraining (*F*=.090, *p*=.914) and after 4 weeks of detraining (*F*=1.955, *p*=.174) did not show a significant difference.

As a result of a paired-sample t-test to confirm the change within the group, the mean change in SMM in NTG was .99±.23 (kg), showing a significant difference (*t*=-10.610, *p*=.001). The mean change in SMM in LIG was .11±.20 (kg), showing a no significant difference (*t*=-1.363, *p*=.231). On the other hand, the mean change in SMM in MIG was 1.65±.40 (kg), showing a significantly difference (*t*=11.062, *p*=.001).

Summarizing the changes in SMM, <Figure 3> showed no significant difference in the prior value of SMM between groups.

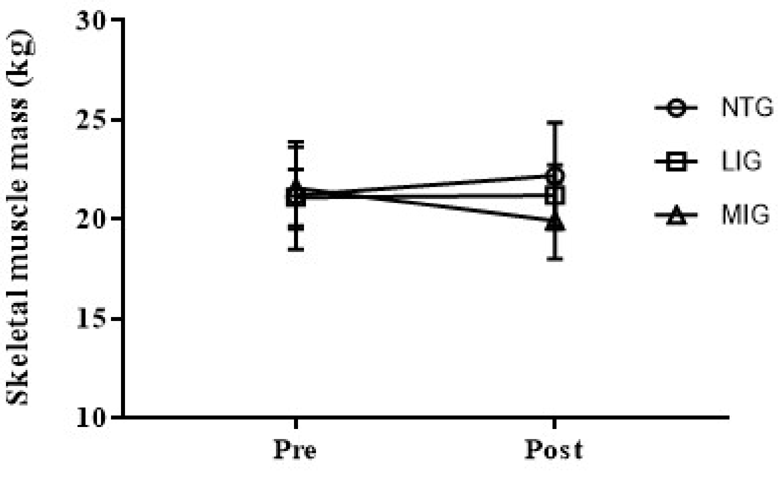

Figure 3. Change of skeletal muscle mass after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

③ Fat free mass (FFM)

<Table 16>, <Table 17>, and <Figure 4> present the results of changes in FFM in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 16. Descriptive statistics and one-way ANOVA results of fat free mass (kg)

Group	Pre	Post	Total
NTG[a]	38.99±4.83	40.99±5.01	39.99±4.92
LIG[b]	40.08±3.56	40.50±3.97	40.29±3.76
MIG[c]	40.36±4.41	38.76±4.47	39.56±4.44
Total	39.84±4.10	40.01±4.36	39.93±4.23
F	.176	.448	
p	.840	.647	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 17. The result of two-way repeated measures ANOVA for fat free mass

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	3.539	2	1.770	.047	.955	.006	.056
Error	607.136	16	37.946				
Within Subject							
Period	.708	1	.708	.827	.377	.049	.137
Group×Period	21.130	2	10.565	12.341	.001	.607	.986
Error	13.697	16	.856				

<Table 16> shows the mean and standard deviation of the change in FFM by measurement period according to exercise intensity during 4 weeks of detraining. <Table 17> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in FFM changes.

In <Table 17>, there was no significant difference between the groups (F=.047, p=.955), and no significant difference was found in the measurement period within the group (F=.827, p=.377). On the other hand, there was a significant difference in the interaction effect between groups and the measurement period (F=12.341, p=.001).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in FFM in NTG was 2.00±1.23 (㎏), showing a significant difference (t=-3.966, p=.011). The mean change in FFM in LIG was .42±1.25 (㎏), showing a no significant difference (t=-.825, p=.447). On the other hand, the mean change in FFM in MIG was 1.60±1.41 (㎏), showing a difference (t=2.993, p=.024).

Summarizing the changes in FFM, there was no significant difference in the prior values of FFM between groups in <Figure 4>. After detraining, NTG increased from the pre-value, but MIG decreased from the pre-value.

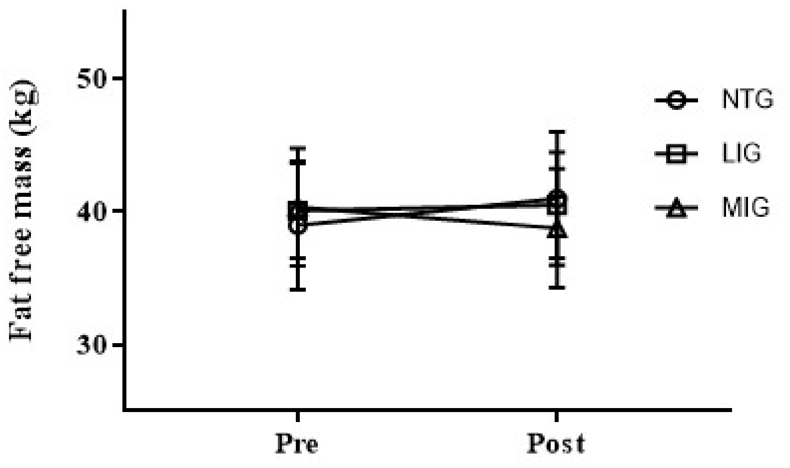

Figure 4. Change of fat free mass after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

④ Body fat mass (BFM)

<Table 18>, <Table 19>, and <Figure 4> present the results of changes in BFM in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 18. Descriptive statistics and one-way ANOVA results of body fat mass (kg)

Variables	Pre	Post	Total
NTG[a]	23.36±4.97	24.28±4.50	23.82±4.73
LIG[b]	21.99±1.82	21.90±2.48	21.94±2.15
MIG[c]	23.09±4.59	19.83±3.75	21.46±4.17
Total	22.82±3.89	21.89±3.94	22.36±3.92
F	.192	2.372	
p	.827	.125	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 19. The result of two-way repeated measures ANOVA for fat free mass

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	39.002	2	19.501	.660	.531	.076	.141
Error	472.989	16	29.562				
Within Subject							
Period	6.192	1	6.192	10.620	.005	.399	.864
Group×Period	31.393	2	15.697	26.923	.001	.771	1.000
Error	9.328	16	.583				

<Table 18> shows the mean and standard deviation of the change in BFM by measurement period according to exercise intensity during 4 weeks of detraining. <Table 19> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in BFM changes.

In <Table 19>, there was no significant difference between the groups (F=.660, p=.531), but a significant difference was found in the measurement period within the group (F=10.620, p=.005). In addition, there was a significant difference in the interaction effect between groups and the measurement period (F=26.923, p=.001).

As a result of one-way ANOVA to confirm the difference according to the measurement period between the groups, there was no significant difference between before applying detraining (F=.192, p=.827) and 4 weeks after detraining (F=2.372, p=.125).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in BFM in NTG was .92±1.23 (㎏), showing a no significant difference (t=-1.838, p=.126). The mean change in BFM in LIG was .09±1.05 (㎏), showing a no significant difference (t=.206, p=.845). On the other hand, the mean change in BFM in MIG was 3.26±.97 (㎏), showing a significantly difference (t=8.908, p=.001).

Summarizing the changes in BFM, there was no significant difference in the prior values of BFM between groups in <Figure 5>. After detraining, MIG decreased from the pre-value.

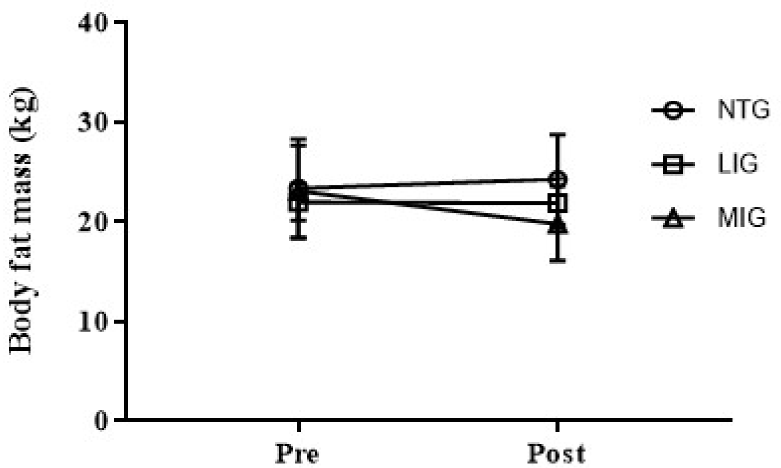

Figure 5. Change of body fat mass after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑤ Body mass index (BMI)

<Table 20>, <Table 21>, and <Figure 6> present the results of changes in BMI in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 20. Descriptive statistics and one-way ANOVA results of body fat mass (%)

Variables	Pre	Post	Total
NTG[a]	23.44±1.60	24.55±1.57	23.99±1.59
LIG[b]	23.54±1.86	23.67±1.95	23.60±1.90
MIG[c]	24.83±3.28	22.91±2.87	23.87±3.08
Total	23.98±2.39	23.67±2.23	23.82±2.31
F	.674	.853	
p	.523	.445	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 21. The result of two-way repeated measures ANOVA for fat free mass

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	.952	2	.476	.044	.957	.005	.056
Error	174.069	16	10.879				
Within Subject							
Period	.484	1	.484	5.486	.032	.255	.595
Group×Period	15.645	2	7.823	88.631	.001	.917	1.000
Error	1.412	16	.088				

<Table 20> shows the mean and standard deviation of the change in BMI by measurement period according to exercise intensity during 4 weeks of detraining. <Table 21> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in BMI changes.

In <Table 21>, there was no significant difference between the groups (F=.044, p=.957), and no significant difference was found in the measurement period within the group (F=5.486, p=.032). On the other hand, there was a significant difference in the interaction effect between groups and the measurement period (F=88.631, p=.001).

As a result of one-way ANOVA to confirm the difference between groups according to the measurement period, before applying detraining (F=.674, p=.523) and after 4 weeks of detraining (F=.853, p=.445) did not show a significant difference.

As a result of conducting a paired-sample t-test to confirm the change within the group, the average change in BMI of NTG was 1.11±.30 (%), showing a significant difference (t=-8.958, p=.001). The average change in BMI of LIG was .13±.23 (%), showing a no significant difference (t=-1.371, p=.229). On the other hand, the average change in BMI of MIG was 1.92±.59 (%), showing a significant difference (t=8.552, p=.001).

Summarizing the changes in BMI, <Figure 6> showed no significant difference in the pre-value of BMI between the groups. After detraining, the BMI increased from the pre-value in the NTG and decreased from the pre-value in the MIG.

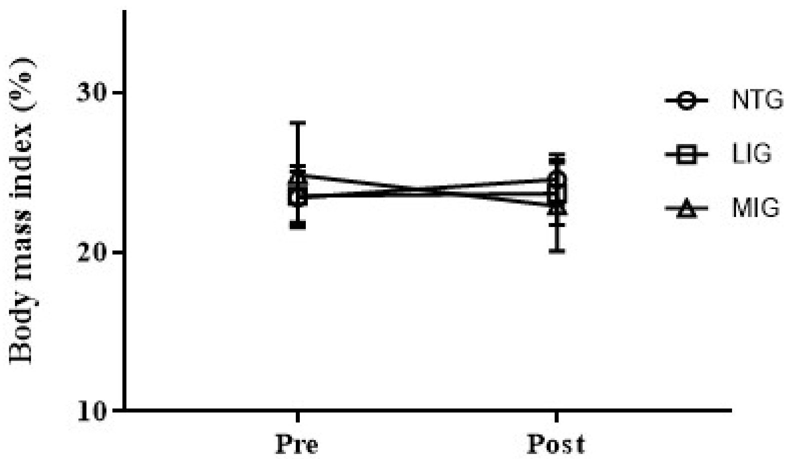

Figure 6. Change of body mass index after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑥ Percent body fat (%BF)

<Table 22>, <Table 23>, and <Figure 7> present the results of changes in %BF in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 22. Descriptive statistics and one-way ANOVA results of percent body fat (%)

Variables	Pre	Post	Total
NTG[a]	37.28±4.84	37.09±4.44	37.19±4.64
LIG[b]	35.47±2.54	35.13±3.54	35.30±3.04
MIG[c]	36.27±5.28	33.79±4.96	35.03±5.12
Total	36.34±4.26	35.25±4.38	35.79±4.32
F	.250	.914	
p	.782	.421	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 23. The result of two-way repeated measures ANOVA for percent body fat

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	.250	.914	26.898	.376	.692	.040	.101
Error	.782	.421	71.491				
Within Subject							
Period	6.881	1	6.881	9.564	.006	.347	.833
Group×Period	2.339	2	1.170	1.626	.224	.153	.298
Error	12.950	18	.719				

<Table 22> shows the mean and standard deviation of the change in %BF by measurement period according to exercise intensity during 4 weeks of detraining. <Table 23> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in %BF changes.

In <Table 23>, there was no significant difference between the groups (F=.376, p=.692), but a significant difference was found in the measurement period within the group (F=9.564, p=.006). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=1.626, p=.224).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, there was no significant difference before (F=.250, p=.782) and after 4 weeks (F=.914, p=.421) of detraining.

As a result of a paired-sample t-test to confirm the change within the group, the mean change in %BF of NTG was .19±1.82 (%), showing a no significant difference (t=.261, p=.805) , the mean change in %BF of LIG was .34±1.78 (%), showing a no significant difference (t=.469, p=.659). On the other hand, the mean change in %BF of MIG was 2.48±1.40 (%), showing a significant difference (t=4.699, p=.003).

Summarizing the changes in %BF, in <Figure 7>, there was no difference in the prior value of %BF between the groups, and only in the MIG after detraining, the %BF decreased from the prior value.

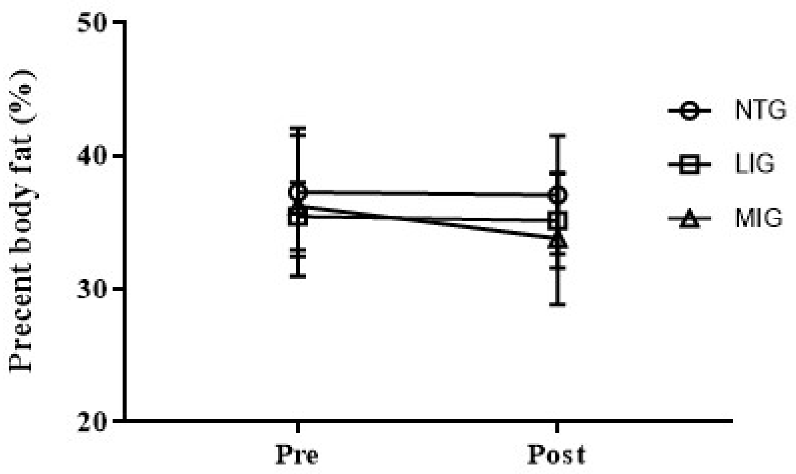

Figure 7. Change of percent body fat after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑦ Waist circumference (WC)

<Table 24>, <Table 25>, and <Figure 8> present the results of changes in WC in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 24. Descriptive statistics and one-way ANOVA results of waist circumference (㎝)

Variables	Pre	Post	Total
NTG[a]	80.67±5.33	83.72±4.68	82.19±5.00
LIG[b]	76.05±4.47	76.90±4.60	76.48±4.53
MIG[c]	80.04±6.19	75.60±4.10	77.82±5.14
Total	78.98±5.52	78.57±5.55	78.78±5.53
F	1.298	6.008	
p	.300	.011	
Scheffe	-	b,c<a	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 25. The result of two-way repeated measures ANOVA for waist circumference

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	216.293	2	108.147	2.277	.135	.222	.395
Error	760.060	16	47.504				
Within Subject							
Period	.309	1	.309	.180	.677	.011	.069
Group×Period	97.601	2	48.801	28.441	.001	.780	1.000
Error	27.454	16	1.716				

<Table 24> shows the mean and standard deviation of the change in WC by measurement period according to exercise intensity during 4 weeks of detraining. <Table 25> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in WC changes.

In <Table 25>, there was no significant difference between the groups (*F*=2.277, *p*=.135), and no significant difference was found in the measurement period within the group (*F*=.180, *p*=.677). On the other hand, there was a significant difference in the interaction effect between the groups and the measurement period (*F*=28.441, *p*=.001).

As a result of one-way ANOVA to confirm the difference according to the measurement period between groups, there was no significant difference before detraining (*F*=1.298, *p*=.300), but a significant difference was found after 4 weeks of detraining (*F*=6.008, *p*=.011). As a result of the post-hoc test, the WC increased in NTG than in LIG and MIG.

As a result of conducting a paired-sample t-test to confirm the change within the group, the mean change in WC of NTG was .19±1.82 (㎝), showing a no significant difference (*t*=.261, *p*=.805). The mean change in WC of LIG was .34±1.78 (㎝), showing a no significant difference (*t*=.469, *p*=.659). On the other hand, the mean change in WC of MIG was 2.48±1.40 (㎝), showing a significant difference (*t*=4.699, *p*=.003).

Summarizing the changes in WC, in <Figure 8>, there was no difference in the prior value of WC between the groups, and only in the MIG after detraining, the WC decreased from the prior value.

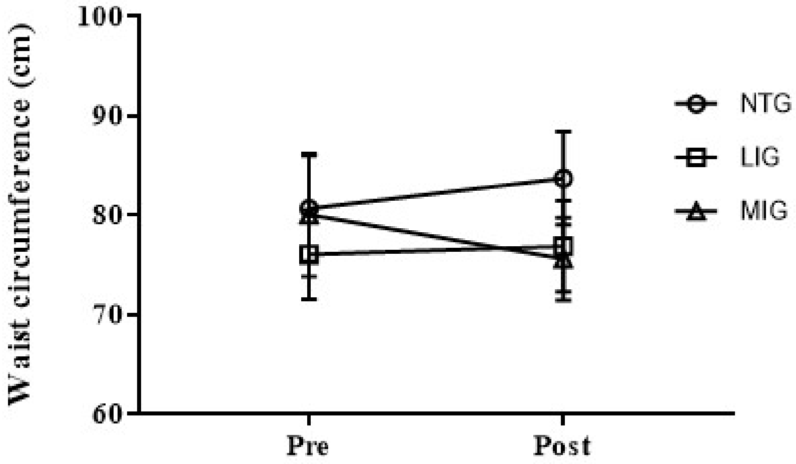

Figure 8. Change of waist circumference after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑧ Hip circumference (HC)

<Table 26>, <Table 27>, and <Figure 9> present the results of changes in HC in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 26. Descriptive statistics and one-way ANOVA results of hip circumference (㎝)

Variables	Pre	Post	Total
NTG[a]	98.57	3.49	100.80
LIG[b]	96.15	3.16	97.02
MIG[c]	98.50	1.56	94.97
Total	97.78	2.87	97.46
F	1.488	9.634	
p	.255	.002	
Scheffe	-	b,c<a	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 27. The result of two-way repeated measures ANOVA for hip circumference

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	216.293	2	108.147	2.277	.135	.222	.395
Error	760.060	16	47.504				
Within Subject							
Period	.309	1	.309	.180	.677	.011	.069
Group×Period	97.601	2	48.801	28.441	.001	.780	1.000
Error	27.454	16	1.716				

<Table 26> shows the mean and standard deviation of the change in HC by measurement period according to exercise intensity during 4 weeks of detraining. <Table 27> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in HC changes.

In <Table 27>, there was no significant difference between the groups (*F*=2.277, *p*=.135), and no significant difference was found in the measurement period within the group (*F*=.180, *p*=.677). On the other hand, there was a significant difference in the interaction effect between groups and the measurement period (*F*=28.441, *p*=.001).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, there was no significant difference before detraining (*F*=1.488, *p*=.255), but after 4 weeks of detraining (*F*=9.634, A significant difference was found at *p*=.002). As a result of the post-hoc test, HC increased in NTG than in LIG and MIG.

As a result of conducting a paired-sample t-test to confirm the change within the group, the mean change of HC in NTG was 2.23±1.48 (㎝), showing a significant difference (*t*=-3.686, *p*=.014). The mean change in HC of LIG was .87±1.13 (㎝), showing a no significant difference (*t*=-1.872, *p*=.120). On the other hand, the mean change in HC of MIG was 3.53±1.27 (㎝), showing a significant difference (*t*=7.345, *p*=.001).

Summarizing the changes in HC, <Figure 9> showed no significant difference in the prior value of HC between groups. After detraining, HC increased from the prior value in NTG, but decreased from the prior value in MIG.

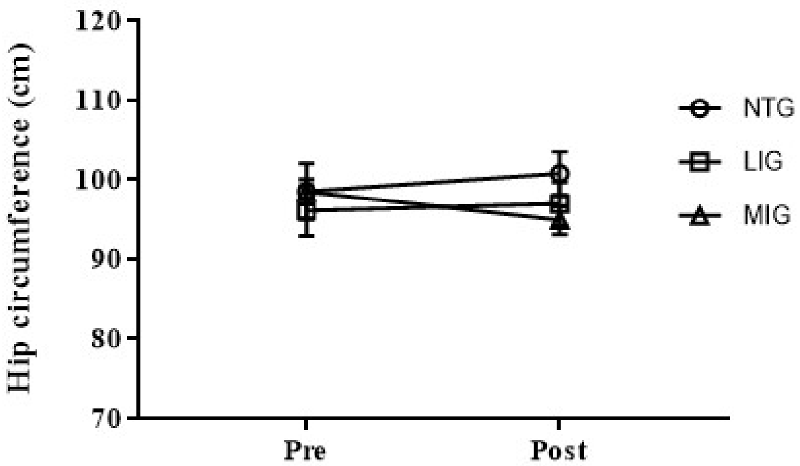

Figure 9. Change of hip circumference after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑨ Waist to hip ratio (WHR)

<Table 28>, <Table 29>, and <Figure 10> present the results of changes in WHR in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 28. Descriptive statistics and one-way ANOVA results of waist to hip ratio (%)

Variables	Pre	Post	Total
NTG[a]	.82±.04	.83±.04	.82±.04
LIG[b]	.79±.03	.79±.03	.79±.03
MIG[c]	.81±.06	.80±.03	.80±.05
Total	.81±.05	.81±.04	.81±.04
F	.555	1.993	
p	.585	.169	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 29. The result of two-way repeated measures ANOVA for waist to hip ratio

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	.006	2	.003	.971	.400	.108	.189
Error	.051	16	.003				
Within Subject							
Period	.001	1	.001	.052	.822	.003	.055
Group×Period	.001	2	.001	2.412	.122	.232	.415
Error	.005	16	.001				

<Table 28> shows the mean and standard deviation of the change in WHR by measurement period according to exercise intensity during 4 weeks of detraining. <Table 29> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in WHR changes.

In <Table 29>, there was no significant difference between the groups (F=971, p=.400), and no significant difference was found in the measurement period within the group (F=.052, p=.822). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=.122, p=.232).

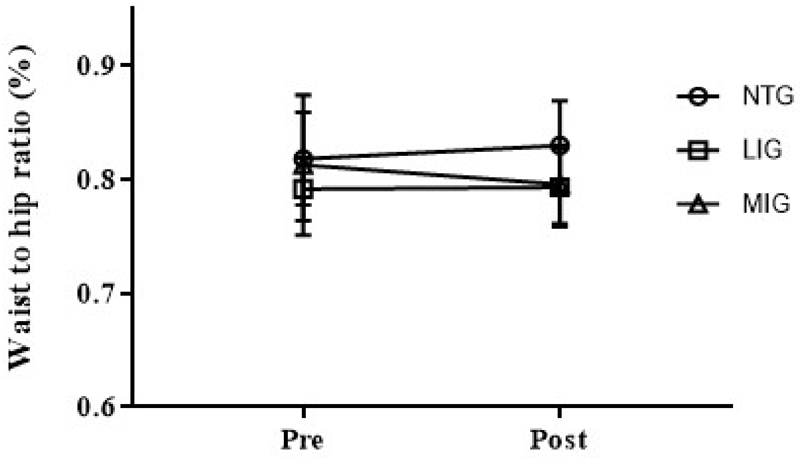

Figure 10. Change of waist to hip ratio after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑩ Waist to height ratio (WHtR)

<Table 30>, <Table 31>, and <Figure 11> present the results of changes in WHtR in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 30. Descriptive statistics and one-way ANOVA results of waist to height ratio (%)

Variables	Pre	Post	Total
NTG[a]	.50±.02	.52±.02	.51±.02
LIG[b]	.47±.03	.47±.03	.47±.03
MIG[c]	.50±.05	.47±.04	.48±.04
Total	.49±.04	.48±.04	.49±.04
F	1.171	4.587	
p	.335	.027	
Scheffe	-	c<a	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 31. The result of two-way repeated measures ANOVA for waist to height ratio

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	.007	2	.004	1.739	.207	.179	.311
Error	.034	16	.002				
Within Subject							
Period	.000	1	.001	.379	.547	.023	.089
Group×Period	.004	2	.002	32.459	.001	.802	1.000
Error	.001	16	.001				

<Table 30> shows the mean and standard deviation of the change in WHtR by measurement period according to exercise intensity during 4 weeks of detraining. <Table 31> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in WHtR changes.

In <Table 31>, there was no significant difference between the groups (*F*=1.739, *p*=.207), but there was no significant difference in the measurement period within the group (*F*=.379, *p*=.547). In addition, there was a significant difference in the interaction effect between groups and the measurement period (*F*=32.459, *p*=.001).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, there was no significant difference before detraining (*F*=1.171, *p*=.335), but after 4 weeks of detraining (*F*=4.587, *p*=4.587, p =.027) showed a significant difference. As a result of the post-hoc test, WHtR increased in NTG than in MIG.

As a result of conducting a paired-sample t-test to confirm the change within the group, the mean change in WHtR of NTG was .02±.01 (%), showing a significant difference (*t*=-5.398, *p*=.003). The mean change in WHtR of LIG was .01±.01 (%), showing a no significant difference (*t*=-1.581, *p*=.175). On the other hand, the mean change in WHtR of MIG was .03±.02 (%), showing a significant difference (*t*=4.861, *p*=.003).

Summarizing the changes in WHtR, <Figure 11> showed no significant difference in the prior value of WHtR between groups. After detraining, WHtR increased from the prior value in NTG, but decreased from the prior value in MIG.

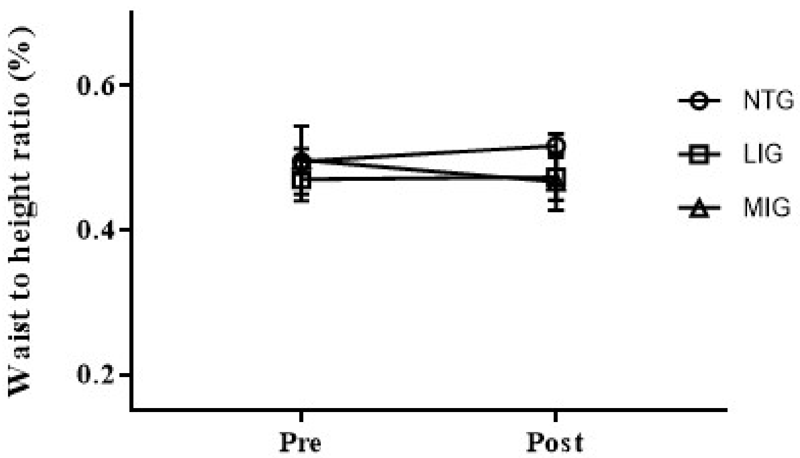

Figure 11. Change of waist to height ratio after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

(2) Cardiovascular risk factors

① Systolic blood pressure (SBP)

<Table 32>, <Table 33>, and <Figure 12> present the results of changes in SBP in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 32. Descriptive statistics and one-way ANOVA results of systolic blood pressure (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	110.83±6.01	111.50±8.04	111.17±7.03
LIG[b]	113.00±9.90	113.83±12.14	113.42±11.02
MIG[c]	117.43±9.25	114.71±11.76	116.07±10.51
Total	113.95±8.61	113.42±10.34	113.68±9.47
F	1.002	.148	
p	.389	.864	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 33. The result of two-way repeated measures ANOVA for systolic blood pressure

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	39.409	2	19.704	1.059	.370	.117	.203
Error	297.645	16	18.603				
Within Subject							
Period	1277.393	1	1277.393	221.037	.001	.933	1.000
Group×Period	4.558	2	2.279	.394	.681	.047	.103
Error	92.465	16	5.779				

<Table 32> shows the mean and standard deviation of the change in SBP by measurement period according to exercise intensity during 4 weeks of detraining. <Table

33> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in SBP changes.

In <Table 33>, there was no significant difference between the groups (F=1.059, p=.370), but a significant difference was found in the measurement period within the group (F=221.037, p=.001). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.394, p=.681).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in SBP of NTG was .67±5.96 (㎜Hg), showing a no significant difference (t=-.274, p=.795). The mean change in SBP of LIG was .83±13.61 (㎜Hg), showing a no significant difference (t=-.150, p=.887). In addition, the mean change in SBP of MIG was 2.71±11.03 (㎜Hg), showing a no significant difference (t=.651, p=.539).

Summarizing the changes in SBP, in <Figure 12>, there was no significant difference in the prior values of SBP between the groups, and after detraining, the SBP tended to decrease from the prior values in the MIG.

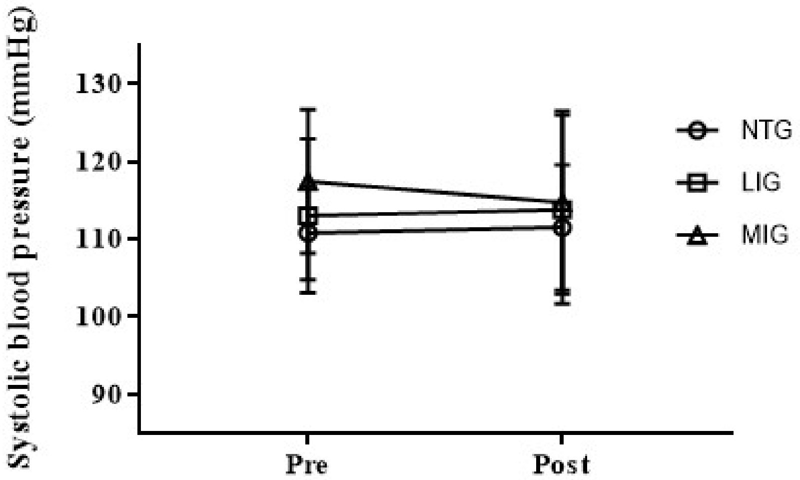

Figure 12. Change of systolic blood pressure after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

② Diastolic blood pressure (DBP)

<Table 34>, <Table 35>, and <Figure 13> present the results of changes in DBP in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 34. Descriptive statistics and one-way ANOVA results of diastolic blood pressure (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	69.83±7.14	71.50±7.23	70.67±7.19
LIG[b]	72.50±8.34	70.00±7.46	71.25±7.90
MIG[c]	72.57±4.08	69.29±6.78	70.93±5.43
Total	71.68±6.38	70.21±6.80	70.95±6.59
F	1.002	.148	
p	.389	.864	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 35. The result of two-way repeated measures ANOVA for diastolic blood pressure

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	156.699	2	78.349	.581	.571	.068	.130
Error	2157.512	16	134.844				
Within Subject							
Period	1.548	1	1.548	.027	.871	.002	.053
Group×Period	26.571	2	13.285	.232	.796	.028	.080
Error	916.798	16	57.300				

<Table 34> shows the mean and standard deviation of the change in DBP by measurement period according to exercise intensity during 4 weeks of detraining. <Table 35> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in DBP changes.

In <Table 35>, there was no significant difference between the groups (F=.581, p=.571), and no significant difference was found in the measurement period within the group (F=.027, p=.871). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.232, p=.796).

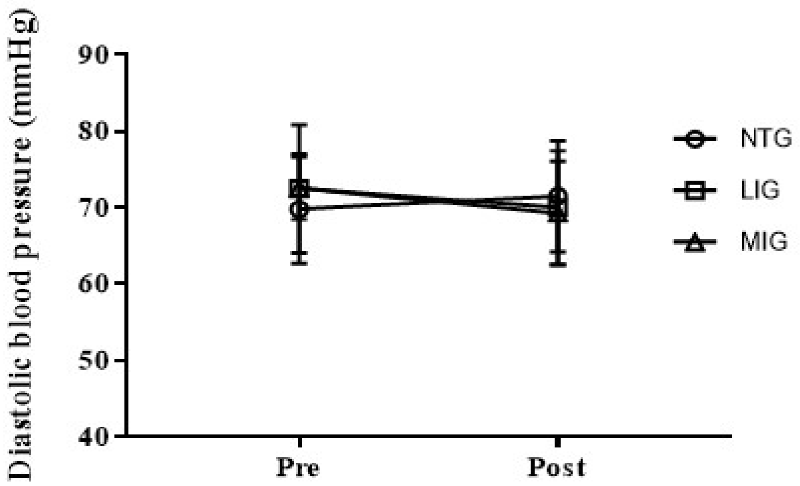

Figure 13. Change of diastolic blood pressure after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

③ Total cholesterol (TC)

<Table 36>, <Table 37>, and <Figure 14> present the results of changes in TC in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 36. Descriptive statistics and one-way ANOVA results of total cholesterol (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	198.33±40.18	180.50±35.92	189.42±38.05
LIG[b]	194.00±23.31	187.17±22.74	190.59±23.02
MIG[c]	199.00±31.66	184.29±30.29	191.65±30.97
Total	197.21±30.64	184.00±28.55	190.61±29.59
F	.044	.074	
p	.957	.929	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 37. The result of two-way repeated measures ANOVA for total cholesterol

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	2.049	2	1.025	.013	.987	.002	.052
Error	1229.845	16	76.865				
Within Subject							
Period	17.815	1	17.815	.993	.334	.058	.155
Group×Period	44.237	2	22.119	1.233	.318	.133	.230
Error	287.131	16	17.946				

<Table 36> shows the mean and standard deviation of the change in TC by measurement period according to exercise intensity during 4 weeks of detraining. <Table 37> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in TC changes.

In <Table 37>, there was no significant difference between the groups (F=.013, p=.987), and no significant difference was found in the measurement period within the group (F=.993, p=.334). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=1.233, p=.318).

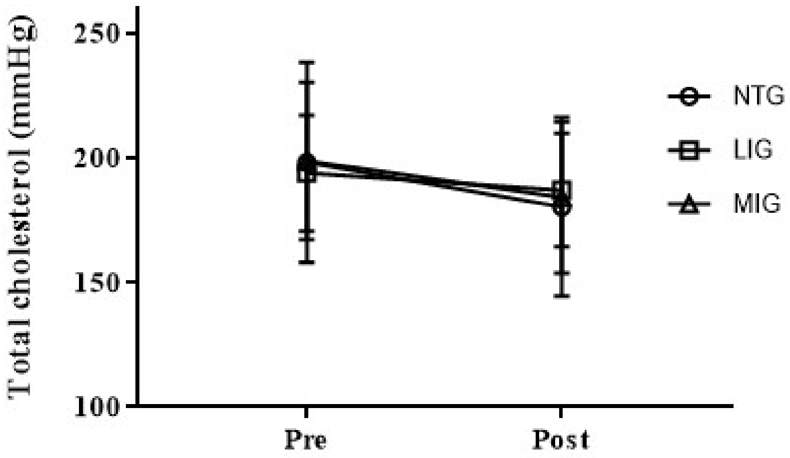

Figure 14. Change of total cholesterol after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

④ Triglycerides (TG)

<Table 38>, <Table 39>, and <Figure 15> present the results of changes in TG in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 38. Descriptive statistics and one-way ANOVA results of triglycerides (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	131.00±34.65	131.17±46.16	131.08±40.40
LIG[b]	138.83±29.02	133.67±23.70	136.25±26.36
MIG[c]	158.57±30.055	150.43±28.930	154.50±29.49
Total	142.80±31.24	138.42±32.93	140.61±32.09
F	1.630	.629	
p	.285	.546	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 39. The result of two-way repeated measures ANOVA for triglycerides

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	3997.886	2	1998.943	1.357	.286	.145	.250
Error	23574.167	16	1473.385				
Within Subject							
Period	181.371	1	181.371	.275	.607	.017	.078
Group×Period	113.054	2	56.527	.086	.918	.011	.061
Error	10542.262	16	658.891				

<Table 38> shows the mean and standard deviation of the change in TG by measurement period according to exercise intensity during 4 weeks of detraining. <Table 39> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in TG changes.

In <Table 39>, there was no significant difference between the groups (F=1.357, p=.286), and no significant difference was found in the measurement period within the group (F=.275, p=.607). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.086, p=.918).

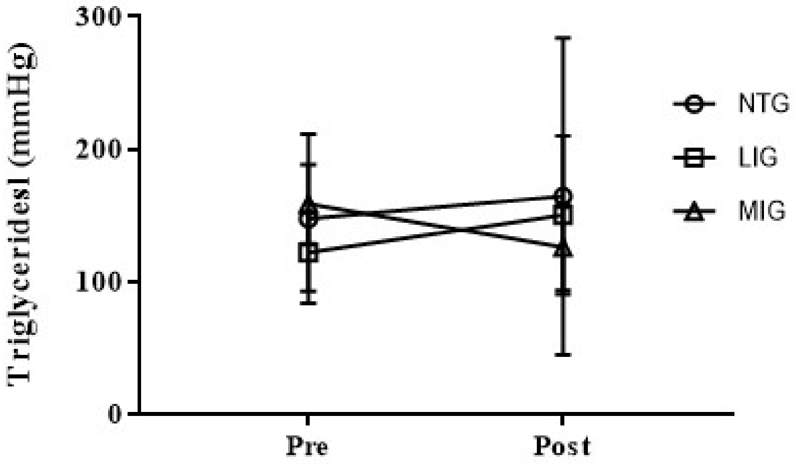

Figure 15. Change of triglycerides after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑤ High density cholesterol (HDL)

<Table 40>, <Table 41>, and <Figure 16> present the results of changes in HDL in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 40. Descriptive statistics and one-way ANOVA results of high density cholesterol (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	58.67±14.95	49.50±9.83	54.09±12.39
LIG[b]	61.00±9.21	60.00±9.42	60.50±9.32
MIG[c]	63.29±22.16	61.29±17.26	62.29±19.71
Total	61.11±15.91	57.16±13.41	59.14±14.66
F	.123	1.531	
p	.885	.246	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 41. The result of two-way repeated measures ANOVA for high density cholesterol

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	2488.487	2	1244.244	.197	.823	.024	.076
Error	101079.881	16	6317.493				
Within Subject							
Period	165.943	1	165.943	.109	.745	.007	.061
Group×Period	6862.152	2	3431.076	2.260	.137	.220	.392
Error	24293.690	16	1518.356				

<Table 40> shows the mean and standard deviation of the change in HDL by measurement period according to exercise intensity during 4 weeks of detraining. <Table 41> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in HDL changes.

In <Table 41>, there was no significant difference between the groups (F=.197, p=.823), and no significant difference was found in the measurement period within the group (F=.109, p=.745). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=2.260, p=.137).

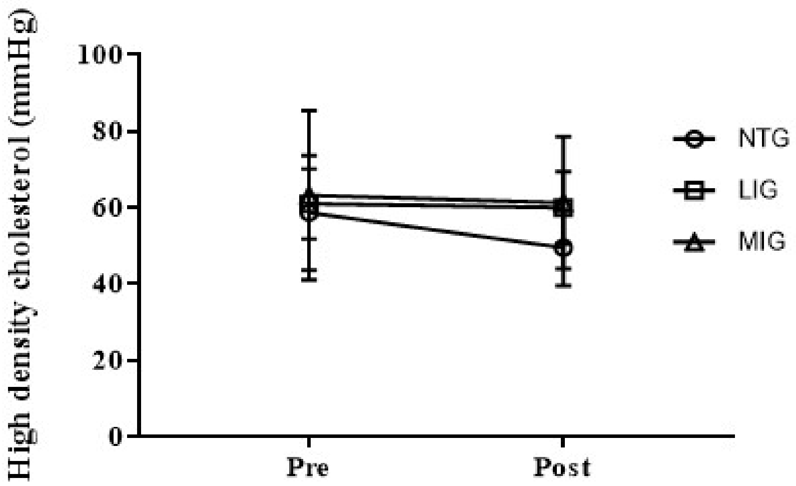

Figure 16. Change of high-intensity cholesterol after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑥ Low density cholesterol (LDL)

<Table 42>, <Table 43>, and <Figure 17> present the results of changes in LDL in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 42. Descriptive statistics and one-way ANOVA results of low density cholesterol (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	105.00±41.31	95.17±39.71	100.09±40.51
LIG[b]	108.00±24.03	94.17±20.44	101.09±22.24
MIG[c]	101.43±28.76	95.43±26.23	98.43±27.49
Total	104.63±30.30	94.95±28.00	99.79±29.15
F	.069	.003	
p	.934	.997	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 43. The result of two-way repeated measures ANOVA for low density cholesterol

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	467.568	2	233.784	.551	.587	.064	.125
Error	6786.274	16	424.142				
Within Subject							
Period	155.429	1	155.429	5.958	.027	.271	.630
Group×Period	121.057	2	60.529	2.320	.130	.225	.401
Error	417.417	16	26.089				

<Table 42> shows the mean and standard deviation of the change in LDL by measurement period according to exercise intensity during 4 weeks of detraining. <Table 43> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in LDL changes.

In <Table 43>, there was no significant difference between the groups (*F*=.551, *p*=.587), and no significant difference was found in the measurement period within the group (*F*=5.958, *p*=.027). In addition, there was no significant difference in the interaction effect between groups and the measurement period (*F*=2.320, *p*=.130).

As a result of one-way ANOVA to confirm the difference between groups according to the measurement period, before applying detraining (*F*=.069, *p*=.934) and after 4 weeks of detraining (*F*=.003, *p*=.997) did not show a significant difference.

As a result of a paired-sample t-test to confirm the change within the group, the mean change in LDL in NTG was 9.83±38.18 (㎜Hg), showing a no significant difference (*t*=.631, *p*=.556). The mean LDL change in LIG was 13.83±22.99 (㎜Hg), showing a no significant difference (*t*=1.474, *p*=.201). In addition, the mean change in LDL of MIG was 6.00±11.96 (㎜Hg), showing a no significant difference (*t*=1.327, *p*=.233).

Summarizing the changes in LDL, in <Figure 17>, there was no significant difference in the prior values of LDL between the groups, and after detraining, the LDL tended to decrease from the prior values in the MIG.

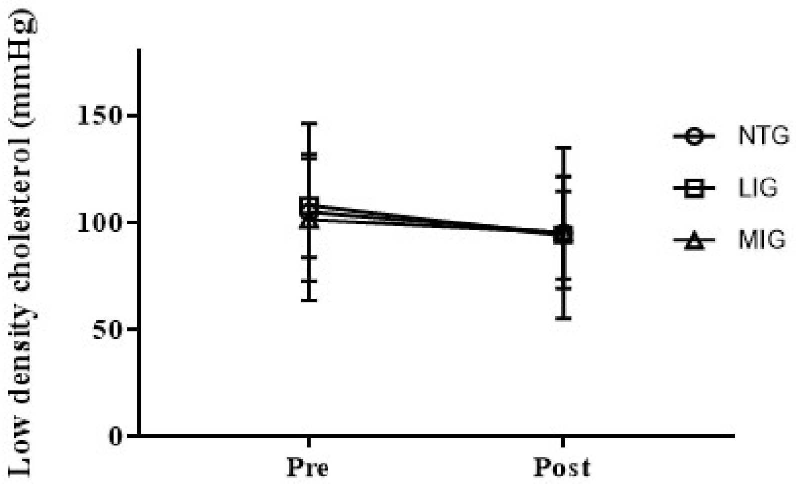

Figure 17. Change of low-intensity cholesterol after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑦ Fasting blood glucose (FBG)

<Table 44>, <Table 45>, and <Figure 18> present the results of changes in FBG in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 44. Descriptive statistics and one-way ANOVA results of fasting blood glucose (㎜Hg)

Variables	Pre	Post	Total
NTG[a]	90.83±8.75	95.33±2.34	93.08±5.54
LIG[b]	91.00±8.99	93.83±6.37	92.42±7.68
MIG[c]	98.43±7.46	94.57±5.22	96.50±6.34
Total	93.68±8.73	94.58±4.72	94.13±6.72
F	1.782	.137	
p	.200	.873	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 45. The result of two-way repeated measures ANOVA for fasting blood glucose

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	47.054	2	23.527	.015	.985	.002	.052
Error	25088.262	16	1568.016				
Within Subject							
Period	924.117	1	924.117	2.741	.117	.146	.344
Group×Period	99.219	2	49.610	.147	.864	.018	.069
Error	5394.833	16	337.177				

<Table 44> shows the mean and standard deviation of the change in FBG by measurement period according to exercise intensity during 4 weeks of detraining. <Table 45> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in FBG changes.

In <Table 45>, there was no significant difference between the groups (F=.015, p=.985), and no significant difference was found in the measurement period within the group (F=2.741, p=.117). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.147, p=.864).

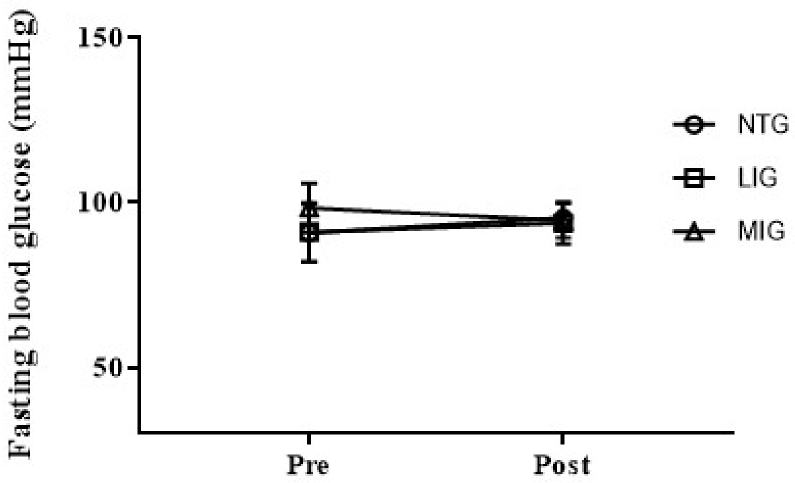

Figure 18. Change of fasting blood glucose after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

(3) Physical fitness

① Grip strength (GS)

<Table 46>, <Table 47>, and <Figure 19> present the results of changes in GS in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 46. Descriptive statistics and one-way ANOVA results of grip strength (kg)

Variables	Pre	Post	Total
NTG[a]	27.77±9.66	28.23±8.76	28.00±9.21
LIG[b]	27.50±3.11	29.17±3.04	28.33±3.07
MIG[c]	29.09±6.51	29.94±5.47	29.51±5.99
Total	28.17±6.57	29.16±5.87	28.66±6.22
F	.099	.124	
p	.906	.884	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 47. The result of two-way repeated measures ANOVA for grip strength

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	127.009	2	63.504	.913	.421	.102	.180
Error	1112.833	16	69.552				
Within Subject							
Period	12.688	1	12.688	.506	.487	.031	.103
Group×Period	129.299	2	64.650	2.576	.107	.244	.440
Error	401.595	16	25.100				

<Table 46> shows the mean and standard deviation of the change in GS by measurement period according to exercise intensity during 4 weeks of detraining. <Table

47> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in GS changes.

In <Table 47>, there was no significant difference between the groups (F=.913, p=.421), and no significant difference was found in the measurement period within the group (F=.506, p=.487). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=2.576, p=.107).

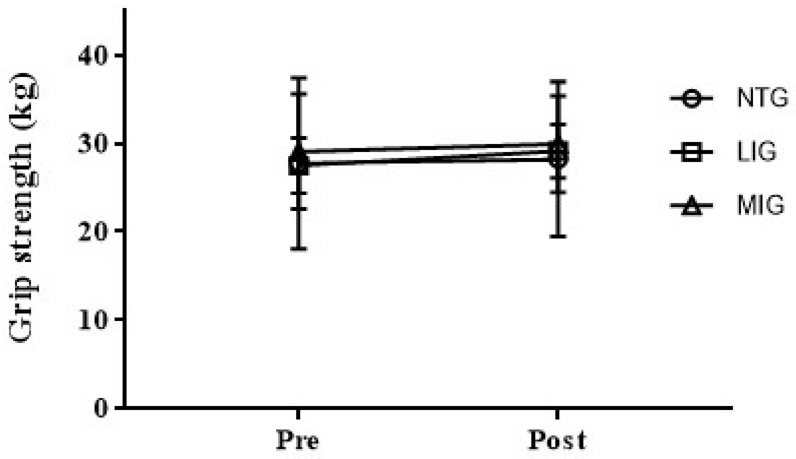

Figure 19. Change of grip strength after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

② Back strength (BS)

<Table 48>, <Table 49>, and <Figure 20> present the results of changes in BS in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 48. Descriptive statistics and one-way ANOVA results of back strength (kg)

Variables	Pre	Post	Total
NTG[a]	64.18±22.89	60.57±21.38	62.38±22.14
LIG[b]	69.58±10.23	70.20±12.13	69.89±11.18
MIG[c]	74.40±13.78	78.97±11.67	76.69±12.73
Total	69.65±16.02	70.39±16.56	70.02±16.29
F	.630	2.281	
p	.545	.134	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 49. The result of two-way repeated measures ANOVA for back strength

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	16.725	2	8.362	.100	.905	.012	.063
Error	1338.314	16	83.645				
Within Subject							
Period	9.390	1	9.390	3.738	.071	.189	.443
Group×Period	2.257	2	1.129	.449	.646	.053	.111
Error	40.192	16	2.512				

<Table 48> shows the mean and standard deviation of the change in BS by measurement period according to exercise intensity during 4 weeks of detraining. <Table 49> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in BS changes.

In <Table 49>, there was no significant difference between the groups (F=.100, p=.905), and no significant difference was found in the measurement period within the group (F=3.738, p=.071). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.449, p=.646).

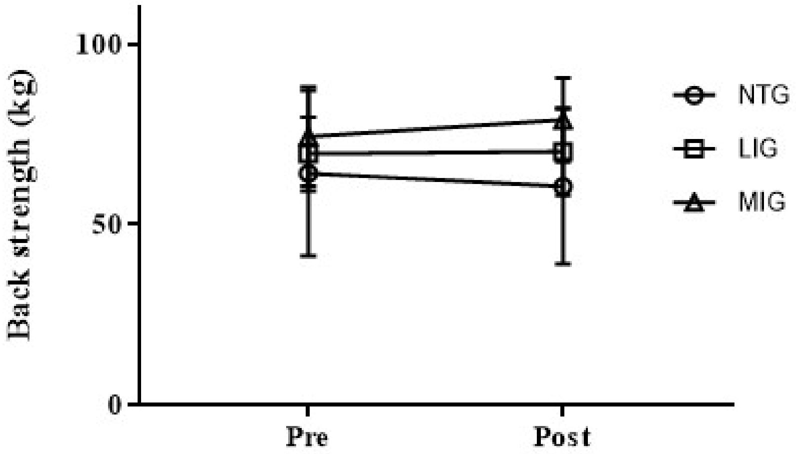

Figure 20. Change of back strength after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

③ Trunk flexion (TF)

<Table 50>, <Table 51>, and <Figure 21> .present the results of changes in TF in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 50. Descriptive statistics and one-way ANOVA results of trunk flexion (㎝)

Variables	Pre	Post	Total
NTG[a]	64.18±22.89	60.57±21.38	62.38±22.14
LIG[b]	69.58±10.23	70.20±12.13	69.89±11.18
MIG[c]	74.40±13.78	78.97±11.67	76.69±12.73
Total	69.65±16.02	70.39±16.56	70.02±16.29
F	.087	1.442	
p	.917	.266	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 51. The result of two-way repeated measures ANOVA for trunk flexion

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1323.594	2	661.797	1.323	.294	.142	.244
Error	8004.049	16	500.253				
Within Subject							
Period	2.593	1	2.593	.353	.561	.022	.087
Group×Period	108.367	2	54.183	7.376	.005	.480	.887
Error	117.535	16	7.346				

<Table 50> shows the mean and standard deviation of the change in TF by measurement period according to exercise intensity during 4 weeks of detraining. <Table 51> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in TF changes.

In <Table 51>, there was no significant difference between the groups (F=1.323, p=.294), and no significant difference was found in the measurement period within the group (F=.353, p=.561). On the other hand, there was a significant difference in the interaction effect between the groups and the measurement period (F=7.376, p=.005).

As a result of one-way ANOVA to confirm the difference according to the measurement period between groups, there was no significant difference before detraining (F=.087, p=.917), but a significant difference was found after 4 weeks of detraining (F=1.442, p=.266).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in TF of NTG was 3.82±9.41 (㎝), showing a no significant difference (t=.994, p=.366), and LIG The mean change in TF of -7.52±15.22 (㎝) showing a no significant difference (t=-1.210, p=.280). In addition, the mean change in TF of MIG was .36±1.33 (㎝), showing a no significant difference (t=.713, p=.503).

Summarizing the changes in TF, in <Figure 21>, there was no significant difference in the prior value of TF between groups, and no significant difference was found in the prior value of TF in all groups after detraining.

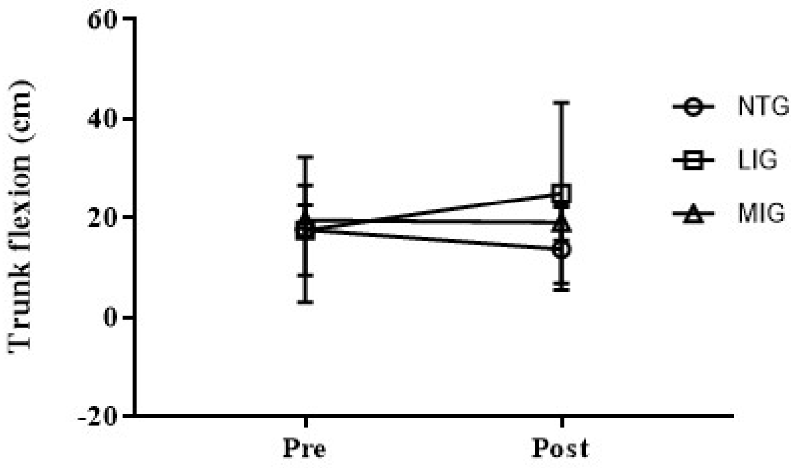

Figure 21. Change of trunk flexion after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

④ Trunk extension (TE)

<Table 52>, <Table 53>, and <Figure 22> present the results of changes in TE in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 52. Descriptive statistics and one-way ANOVA results of trunk extension (㎝)

Variables	Pre	Post	Total
NTG[a]	44.69±7.04	50.07±5.17	47.38±6.10
LIG[b]	47.26±12.23	46.79±8.62	47.02±10.42
MIG[c]	46.49±5.29	47.29±7.41	46.89±6.35
Total	46.14±8.33	48.05±7.00	47.10±4.66
F	.161	.852	
p	.422	.662	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 53. The result of two-way repeated measures ANOVA for trunk extension

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1.815	2	.907	.008	.992	.001	.051
Error	2028.764	18	112.709				
Within Subject							
Period	38.095	1	38.095	2.549	.128	.124	.327
Group×Period	66.443	2	33.222	2.223	.137	.198	.394
Error	268.961	18	14.942				

<Table 52> shows the mean and standard deviation of the change in TE by measurement period according to exercise intensity during 4 weeks of detraining. <Table 53> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in TE changes.

In <Table 53>, there was no significant difference between the groups (F=.537, p=.595), and no significant difference was found in the measurement period within the group (F=.233, p=.636). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=2.020, p=.165).

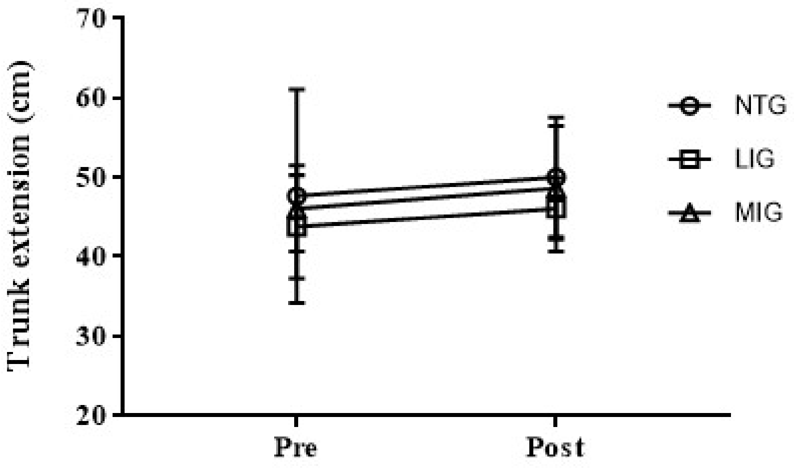

Figure 22. Change of trunk extension after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑤ Sit-up (SU)

<Table 54>, <Table 55>, and <Figure 23> present the results of changes in SU in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 54. Descriptive statistics and one-way ANOVA results of sit-up (rep)

Variables	Pre	Post	Total
NTG[a]	17.17±8.89	15.33±7.71	16.25±8.30
LIG[b]	23.67±4.32	22.67±3.33	23.17±3.82
MIG[c]	22.71±11.24	27.71±8.67	25.21±9.96
Total	21.26±8.81	22.21±8.50	21.74±8.65
F	.964	4.945	
p	.402	.021	
Scheffe	-	a<c	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 55. The result of two-way repeated measures ANOVA for sit-up

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	555.095	2	277.547	2.217	.141	.217	.385
Error	2003.274	16	125.205				
Within Subject							
Period	4.929	1	4.929	1.699	.211	.096	.232
Group×Period	92.057	2	46.029	15.866	.001	.665	.997
Error	46.417	16	2.901				

<Table 54> shows the mean and standard deviation of the change in TE by measurement period according to exercise intensity during 4 weeks of detraining. <Table 55> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in TE changes.

In <Table 55>, there was no significant difference between the groups (*F*=2.217, *p*=.141), and no significant difference was found in the measurement period within the group (*F*=1.699, *p*=.211). On the other hand, there was a significant difference in the interaction effect between groups and the measurement period (*F*=15.866, *p*=.001).

As a result of one-way ANOVA to confirm the difference according to the measurement period between groups, there was no significant difference before detraining (*F*=.964, *p*=.402), but a significant difference was found 4 weeks after detraining (*F*=4.945, *p*=.021). As a result of the post-hoc analysis, there was a significant increase in sit-ups in the MIG than in the NTG.

As a result of a paired-sample t-test to confirm the change within the group, the mean change in SU of NTG was 1.83±2.23 (rep), showing a no significant difference (*t*=2.015, *p*=.100), the mean change in SU of LIG was 1.00±1.79 (rep), showing a no significant difference (*t*=1.369, *p*=.229). On the other hand, the mean change in SU of MIG was -5.00±2.94 (rep), showing a significant difference (*t*=-4.494, *p*=.004).

Summarizing the changes in SU, there was no significant difference in the prior value of SU between the groups in <Figure 23>, but after detraining, the SU increased significantly from the prior value at MIT.

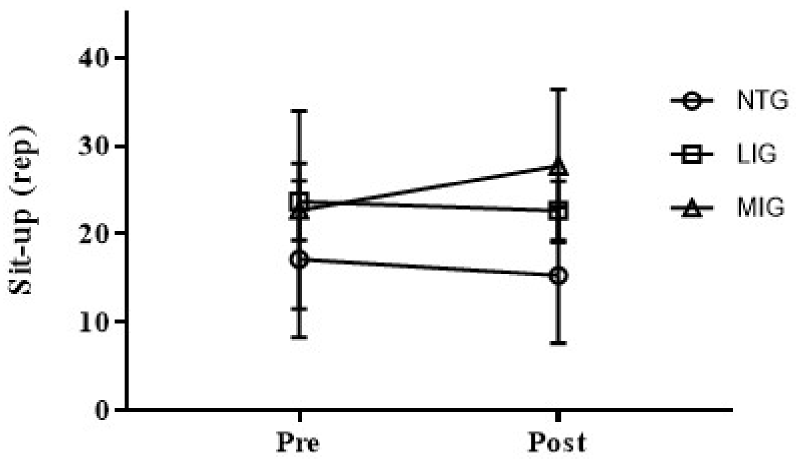

Figure 23. Change of sit-up after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑥ Physical efficiency index (PEI)

<Table 56>, <Table 57>, and <Figure 24> present the results of changes in PEI in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 56. Descriptive statistics and one-way ANOVA results of physical efficiency index (%)

Variables	Pre	Post	Total
NTG[a]	17.17±8.89	15.33±7.71	16.25±8.30
LIG[b]	23.67±4.32	22.67±3.33	23.17±3.82
MIG[c]	22.71±11.24	27.71±8.67	25.21±9.96
Total	21.26±8.81	22.21±8.50	21.74±8.65
F	2.941	6.742	
p	.082	.008	
Scheffe	-	a<b,c	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 57. The result of two-way repeated measures ANOVA for physical efficiency index

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	850.976	2	425.488	2.274	.132	.202	.401
Error	3368.310	18	187.128				
Within Subject							
Period	95.402	1	95.402	6.613	.019	.269	.682
Group×Period	148.261	2	74.131	5.138	.017	.363	.754
Error	259.681	18	14.427				

<Table 56> shows the mean and standard deviation of the change in PEI by measurement period according to exercise intensity during 4 weeks of detraining. <Table 57> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in PEI changes.

In <Table 57>, there was no significant difference between the groups (F=2.274, p=.132), but significant difference was found in the measurement period within the group (F=6.613 p=.019). In addition, there was a significant difference in the interaction effect between groups and the measurement period (F=5.138, p=.017).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, there was no significant difference before detraining (F=2.941, p=.082), and after 4 weeks of detraining (F=6.742, p=.008) showed a significant difference. As a result of post hoc test, LIG and MIG increased body efficiency index more than NTG.

As a result of conducting a paired-sample t-test to confirm the change within the group, the average change in PEI of NTG was 2.67±1.80 (%), showing a significant difference (t=3.632, p=.015), and LIG's The average change in PEI was .30±1.33 (%), showing a no significant difference (t=.557, p=.602). On the other hand, the average change in PEI of MIG was 5.15±2.04 (%), showing a significant difference (t=-6.688, p=.001).

Summarizing the changes in PEI, in <Figure 24>, there was no significant difference in the prior value of PEI between the groups. After detraining, PEI decreased significantly from the prior value in NTG, and in MIG, PEI was significantly higher than the prior value in has increased.

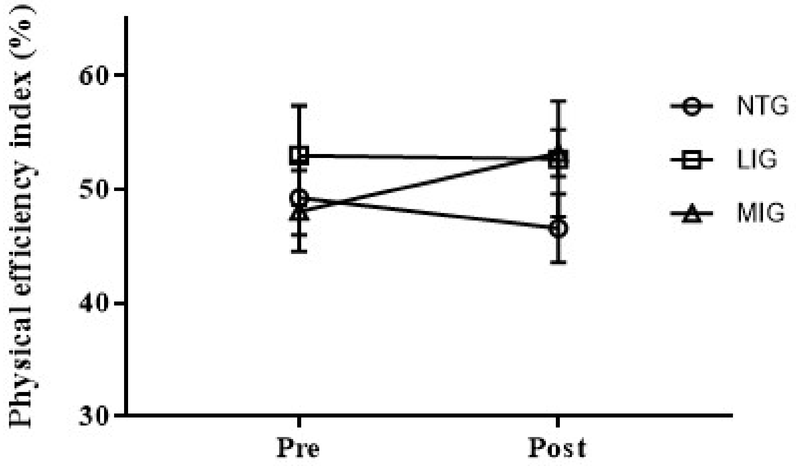

Figure 24. Change of physical efficiency index after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑦ Vertical jump (VJ)

<Table 58>, <Table 59>, and <Figure 25> present the results of changes in VJ in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 58. Descriptive statistics and one-way ANOVA results of vertical jump (㎝)

Variables	Pre	Post	Total
NTG[a]	24.33±4.50	22.17±3.87	23.25±4.19
LIG[b]	26.17±2.23	25.67±1.63	25.92±1.93
MIG[c]	28.57±3.16	29.71±2.36	29.14±2.76
Total	26.47±3.69	26.05±4.13	26.26±3.91
F	2.533	12.195	
p	.111	.001	
Scheffe	-	a<c	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 59. The result of two-way repeated measures ANOVA for vertical jump

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	146.111	2	73.056	2.917	.083	.267	.489
Error	400.756	16	25.047				
Within Subject							
Period	4.940	1	4.940	3.166	.094	.165	.387
Group×Period	105.736	2	52.868	33.879	.001	.809	1.000
Error	24.968	16	1.560				

<Table 58> shows the mean and standard deviation of the change in VJ by measurement period according to exercise intensity during 4 weeks of detraining. <Table 59> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in VJ changes.

In <Table 59>, there was no significant difference between the groups (*F*=2.917, *p*=.083), and no significant difference was found in the measurement period within the group (*F*=3.166, *p*=.094). On the other hand, there was a significant difference in the interaction effect between groups and the measurement period (*F*=33.879, *p*=.001).

As a result of one-way ANOVA to confirm the difference according to the measurement period between the groups, there was no significant difference before detraining (*F*=2.533, *p*=.111), and a significant difference was found after 4 weeks of detraining (*F*=12.195, *p*=.001). As a result of the post-hoc test, MIG increased VJ more than NTG.

As a result of a paired-sample t-test to confirm the change within the group, the mean change in VJ of NTG was 2.17±.75 (㎝), showing a significant difference (*t*=7.050, *p*=.001), and LIG The mean change in VJ of was .50±1.64 (㎝), showing a no significant difference (*t*=.745, *p*=.490). On the other hand, the mean change in VT of MIG was 1.14±1.21 (㎝), showing a significant difference (*t*=-2.489, *p*=.047).

Summarizing the changes in VJ, in <Figure 25>, there was no significant difference in the prior value of VJ between the groups. After detraining, VJ decreased significantly from the prior value in NTG, and in MIG, VJ was significantly higher than the prior value. has increased.

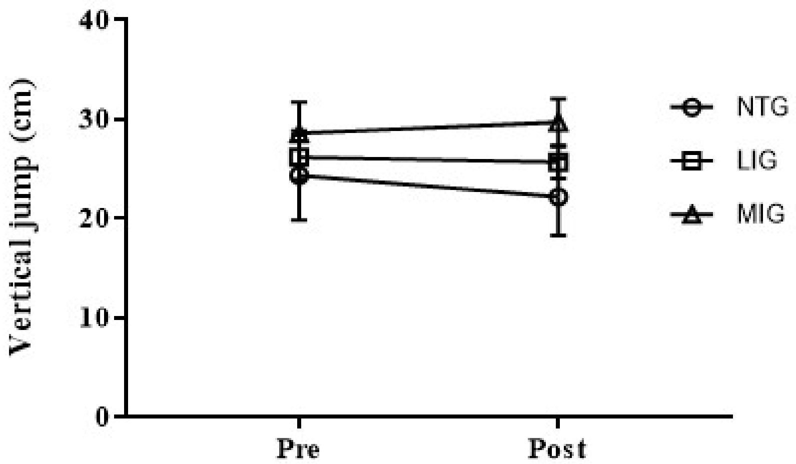

Figure 25. Change of vertical jump after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑧ Sit to stand (STS)

<Table 60>, <Table 61>, and <Figure 26> present the results of changes in STS in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 60. Descriptive statistics and one-way ANOVA results of sit to stand (rep)

Variables	Pre	Post	Total
NTG[a]	33.17±9.11	30.00±6.03	31.59±7.57
LIG[b]	35.67±8.87	36.83±6.21	36.25±7.54
MIG[c]	35.71±6.85	41.57±6.66	38.64±6.75
Total	34.89±7.87	36.42±7.73	35.66±7.80
F	.192	5.421	
p	.827	.016	
Scheffe	-	a<c	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 61. The result of two-way repeated measures ANOVA for sit to stand

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	226.487	2	113.244	6.145	.010	.434	.820
Error	294.881	16	18.430				
Within Subject							
Period	2.438	1	2.438	3.097	.098	.162	.380
Group×Period	17.721	2	8.860	11.255	.001	.585	.977
Error	12.595	16	.787				

<Table 60> shows the mean and standard deviation of the change in STS by measurement period according to exercise intensity during 4 weeks of detraining. <Table 61> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in STS changes.

In <Table 61>, there was a significant difference between the groups (*F*=6.145, *p*=.010), and no significant difference was found in the measurement period within the group (*F*=3.097, *p*=.098). On the other hand, there was a significant difference in the interaction effect between groups and the measurement period (*F*=11.255, *p*=.001).

As a result of one-way ANOVA to confirm the difference according to the measurement period between the groups, there was no significant difference before detraining (*F*=.192, *p*=.827), and a significant difference was found after 4 weeks of detraining (*F*=5.421, *p*=.016). As a result of the post-hoc test, MIG increased sitting and STS more than NTG.

As a result of a paired-sample t-test to confirm the change within the group, the average change in the STS of NTG was 3.17±4.88 (rep), showing a no significant difference (*t*=1.591, *p*=.172), and the LIG The average change in STS was 1.17±6.46 (rep), showing a no significant difference (*t*=-442, *p*=.677). On the other hand, the average change in STS of MIG was 5.86±3.58 (rep), showing a significant difference (*t*=-4.330, *p*=.005).

Summarizing the changes in the standing high jump, in <Figure 26>, there was no significant difference in the prior values of STS between groups, and after detraining, the MIG showed a significant increase in STS compared to the prior values.

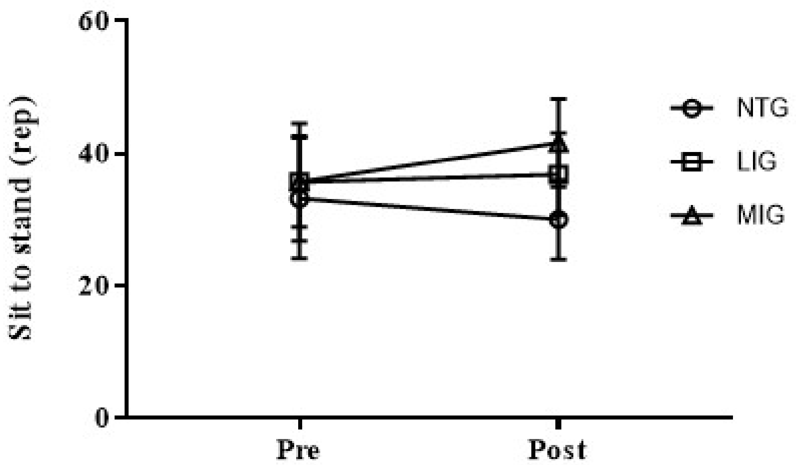

Figure 26. Change of sit to stand after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

(4) Knee isokinetic muscle strength (60°/sec)

① Absolute value of peak torque in right extensor

<Table 62>, <Table 63>, and <Figure 27> present the results of changes in absolute value of peak torque in right extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 62. Descriptive statistics and one-way ANOVA results of absolute value of peak torque in right extensor (Nm)

Variables	Pre	Post	Total
NTG[a]	96.00±14.09	108.33±22.77	102.17±18.43
LIG[b]	93.17±25.76	100.17±18.85	96.67±22.31
MIG[c]	116.29±19.87	125.57±22.33	120.93±21.10
Total	102.58±22.09	112.11±23.06	107.34±22.58
F	2.522	2.402	
p	.112	.122	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 63. The result of two-way repeated measures ANOVA for absolute value of peak torque in the right extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	4273.291	2	2136.645	2.608	.105	.246	.444
Error	13109.762	16	819.360				
Within Subject							
Period	860.002	1	860.002	14.790	.001	.480	.950
Group×Period	42.987	2	21.494	.370	.697	.044	.099
Error	930.381	16	58.149				

<Table 62> shows the mean and standard deviation of the change in absolute value of peak torque in right extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 63> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in absolute value of peak torque in right extensor changes.

In <Table 63>, there was no significant difference between the groups (F=2.608, p=.105), but a significant difference was found in the measurement period within the group (F=14.790, p=.001). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.370, p=.697).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=2.522, p=.112) and 4 weeks after detraining (F=2.402, p=.122).

As a result of conducting a paired-sample t-test to confirm the change within the group, the mean change in the absolute value of peak torque in right extensor muscle of NTG was 12.33±11.22 (Nm), showing a significant difference (t=-2.693, p= .043), and the mean change in the absolute value of peak torque in right extensor muscle of the LIG was 7.00±12.93 (Nm), showing a no significant difference (t=-1.326, p=.242). On the other hand, the mean change in the absolute value of peak torque in right extensor muscle of the MIG was 9.29±8.12 (Nm), showing a significant difference (t=-3.026, p=.023).

Summarizing the changes in absolute value of peak torque in right extensor, in <Figure 27>, there was no significant difference in the prior value of absolute value of peak torque in right extensor between the groups. However, after detraining, absolute value of right extensor muscle in NTG and MIG increased significantly compared to the previous value.

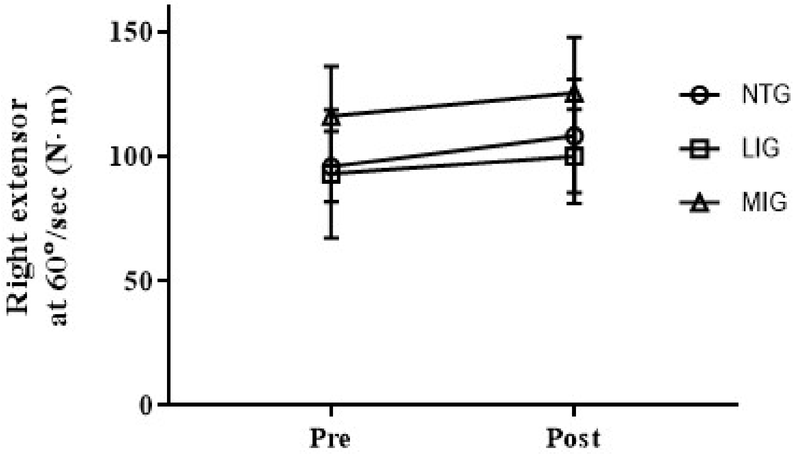

Figure 27. Change of absolute value of peak torque in right extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

② Relative value of peak torque in right extensor

<Table 64>, <Table 65>, and <Figure 28> show the results of changes in relative value of peak torque in right extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 64. Descriptive statistics and one-way ANOVA results of relative value of peak torque in right extensor (%BW)

Variables	Pre	Post	Total
NTG[a]	155.83±12.42	133.50±57.11	144.67±34.76
LIG[b]	145.00±32.95	156.00±20.93	150.50±26.94
MIG[c]	181.00±24.47	194.43±26.18	187.71±25.33
Total	161.68±28.17	163.05±44.12	162.37±36.14
F	3.665	.430	
p	.049	.839	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 65. The result of two-way repeated measures ANOVA for relative value of peak torque in right extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	8800.429	2	4400.214	1.172	.332	.115	.224
Error	67605.857	18	3755.881				
Within Subject							
Period	32.595	1	32.595	.047	.831	.003	.055
Group×Period	814.333	2	407.167	.585	.567	.061	.132
Error	12527.571	18	695.976				

<Table 64> shows the mean and standard deviation of the change in absolute value of peak torque in right extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 65> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in absolute value of peak torque in right extensor changes.

In <Table 65>, there was no significant difference between the groups (F=1.172, p=.332), and no significant difference was found in the measurement period within the group (F=.047, p=.831). Also, there was no significant difference in the interaction effect between groups and measurement period (F=.585, p=.567).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, a significant difference was found before applying detraining (F=3.665, p=.049), and the prior variable was controlled with ANCOVA. No significant difference was found after 4 weeks of detraining (F=.354, p=.709).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in the relative value of peak torque in right extensor of the NTG was 22.33±61.36 (%BW), showing a no significant difference (t=.892, p=.413), and the mean change in the relative value of peak torque in right extensor muscle of the LIG was 11.00±20.05 (%BW), showing a no significant difference (t=-1.344, p=.237). In addition, the mean change in peak torque in relative value of right extensor muscle of MIG was 13.43±13.05 (%BW), showing a no significant difference (t=-2.723, p=.035).

Summarizing the changes in relative value of peak torque in right extensor, in <Figure 28>, a significant difference was found in the prior values of peak torque in relative value of right extensor between the groups, and the prior variables were controlled. however, the LIG group showed a tendency to increase, but the NTG group showed a tendency to decrease.

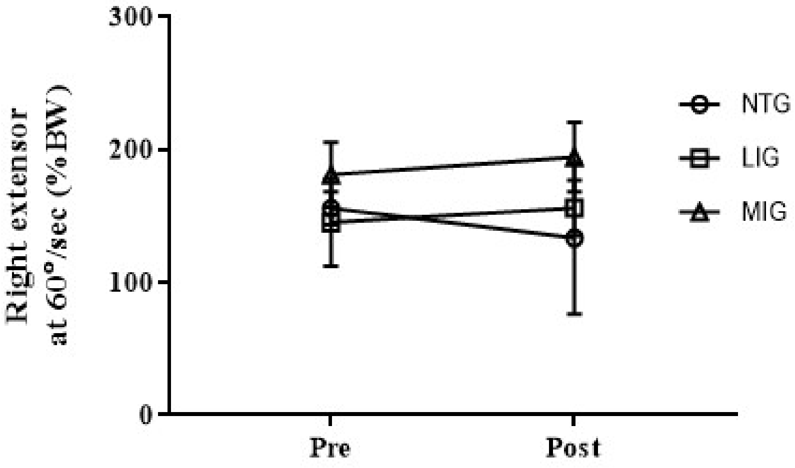

Figure 28. Change of relative value of peak torque in right extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

③ Absolute value of peak torque in left extensor

<Table 66>, <Table 67>, and <Figure 29> show the results of changes in absolute value of peak torque in left extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 66. Descriptive statistics and one-way ANOVA results of absolute value of left extensor (Nm)

Variables	Pre	Post	Total
NTG[a]	98.50±19.52	105.33±12.71	101.92±16.11
LIG[b]	96.83±25.86	100.83±23.34	98.83±24.60
MIG[c]	122.00±26.37	125.00±23.30	123.50±24.84
Total	106.63±25.87	111.16±22.33	108.89±24.10
F	2.230	2.574	
p	.140	.107	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 67. The result of two-way repeated measures ANOVA for absolute value of left extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	4785.496	2	2392.748	2.499	.114	.238	.428
Error	15318.083	16	957.380				
Within Subject							
Period	200.929	1	200.929	3.602	.076	.184	.430
Group×Period	24.952	2	12.476	.224	.802	.027	.079
Error	892.417	16	55.776				

<Table 66> shows the mean and standard deviation of the change in absolute value of peak torque in left extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 67> shows the results of two-way repeated measures

analysis of variance to confirm statistical differences in absolute value of peak torque in right extensor changes.

In <Table 67>, there was no significant difference between the groups (F=2.499, p=.114), and no significant difference was found in the measurement period within the group (F=3.602, p=.076). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.224, p=.802).

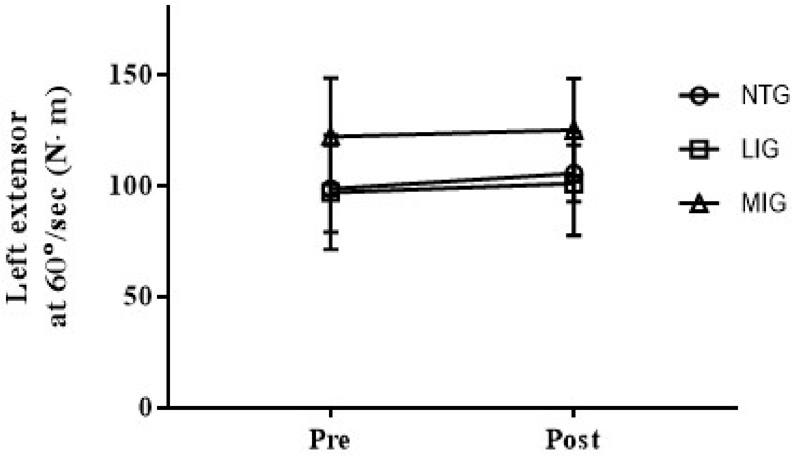

Figure 29. Change of absolute value of left extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

④ Relative value of peak torque in left extensor

<Table 68>, <Table 69>, and <Figure 30> show the results of changes in relative value of peak torque in left extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 68. Descriptive statistics and one-way ANOVA results of relative value of peak torque in left extensor (%BW)

Variables	Pre	Post	Total
NTG[a]	98.50±19.52	105.33±12.71	101.92±16.11
LIG[b]	96.83±25.86	100.83±23.34	98.83±24.60
MIG[c]	122.00±26.37	125.00±23.30	123.50±24.84
Total	106.63±25.87	111.16±22.33	108.89±24.10
F	3.236	4.062	
p	.066	.037	
Scheffe	-	b<c	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 69. The result of two-way repeated measures ANOVA for relative value of peak torque in left extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	9380.617	2	4690.308	4.028	.038	.335	.632
Error	18628.857	16	1164.304				
Within Subject							
Period	539.467	1	539.467	3.418	.083	.176	.412
Group×Period	52.649	2	26.325	.167	.848	.020	.072
Error	2525.667	16	157.854				

<Table 68> shows the mean and standard deviation of the change in relative value of peak torque in left extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 69> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in relative value of peak torque in left extensor changes.

In <Table 69>, there was a significant difference between the groups (F=4.028, p=.038), and no significant difference was found in the measurement period within the group (F=3.418, p=.083). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.167, p=.848).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, there was no significant difference before detraining (F=3.236, p=.066), but a significant difference was found after 4 weeks of detraining (F=4.062, p=.037). As a result of the post-hoc test, it increased in MIG than in LIG.

As a result of a paired-sample t-test to confirm the change within the group, the mean change in the relative value of peak torque in left extensor muscle of the NTG was 10.67±18.23 (%BW), showing a no significant difference (t=-1.433, p=.211). The mean change in the relative value of peak torque in left extensor muscle of the LIG was 7.00±24.57 (%BW), showing a no significant difference (t=-.698, p=.516). In addition, the mean change in the relative value of peak torque in left extensor muscle of the MIG was 5.00±7.87 (%BW), showing a no significant difference (t=-1.680, p=.144).

Summarizing the changes in relative value of peak torque in left extensor, in <Figure 30>, there was no significant difference in the prior value of relative value of peak torque in left extensor between the groups. After detraining, relative value of peak torque in left extensor in all groups did not show a significant difference from the previous value.

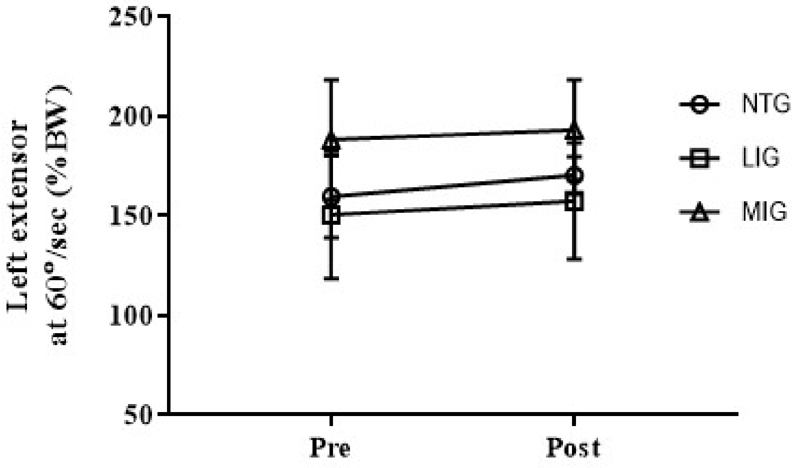

Figure 30. Change of relative value of left extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑤ Bilateral balance ratio of knee extensor

<Table 70>, <Table 71>, and <Figure 31> show the results of changes in bilateral balance ratio of knee extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 70. Descriptive statistics and one-way ANOVA results of bilateral balance ratio of knee extensor (%)

Variables	Pre	Post	Total
NTG[a]	8.83±1.83	7.33±4.08	8.08±2.96
LIG[b]	10.00±10.20	6.33±3.67	8.17±6.93
MIG[c]	5.00±6.06	3.71±1.80	4.36±3.93
Total	7.79±6.86	5.68±3.46	6.74±5.16
F	.955	2.164	
p	.406	.147	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 71. The result of two-way repeated measures ANOVA for bilateral balance ratio of knee extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	125.571	2	62.785	2.326	.130	.225	.402
Error	431.798	16	26.987				
Within Subject							
Period	43.715	1	43.715	1.413	.252	.081	.201
Group×Period	10.764	2	5.382	.174	.842	.021	.072
Error	495.131	16	30.946				

<Table 70> shows the mean and standard deviation of the change in bilateral balance ratio of knee extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 71> shows the results of two-way repeated measures

analysis of variance to confirm statistical differences in bilateral balance ratio of knee extensor changes.

In <Table 71>, there was no significant difference between the groups (F=2.326, p=.130), and no significant difference was found in the measurement period within the group (F=1.413 p=.252). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=5.382, p=.174).

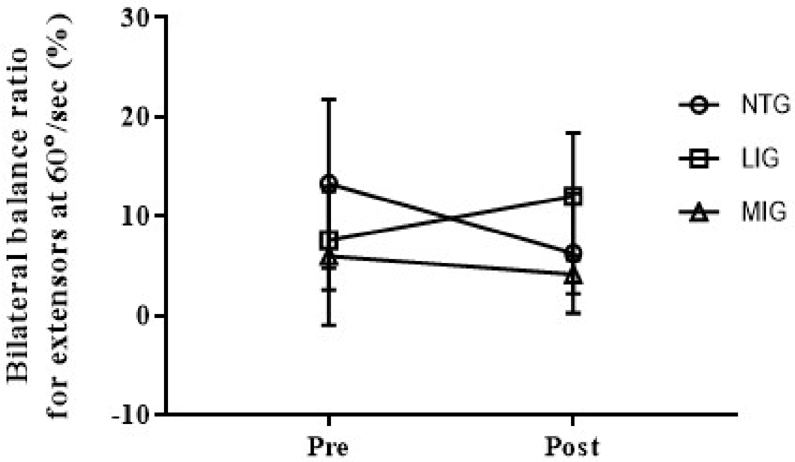

Figure 31. Change of Bilateral balance ratio of extensors after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑥ Absolute value of peak torque in right flexor

<Table 72>, <Table 73>, and <Figure 32> show the results of changes in the absolute value of peak torque in the right flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 72. Descriptive statistics and one-way ANOVA results of Absolute value of peak torque in right flexor (Nm)

Variables	Pre	Post	Total
NTG[a]	51.50±13.81	57.83±13.27	54.67±13.54
LIG[b]	44.33±14.50	49.50±13.13	46.92±13.81
MIG[c]	60.00±14.14	64.71±18.62	62.36±16.38
Total	52.37±14.92	57.74±15.93	55.05±15.42
F	1.996	1.566	
p	.168	.239	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 73. The result of two-way repeated measures ANOVA for absolute value of peak torque in right flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1543.097	2	771.549	1.827	.193	.186	.325
Error	6755.798	16	422.237				
Within Subject							
Period	276.048	1	276.048	16.310	.001	.505	.966
Group×Period	4.413	2	2.206	.130	.879	.016	.067
Error	270.798	16	16.925				

<Table 72> shows the mean and standard deviation of the change in absolute value of peak torque in right flexor by measurement period according to exercise intensity during

4 weeks of detraining. <Table 73> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in absolute value of peak torque in right flexor changes.

In <Table 73>, there was no significant difference between the groups (F=1.8271, p=.193), but a significant difference was found in the measurement period within the group (F=16.310, p=.001). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.130, p=.879).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=1.996, p=.168) and 4 weeks after detraining (F=1.566, p=.239).

As a result of conducting a paired-sample t-test to confirm the change within the group, the mean change in the absolute value of the right flexor of the NTG was 6.33±2.88 (Nm), showing a significant difference (t=-5.396, p=.003). The mean change in absolute value of peak torque in right flexor of LIG was 5.17±7.52 (Nm), showing a no significant difference (t=-1.683, p=.153). In addition, the mean change in absolute value of peak torque in right flexor of the MIG was 4.71±6.02 (Nm), showing a no significant difference (t=-2.072, p=.084).

Summarizing the changes in absolute value of peak torque in left extensor, in <Figure 32>, there was no significant difference in the prior value of absolute values of peak torque in right flexor between the groups. After detraining, absolute value of the right flexor muscle in NTG increased significantly compared to the previous value.

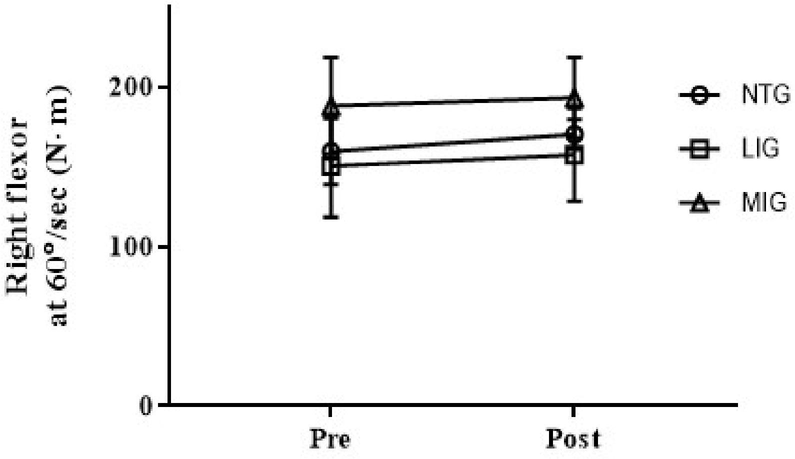

Figure 32. Change of relative value of right flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑦ Relative value of peak torque in right flexor

<Table 74>, <Table 75>, and <Figure 33> show the results of changes in relative value of peak torque in right flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 74. Descriptive statistics and one-way ANOVA results of relative value of peak torque in right flexor(%BW)

Variables	Pre	Post	Total
NTG[a]	83.50±20.50	92.33±16.45	87.92±18.48
LIG[b]	69.67±20.95	76.83±17.07	73.25±19.01
MIG[c]	92.00±16.79	100.14±23.53	96.07±20.16
Total	82.26±20.57	90.32±20.98	86.29±20.77
F	2.171	2.337	
p	.147	.129	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 75. The result of two-way repeated measures ANOVA for Relative value of peak torque in right flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	3411.721	2	1705.860	2.399	.123	.231	.413
Error	11377.595	16	711.100				
Within Subject							
Period	612.021	1	612.021	13.193	.002	.452	.926
Group×Period	4.212	2	2.106	.045	.956	.006	.056
Error	742.262	16	46.391				

<Table 74> shows the mean and standard deviation of the change in relative value of peak torque right flexor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 75> shows the results of two-way repeated measures

analysis of variance to confirm statistical differences in relative value of peak torque right flexor changes.

In <Table 75>, there was no significant difference between the groups (*F*=2.399, *p*=.123), but a significant difference was found in the measurement period within the group (*F*=13.193, *p*=.002). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (*F*=.045, *p*=.956).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (*F*=2.171, *p*=.147) and 4 weeks after detraining (*F*=2.337, *p*=.129).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in relative value of peak torque in right flexor of the NTG was 8.83±7.06 (%BW), showing a significant difference (*t*=-3.067, *p*=.028). The mean change in relative value of peak torque in right flexor of the LIG was 7.17±12.51 (%BW), showing a significant difference (*t*=-1.403, *p*=.022). In addition, the mean change in relative value of peak torque in of the MIG was 8.14±8.69 (%BW), showing a significant difference (*t*=-2.480, *p*=.048).

Summarizing the changes in relative value of peak torque in right flexor, in <Figure 33>, there was no significant difference in the prior values of relative value of peak torque in right flexor between the groups. During detraining, relative value of peak torque in right flexor decreased significantly from the prior values in all groups.

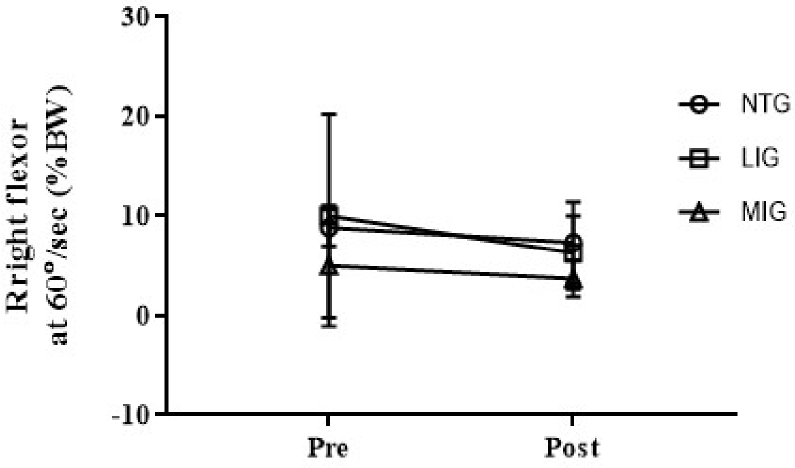

Figure 33. Change of relative value of right flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑧ Absolute value of peak torque in left flexor

<Table 76>, <Table 77>, and <Figure 34> show the results of changes in absolute value of peak torque in left flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 76. Descriptive statistics and one-way ANOVA results of absolute value of peak torque in left flexor (Nm)

Variables	Pre	Post	Total
NTG[a]	48.00±10.66	53.00±13.33	50.50±11.99
LIG[b]	42.83±13.50	48.83±8.54	45.83±11.02
MIG[c]	61.57±14.46	65.00±16.04	63.29±15.25
Total	51.37±14.84	56.11±14.39	53.74±14.62
F	3.612	2.657	
p	.051	.101	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 77. The result of two-way repeated measures ANOVA for absolute value of left peak torque in flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	2151.845	2	1075.922	3.552	.053	.307	.574
Error	4846.524	16	302.908				
Within Subject							
Period	218.593	1	218.593	5.122	.038	.242	.566
Group×Period	10.985	2	5.492	.129	.880	.016	.066
Error	682.857	16	42.679				

<Table 76> shows the mean and standard deviation of the change in absolute value of peak torque in left flexor by measurement period according to exercise intensity during 4

weeks of detraining. <Table 77> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in absolute value of peak torque in left flexor changes.

In <Table 77>, there was no significant difference between the groups (F=3.552, p=.053), but a significant difference was found in the measurement period within the group (F=5.122, p=.038). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.129, p=.880).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=3.612, p=.051) and 4 weeks after detraining (F=2.657, p=.101).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in absolute value of peak torque in left flexor of the NTG was 5.00±6.39 (Nm), showing a no significant difference (t=-1.917, p=.113). The mean change in absolute value of peak torque in left flexor of the LIG was 6.00±8.32 (Nm), showing a no significant difference (t=-1.767, p=.138). In addition, the mean change in absolute value of peak torque in left flexor of the MIG was 3.43±11.66 (Nm), showing a no significant difference (t=-.778, p=.466).

Summarizing the changes in absolute value of peak torque in left flexor, in <Figure 34>, there was no significant difference in the prior values of absolute value of peak torque in left flexor between the groups. During detraining, absolute value of peak torque in left flexor increased from the prior values in all groups.

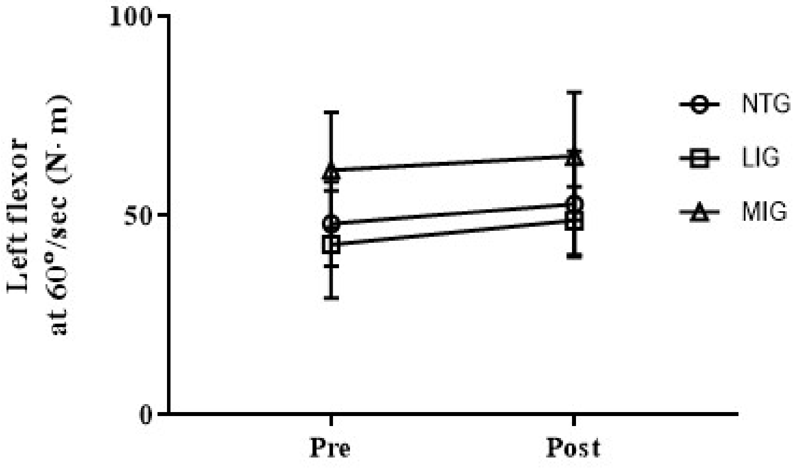

Figure 34. Change of absolute value of left flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑨ Relative value of peak torque in left flexor

<Table 78>, <Table 79>, and <Figure 35> show the results of changes in relative value of peak torque in left flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 78. Descriptive statistics and one-way ANOVA results of relative value of peak torque in left flexor (%BW)

Variables	Pre	Post	Total
NTG[a]	77.83±11.75	85.33±16.15	81.58±13.95
LIG[b]	66.00±18.13	76.00±9.74	71.00±13.93
MIG[c]	95.14±16.25	100.57±22.06	97.86±19.16
Total	80.47±19.33	88.00±19.31	84.24±19.32
F	5.725	3.428	
p	.013	.058	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 79. The result of two-way repeated measures ANOVA for relative value of peak torque in left flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	4784.237	2	2392.119	5.423	.016	.404	.768
Error	7057.131	16	441.071				
Within Subject							
Period	552.005	1	552.005	5.663	.030	.261	.609
Group×Period	33.761	2	16.881	.173	.843	.021	.072
Error	1559.607	16	97.475				

<Table 78> shows the mean and standard deviation of the change in relative value of peak torque in left flexor by measurement period according to exercise intensity during 4

weeks of detraining. <Table 79> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in relative value of peak torque in left flexor changes.

In <Table 79>, there was significant difference between the groups (F=5.423, p=.016), and there was significant difference was found in the measurement period within the group (F=5.122, p=.038). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.173, p=.843).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, a significant difference was found before applying detraining (F=5.725, p=.013), and the prior variable was controlled with ANCOVA. No significant difference was found after 4 weeks of detraining (F=.289, p=.754).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in relative value of peak torque in left flexor of the NTG was 7.50±9.31 (%BW), showing a significant difference (t=-1.973, p=.016). The mean change in relative value of peak torque in left flexor of the LIG was 10.00±12.84 (%BW), showing a no significant difference (t=-1.908, p=.115). In addition, the mean change in relative value of peak torque in left flexor of the MIG was 5.43±17.62 (%BW), showing a no significant difference (t=-.815, p=.446).

Summarizing the changes in relative value of peak torque in left flexor, in <Figure 35>, a significant difference was found in the prior values of relative value of peak torque in left flexor between the groups, and the prior variables were controlled. However, relative value of peak torque in left flexor in NTG after detraining increased significantly from the previous value.

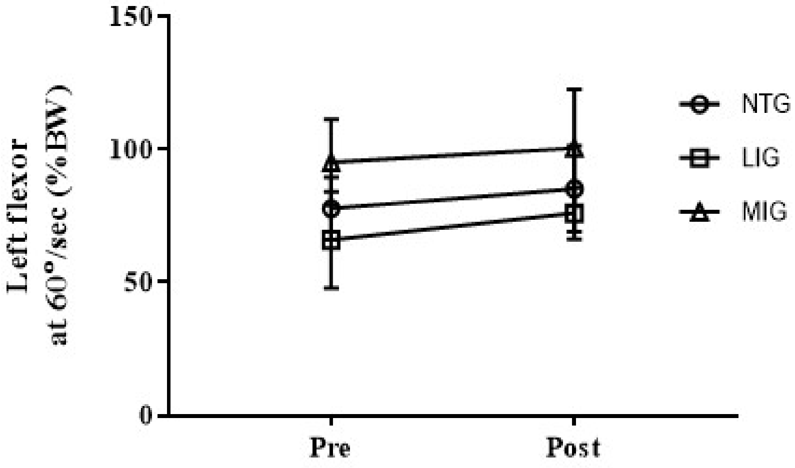

Figure 35. Change of relative value of left flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑩ Bilateral balance ratio of flexors

<Table 80>, <Table 81>, and <Figure 36> show the results of changes in bilateral balance ratio of flexors in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 80. Descriptive statistics and one-way ANOVA results of bilateral balance ratio of flexors(%)

Variables	Pre	Post	Total
NTG[a]	10.17±8.08	10.17±4.17	10.17±6.13
LIG[b]	11.67±11.64	8.83±8.13	10.25±9.89
MIG[c]	4.14±4.30	10.43±6.63	7.29±5.46
Total	8.42±8.58	9.84±6.19	9.13±7.39
F	1.504	.107	
p	.252	.899	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 81. The result of two-way repeated measures ANOVA for bilateral balance ratio of flexors

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	75.568	2	37.784	1.125	.349	.123	.213
Error	537.274	16	33.580				
Within Subject							
Period	12.515	1	12.515	.159	.695	.010	.066
Group×Period	143.185	2	71.592	.910	.422	.102	.180
Error	1259.131	16	78.696				

<Table 80> shows the mean and standard deviation of the change in bilateral balance ratio of flexors by measurement period according to exercise intensity during 4 weeks of detraining. <Table 81> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in bilateral balance ratio of knee flexors

changes.

In <Table 81>, there was no significant difference between the groups (F=1.125, p=.349), and no significant difference was found in the measurement period within the group (F=.159, p=.695). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=.910, p=.422).

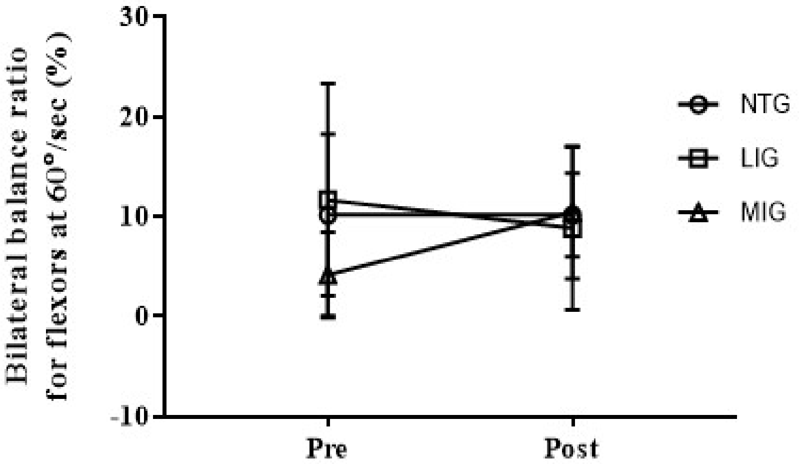

Figure 36. Change of bilateral balance ratio of flexors after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑪ H:Q ratio of the right

<Table 82>, <Table 83>, and <Figure 37> show the results of changes in H:Q ratio of the right in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 82. Descriptive statistics and one-way ANOVA results of H:Q ratio of the right (%)

Variables	Pre	Post	Total
NTG[a]	53.17±9.60	53.33±7.58	53.25±8.59
LIG[b]	48.17±13.96	49.33±8.62	48.75±11.29
MIG[c]	51.71±7.48	51.29±8.24	51.50±7.86
Total	51.05±10.14	51.32±7.87	51.18±9.00
F	.361	.360	
p	.703	.703	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 83. The result of two-way repeated measures ANOVA for H:Q ratio of the right

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	123.711	2	61.855	.387	.685	.046	.102
Error	2555.500	16	159.719				
Within Subject							
Period	.860	1	.860	.049	.828	.003	.055
Group×Period	4.152	2	2.076	.118	.890	.015	.065
Error	281.690	16	17.606				

<Table 82> shows the mean and standard deviation of the change in H:Q ratio of the right by measurement period according to exercise intensity during 4 weeks of detraining. <Table 83> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in H:Q ratio of the right changes.

In <Table 83>, there was no significant difference between the groups (F=.387, p=.685), and no significant difference was found in the measurement period within the group (F=.049 p=.828). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=.118, p=.890).

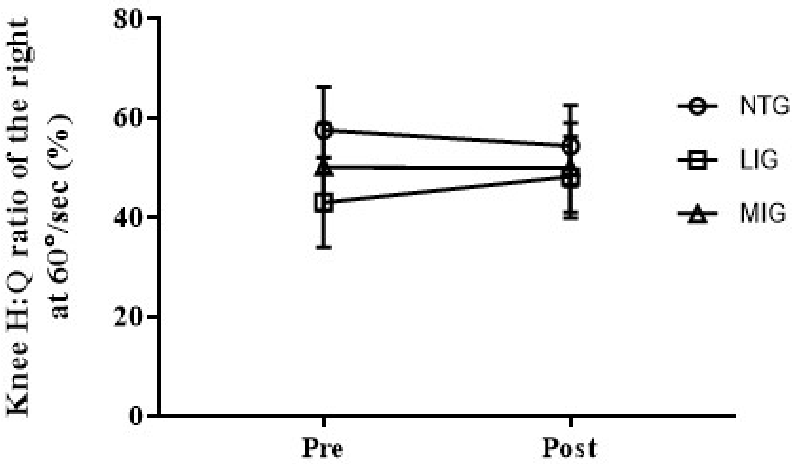

Figure 37. Change of H:Q ratio of the right after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑫ H:Q ratio of the left

<Table 84>, <Table 85>, and <Figure 38> show the results of changes in H:Q ratio of the left in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 84. Descriptive statistics and one-way ANOVA results of H:Q ratio of the left (%)

Variables	Pre	Post	Total
NTG[a]	49.00±5.22	50.00±10.39	87.92±18.48
LIG[b]	44.83±12.69	49.33±9.56	73.25±19.01
MIG[c]	51.29±8.56	52.57±10.60	96.07±20.16
Total	48.53±9.18	50.74±9.75	86.29±20.77
F	.791	.185	
p	.470	.833	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 85. The result of two-way repeated measures ANOVA for H:Q ratio of the left

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	3411.721	2	1705.860	2.399	.123	.231	.413
Error	11377.595	16	711.100				
Within Subject							
Period	612.021	1	612.021	13.193	.002	.452	.926
Group×Period	4.212	2	2.106	.045	.956	.006	.056
Error	742.262	16	46.391				

<Table 84> shows the mean and standard deviation of the change in H:Q ratio of the left by measurement period according to exercise intensity during 4 weeks of detraining. <Table 85> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in H:Q ratio of the left changes.

In <Table 85>, there was no significant difference between the groups (F=2.399, p=.123), but a significant difference was found in the measurement period within the group (F=13.193, p=.002). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.045, p=.956).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=.791, p=.470) and 4 weeks after detraining (F=.185, p=.833).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in H:Q ratio of the left of the NTG was 1.00±6.36 (%), showing a no significant difference (t=-0.765, p=.479). The mean change in H:Q ratio of the left of the LIG was 4.50±14.41 (%), showing a no significant difference (t=-.879, p=.413). In addition, the mean change in H:Q ratio of the left of the MIG was 1.29±9.50 (%), showing a no significant difference (t=-.358, p=.733).

Summarizing the changes in H:Q ratio of the left, in <Figure 38>, there was no significant difference in the prior values of H:Q ratio of the left between the groups. During detraining, H:Q ratio of the left increased from the prior values in all groups.

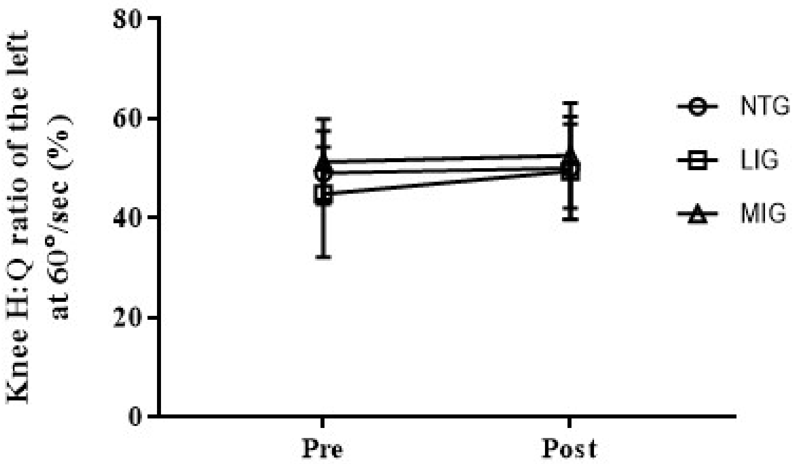

Figure 38. Change of H:Q ratio of the left after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

(5) Knee isokinetic muscle endurance (240°/sec)

① Absolute value of average power in right extensor

<Table 86>, <Table 87>, and <Figure 39> show the results of changes in absolute value of average power in right extensor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 86. Descriptive statistics and one-way ANOVA results of absolute value of average power in right extensor (Nm)

Variables	Pre	Post	Total
NTG[a]	103.00±15.79	111.17±18.27	107.08±17.03
LIG[b]	101.67±32.39	114.67±20.63	108.17±26.51
MIG[c]	114.29±26.58	123.14±29.77	118.71±28.17
Total	106.74±25.13	116.68±23.11	111.71±24.12
F	.475	.438	
p	.630	.653	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 87. The result of two-way repeated measures ANOVA for absolute value of average power in right extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1094.375	2	547.188	.505	.613	.059	.119
Error	17335.940	16	1083.496				
Within Subject							
Period	946.501	1	946.501	6.043	.026	.274	.637
Group×Period	41.628	2	20.814	.133	.877	.016	.067
Error	2505.845	16	156.615				

<Table 86> shows the mean and standard deviation of the change in absolute value of average power in right extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 87> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in absolute value of average power in right extensor changes.

In <Table 87>, there was no significant difference between the groups (F=.505, p=.613), but a significant difference was found in the measurement period within the group (F=6.043, p=.026). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.133, p=.877).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=.475, p=.630) and 4 weeks after detraining (F=.438, p=.653).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in absolute value of average power in right extensor of the NTG was 11.17±9.52 (Nm), showing a significant difference (t=-2.874, p=.035). The mean change in absolute value of average power in right extensor of the LIG was 20.83±22.35 (Nm), showing a no significant difference (t=-2.284, p=.071). In addition, the mean change in absolute value of average power in right extensor of the MIG was 8.14±39.93 (Nm), showing a no significant difference (t=-.540, p=.609).

Summarizing the changes in absolute value of average power in right extensor, in <Figure 39>, there was no significant difference in the prior values of absolute value of average power in right extensor between the groups. During detraining, absolute value of average power in right extensor increased from the prior values in all groups.

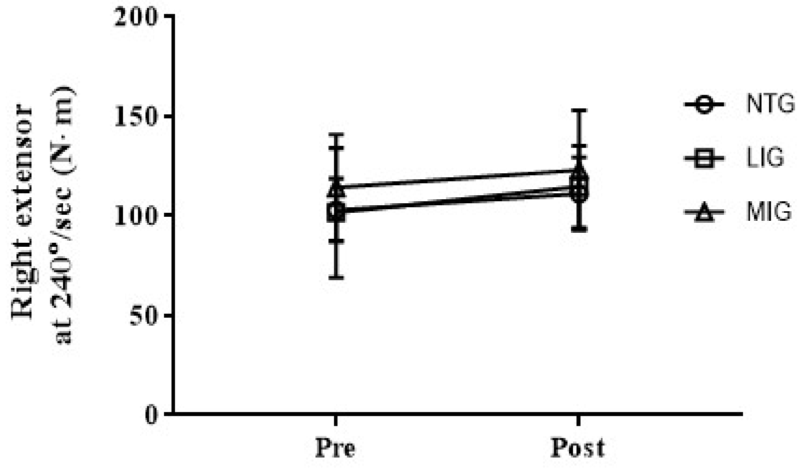

Figure 39. Change of absolute value of average power in right extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

② Relative value of average power in right extensor

<Table 88>, <Table 89>, and <Figure 39> present the results of changes in relative value of average power in right extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 88. Descriptive statistics and one-way ANOVA results of relative value of average power in right extensor (%BW)

Variables	Pre	Post	Total
NTG[a]	167.67±10.61	178.83±14.47	173.25±12.54
LIG[b]	158.00±44.53	178.83±24.64	168.42±34.58
MIG[c]	177.00±33.14	185.14±37.04	181.07±35.09
Total	168.05±31.83	181.16±26.34	174.61±29.08
F	.547	.114	
p	.589	.893	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 89. The result of two-way repeated measures ANOVA for relative value of average power in right extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1066.984	2	533.492	.369	.697	.044	.099
Error	23121.595	16	1445.100				
Within Subject							
Period	1692.021	1	1692.021	4.326	.054	.213	.498
Group×Period	276.633	2	138.316	.354	.707	.042	.097
Error	6258.262	16	391.141				

<Table 88> shows the mean and standard deviation of the change in relative value of average power in right extensor by measurement period according to exercise intensity

during 4 weeks of detraining. <Table 89> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in relative value of average power in right extensor changes.

In <Table 89>, there was no significant difference between the groups (*F*=.369, *p*=.697), and no significant difference was found in the measurement period within the group (*F*=4.326, *p*=.054). In addition, there was no significant difference in the interaction effect between groups and the measurement period (*F*=.354, *p*=.707).

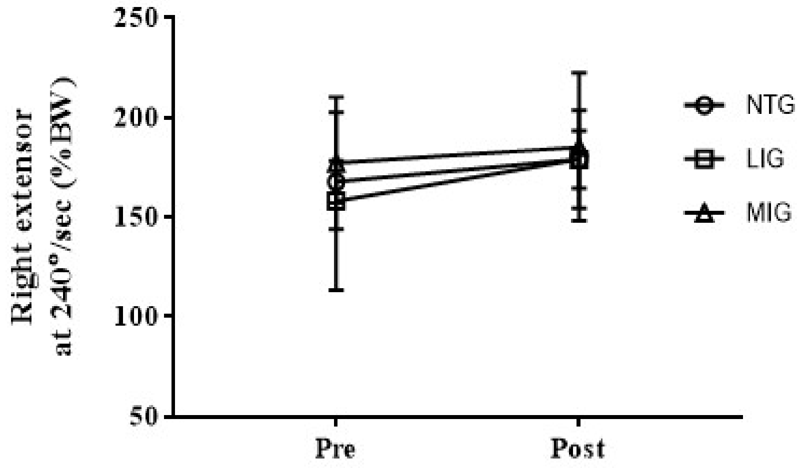

Figure 40. Change of relative value of average power in right extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

③ Absolute value of average power in left extensor

<Table 90>, <Table 91>, and <Figure 40> present the results of changes in absolute value of average power in left extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 90. Descriptive statistics and one-way ANOVA results of absolute value of average power in left extensor (Nm)

Variables	Pre	Post	Total
NTG[a]	103.00±22.92	106.50±9.33	104.75±16.12
LIG[b]	107.50±24.06	111.67±27.48	109.58±25.77
MIG[c]	117.29±18.79	120.00±25.96	118.64±22.37
Total	109.68±21.53	113.11±22.19	111.39±21.86
F	.734	.588	
p	.495	.567	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 91. The result of two-way repeated measures ANOVA for absolute value of average power in left extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1304.698	2	652.349	.704	.509	.081	.148
Error	14825.881	16	926.618				
Within Subject							
Period	113.152	1	113.152	1.695	.211	.096	.232
Group×Period	3.435	2	1.717	.026	.975	.003	.053
Error	1067.881	16	66.743				

<Table 90> shows the mean and standard deviation of the change in absolute value of average power in left extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 91> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in absolute value of average power in left extensor changes.

In <Table 91>, there was no significant difference between the groups (F=.704, p=.509), and no significant difference was found in the measurement period within the group (F=1.695, p=.211). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=.026, p=975).

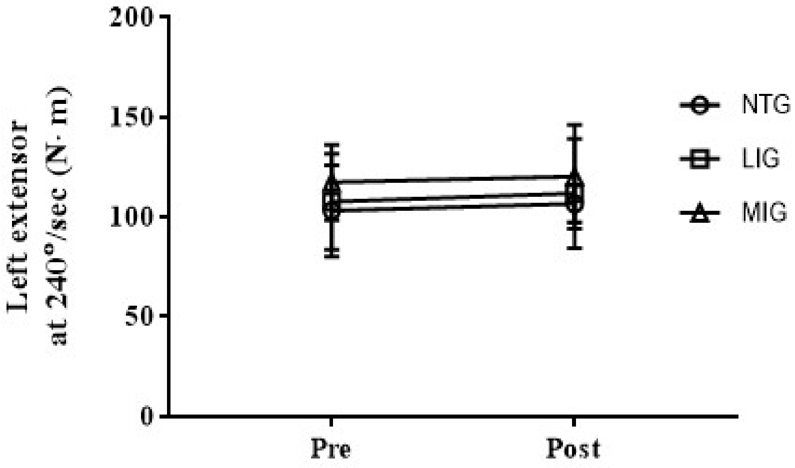

Figure 41. Change of absolute value of average power in left extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

④ Relative value of average power in left extensor

<Table 92>, <Table 93>, and <Figure 42> present the results of changes in relative value of average power in left extensor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 92. Descriptive statistics and one-way ANOVA results of relative value of average power in left extensor (%BW)

Variables	Pre	Post	Total
NTG[a]	166.00±23.04	172.50±12.47	169.25±17.75
LIG[b]	166.67±27.72	173.00±32.83	169.83±30.28
MIG[c]	181.29±16.13	184.43±28.87	182.86±22.50
Total	171.84±22.42	177.05±25.57	174.45±24.00
F	.983	.433	
p	.396	.656	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 93. The result of two-way repeated measures ANOVA for relative value of average power in left extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1569.764	2	784.882	.763	.483	.087	.157
Error	16467.131	16	1029.196				
Within Subject							
Period	268.001	1	268.001	1.554	.230	.089	.216
Group×Period	23.734	2	11.867	.069	.934	.009	.059
Error	2758.845	16	172.428				

<Table 92> shows the mean and standard deviation of the change in relative value of average power in left extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 93> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in relative value of average power in left extensor changes.

In <Table 93>, there was no significant difference between the groups (F=.763, p=.483), and no significant difference was found in the measurement period within the group (F=1.554, p=.230). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=.069, p=.934).

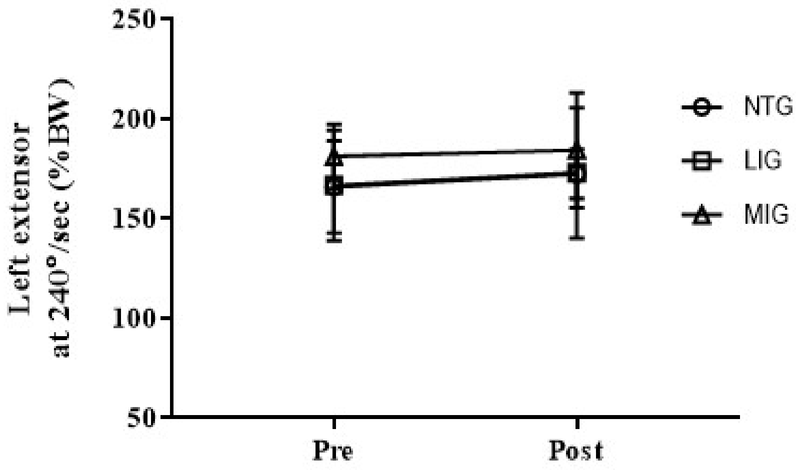

Figure 42. Change of relative value of average power in left extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑤ Absolute value of average power in right flexor

<Table 94>, <Table 95>, and <Figure 43> show the results of changes in absolute value of average power in right flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 94. Descriptive statistics and one-way ANOVA results of absolute value of average power in right flexor (Nm)

Variables	Pre	Post	Total
NTG[a]	60.67±10.05	67.17±12.70	63.92±11.38
LIG[b]	47.00±13.96	61.33±8.14	54.17±11.05
MIG[c]	72.14±21.90	70.14±22.84	71.14±22.37
Total	60.58±18.86	66.42±15.85	63.50±17.35
F	3.749	.479	
p	.046	.628	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 95. The result of two-way repeated measures ANOVA for absolute value of average power in right flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1865.202	2	932.601	1.912	.180	.193	.338
Error	7805.798	16	487.862				
Within Subject							
Period	372.429	1	372.429	7.272	.016	.312	.716
Group×Period	432.846	2	216.423	4.226	.034	.346	.654
Error	819.417	16	51.214				

<Table 94> shows the mean and standard deviation of the change in absolute value of average power in right flexor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 95> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in absolute value of average power in right flexor changes.

In <Table 95>, there was no significant difference between the groups (F=1.912, p=.180), but there was significant difference was found in the measurement period within the group (F=7.272, p=.016). In addition, there was significant difference in the interaction effect between groups and measurement period (F=4.226, p=.034).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, a significant difference was found before applying detraining (F=3.749, p=.046), and the prior variable was controlled with ANCOVA. No significant difference was found after 4 weeks of detraining (F=881, p=.438).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in absolute value of average power in right flexor of the NTG was 6.50±8.26 (Nm), showing a no significant difference (t=-1.927, p=.112). The mean change in absolute value of average power in right flexor of the LIG was 14.33±8.31 (Nm), showing a significant difference (t=-4.225, p=.008). In addition, the mean change in absolute value of average power in right flexor of the MIG was 2.00±12.60 (Nm), showing a no significant difference (t=.420, p=.689).

Summarizing the changes in absolute value of average power in right flexor, in <Figure 43>, a significant difference was found in the prior values of absolute value of average power in right flexor between the groups, and the prior variables were controlled. However, absolute value of average power in right flexor in LIG after detraining increased significantly from the previous value.

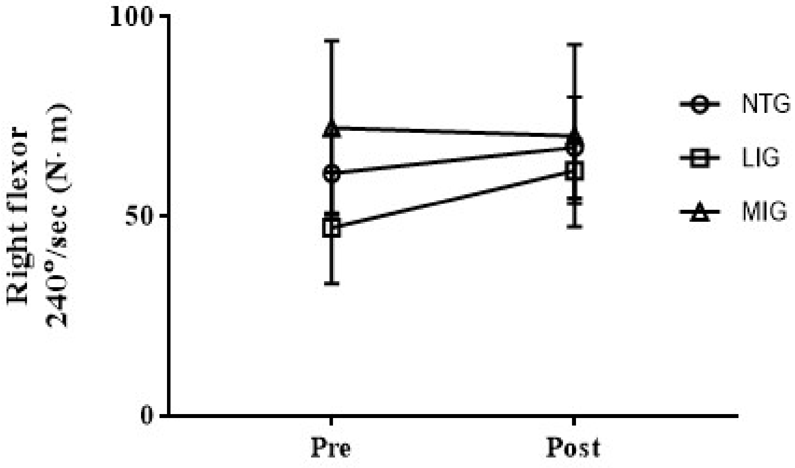

Figure 43. Change of absolute value of average power in right flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑥ Relative value of average power in right flexor

<Table 96>, <Table 97>, and <Figure 44> show the results of changes in relative value of average power in right flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 96. Descriptive statistics and one-way ANOVA results of relative value of average power in right flexor (%BW)

Variables	Pre	Post	Total
NTG[a]	99.50±14.84	106.33±17.88	102.92±16.36
LIG[b]	72.83±20.33	83.17±37.82	78.00±29.08
MIG[c]	111.29±26.63	115.00±24.80	113.14±25.71
Total	95.42±26.19	102.21±29.69	98.82±27.94
F	5.306	2.201	
p	.017	.143	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 97. The result of two-way repeated measures ANOVA for Relative value of average power in right flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	8275.080	2	4137.540	3.593	.051	.310	.580
Error	18426.131	16	1151.633				
Within Subject							
Period	457.815	1	457.815	5.095	.038	.242	.564
Group×Period	70.781	2	35.391	.394	.681	.047	.103
Error	1437.798	16	89.862				

<Table 96> shows the mean and standard deviation of the change in relative value of average power in right flexor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 97> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in relative value of average power in right flexor changes.

In <Table 97>, there was no significant difference between the groups (F=3.593, p=.051), but there was significant difference was found in the measurement period within the group (F=5.095, p=.038). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.394, p=.681).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, a significant difference was found before applying detraining (F=5.036, p=.017), and the prior variable was controlled with ANCOVA. No significant difference was found after 4 weeks of detraining (F=.803, p=.466).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in relative value of average power in right flexor of the NTG was 11.18±9.52 (%BW), showing a significant difference (t=-2.874, p=.035). The mean change in relative value of average power in right flexor of the LIG was 20.83±22.35 (%BW), showing a no significant difference (t=-2.284, p=.071). In addition, the mean change in relative value of average power in right flexor of the MIG was 8.14±39.93 (%BW), showing a no significant difference (t=-.540, p=.609).

Summarizing the changes in relative value of average power in right flexor, in <Figure 44>, a significant difference was found in the prior values of relative value of average power in right flexor between the groups, and the prior variables were controlled. However, relative value of average power in right flexor in NTG after detraining increased significantly from the previous value.

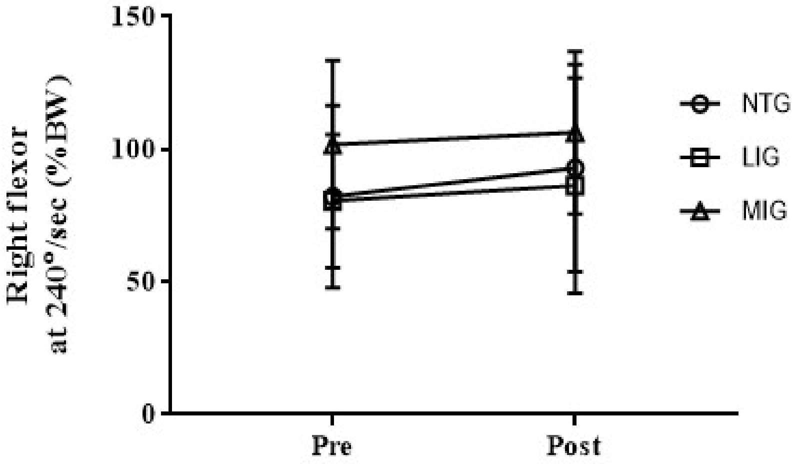

Figure 44. Change of Relative value of average power in right flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑦ Absolute value of average power in left flexor

<Table 98>, <Table 99>, and <Figure 45> present the results of changes in absolute value of average power in left flexor in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 98. Descriptive statistics and oane-way ANOVA results of absolute value of average power in left flexor (Nm)

Variables	Pre	Post	Total
NTG[a]	66.33±11.29	68.83±6.31	67.58±8.80
LIG[b]	56.83±13.78	62.50±13.85	59.67±13.81
MIG[c]	72.57±11.25	76.00±11.99	74.29±11.62
Total	65.63±13.23	69.47±12.05	67.55±12.64
F	2.744	2.346	
p	.095	.128	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 99. The result of two-way repeated measures ANOVA for absolute value of average power in left flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1380.954	2	690.477	3.281	.064	.291	.539
Error	3366.940	16	210.434				
Within Subject							
Period	141.172	1	141.172	2.260	.152	.124	.293
Group×Period	15.989	2	7.995	.128	.881	.016	.066
Error	999.274	16	62.455				

<Table 98> shows the mean and standard deviation of the change in absolute value of average power in left flexor by measurement period according to exercise intensity

during 4 weeks of detraining. <Table 99> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in absolute value of average power in left flexor changes.

In <Table 99>, there was no significant difference between the groups (F=3.281, p=.064), and no significant difference was found in the measurement period within the group (F=2.260, p=.152). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=.128, p=.881).

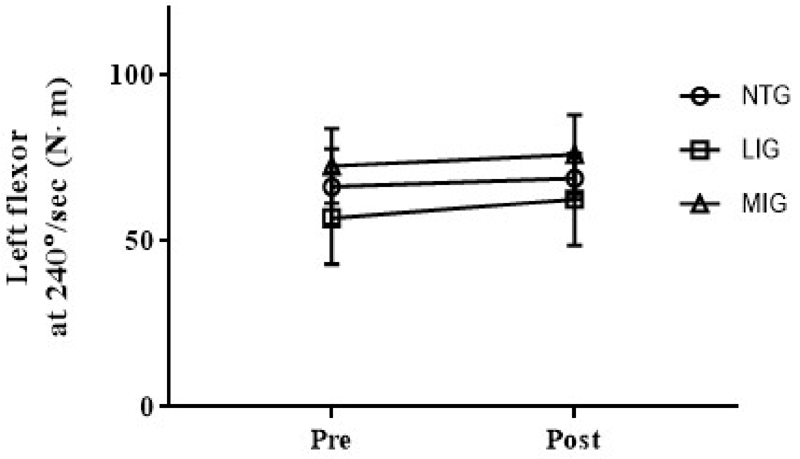

Figure 45. Change of absolute value of average power in left flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑧ Relative value of average power in left flexor

<Table 100>, <Table 101>, and <Figure 46> show the results of changes in relative value of average power in left flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 100. Descriptive statistics and one-way ANOVA results of relative value of average power in left flexor (%BW)

Variables	Pre	Post	Total
NTG[a]	108.17±19.50	111.67±12.23	109.92±15.86
LIG[b]	83.83±26.93	97.50±16.75	90.67±21.84
MIG[c]	112.57±11.82	118.43±18.52	115.50±15.17
Total	102.11±22.80	109.68±17.73	105.89±20.26
F	3.758	2.755	
p	.046	.094	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 101. The result of two-way repeated measures ANOVA for relative value of average power in left flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	4268.496	2	2134.248	4.718	.025	.371	.705
Error	7237.083	16	452.318				
Within Subject							
Period	556.601	1	556.601	2.669	.122	.143	.336
Group×Period	171.471	2	85.735	.411	.670	.049	.105
Error	3336.845	16	208.553				

<Table 100> shows the mean and standard deviation of the change in relative value of average power in left flexor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 101> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in relative value of average power in left flexor changes.

In <Table 101>, there was no significant difference between the groups (F=4.718, p=.025), but there was significant difference was found in the measurement period within the group (F=4.718, p=.025). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.411, p=.670).

As a result of one-way ANOVA to confirm the difference between the groups according to the measurement period, a significant difference was found before applying detraining (F=3.758, p=.046), and the prior variable was controlled with ANCOVA. No significant difference was found after 4 weeks of detraining (F=.223, p=.803).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in relative value of average power in left flexor of the NTG was 3.50±13.72 (Nm), showing a no significant difference (t=-.625, p=.560). The mean change in relative value of average power in left flexor of the LIG was 13.67±26.45 (Nm), showing a no significant difference (t=-1.266, p=.261). In addition, the mean change in relative value of average power in left flexor of the MIG was 5.86±19.30 (Nm), showing a no significant difference (t=-.803, p=.453).

Summarizing the changes in relative value of average power in left flexor, in <Figure 46>, there was a significant difference was found in the prior values of relative value of average power in left flexor between the groups, and the prior variables were controlled. After detraining, there was no significant difference in relative value of average power in left flexor from the pre-value in all groups.

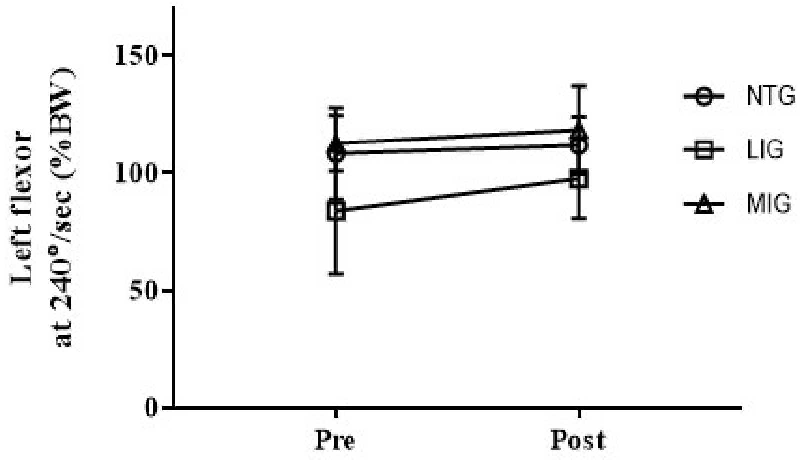

Figure 46. Change of relative value of average power in left flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

(6) Trunk isokinetic muscle strength (30˚/sec)

① Absolute value of peak torque in trunk extensor

<Table 102>, <Table 103>, and <Figure 47> show the results of changes in Absolute value of peak torque in trunk extensor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 102. Descriptive statistics and one-way ANOVA results of absolute value of peak torque in trunk extensor (Nm)

Variables	Pre	Post	Total
NTG[a]	90.83±12.92	101.67±14.25	96.25±13.59
LIG[b]	85.50±35.66	94.50±27.60	90.00±31.63
MIG[c]	113.57±18.66	118.43±28.10	116.00±23.38
Total	97.53±26.06	105.58±25.33	101.55±25.69
F	2.533	1.660	
p	.111	.221	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 103. The result of two-way repeated measures ANOVA for absolute value of peak torque in trunk extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	4861.145	2	2430.572	2.265	.136	.221	.393
Error	17166.750	16	1072.922				
Within Subject							
Period	640.101	1	640.101	6.111	.025	.276	.641
Group×Period	61.628	2	30.814	.294	.749	.035	.089
Error	1675.845	16	104.740				

<Table 102> shows the mean and standard deviation of the change in absolute value of peak torque in trunk extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 103> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in absolute value of peak torque in trunk extensor changes.

In <Table 103>, there was significant difference between the groups (F=4.718, p=.025), but a no significant difference was found in the measurement period within the group (F=2.669, p=.122). In addition, there was no significant difference in the interaction effect between groups and measurement period (F=.411, p=.670).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=2.533, p=.111) and 4 weeks after detraining (F=1.111, p=.221).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in absolute value of peak torque in trunk extensor of the NTG was 10.83±9.26 (Nm), showing a no significant difference (t=-2.865, p=.035). The mean change in absolute value of peak torque in trunk extensor of the LIG was 9.00±16.38 (Nm), showing a no significant difference (t=-1.346, p=.236). In addition, the mean change in absolute value of peak torque in trunk extensor of the MIG was 4.86±16.23 (Nm), showing a no significant difference (t=-.792, p=.459).

Summarizing the changes in absolute value of peak torque in trunk extensor, in <Figure 39>, there was no significant difference in the prior values of absolute value of peak torque in trunk extensor between the groups. After detraining, absolute value of peak torque in trunk extensor in NTG increased significantly compared to the previous value.

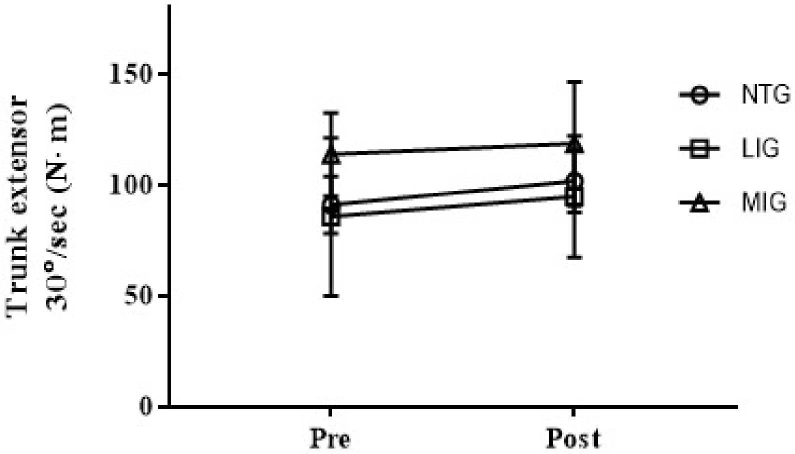

Figure 47. Change of absolute value of peak torque in trunk extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

② Relative value of peak torque in trunk extensor

<Table 104>, <Table 105>, and <Figure 48> show the results of changes in relative value of peak torque in trunk extensor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 104. Descriptive statistics and one-way ANOVA results of relative value of peak torque in trunk extensor (%BW)

Variables	Pre	Post	Total
NTG[a]	149.33±27.31	166.67±24.97	158.00±6.14
LIG[b]	133.17±51.69	147.00±38.45	140.08±45.07
MIG[c]	177.00±23.02	183.43±38.64	180.21±30.83
Total	154.42±38.52	166.63±36.33	160.53±37.42
F	.746	.441	
p	.488	.650	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 105. The result of two-way repeated measures ANOVA for relative value of peak torque in trunk extensor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	10518.200	2	5259.100	2.344	.128	.227	.405
Error	35896.274	16	2243.517				
Within Subject							
Period	1484.072	1	1484.072	6.182	.024	.279	.646
Group×Period	203.638	2	101.819	.424	.661	.050	.107
Error	3840.940	16	240.059				

<Table 104> shows the mean and standard deviation of the change in relative value of peak torque in trunk extensor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 105> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in relative value of peak torque in trunk extensor changes.

In <Table 105>, there was no significant difference between the groups (F=2.344, p=.128), but a significant difference was found in the measurement period within the group (F=6.182, p=.024). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=.424, p=.661).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=.746, p=.488) and 4 weeks after detraining (F=.441, p=.650).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in relative value of peak torque in trunk extensor of the NTG was 17.33±15.15 (%BW), showing a significant difference (t=-2.803, p=.038). The mean change in relative value of peak torque in trunk extensor of the LIG was 13.83±24.93 (%BW), showing a no significant difference (t=-1.359, p=.232). In addition, the mean change in relative value of peak torque in trunk extensor of the MIG was 6.43±23.90 (%BW), showing a no significant difference (t=-.712, p=.503).

Summarizing the changes in relative value of peak torque in trunk extensor, in <Figure 48>, there was no significant difference in the prior values of relative value of peak torque in trunk extensor between the groups. After detraining, relative value of peak torque in trunk extensor in NTG increased significantly compared to the previous value.

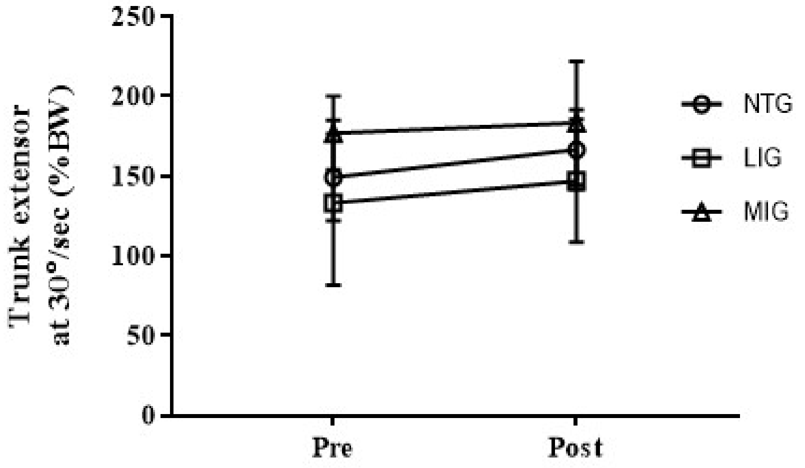

Figure 48. Change of relative value of peak torque in trunk extensor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

③ Absolute value of peak torque in trunk flexor

<Table 106>, <Table 107>, and <Figure 49> show the results of changes in absolute value of peak torque in trunk flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 106. Descriptive statistics and oane-way ANOVA results of absolute value of peak torque in trunk flexor (Nm)

Variables	Pre	Post	Total
NTG[a]	163.83±30.81	184.50±43.21	174.17±37.01
LIG[b]	172.17±54.96	177.50±40.58	174.83±47.77
MIG[c]	194.57±36.59	221.57±42.94	208.07±39.76
Total	177.79±41.64	195.95±44.76	186.87±43.20
F	.955	2.074	
p	.406	.158	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 107. The result of two-way repeated measures ANOVA for absolute value of peak torque in trunk flexor

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	9968.080	2	4984.040	1.543	.244	.162	.279
Error	51689.762	16	3230.610				
Within Subject							
Period	2949.450	1	2949.450	9.782	.006	.379	.835
Group×Period	785.930	2	392.965	1.303	.299	.140	.241
Error	4824.333	16	301.521				

<Table 106> shows the mean and standard deviation of the change in absolute value of peak torque in trunk flexor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 107> shows the results of two-way repeated

measures analysis of variance to confirm statistical differences in absolute value of peak torque in trunk flexor changes.

In <Table 107>, there was no significant difference between the groups (F=1.543, p=.244), but a significant difference was found in the measurement period within the group (F=9.782, p=.006). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=1.303, p=.299).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=.955, p=.406) and 4 weeks after detraining (F=2.074, p=.158).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in absolute value of peak torque in trunk flexor of the NTG was 20.67±15.63 (Nm), showing a significant difference (t=-3.239, p=.023). The mean change in absolute value of peak torque in trunk flexor of the LIG was 5.33±30.24 (Nm), showing a no significant difference (t=-.432, p=.684). On the other hand, the mean change in absolute value of peak torque in trunk flexor of the MIG was 27.00±25.35 (Nm), showing a significant difference (t=-2.818, p=.030).

Summarizing the changes in absolute value of peak torque in trunk flexor, in <Figure 49>, there was no significant difference in the prior values of absolute value of peak torque in trunk flexor between the groups. After detraining, absolute value of peak torque in trunk flexor in NTG and MIG increased significantly from the previous value.

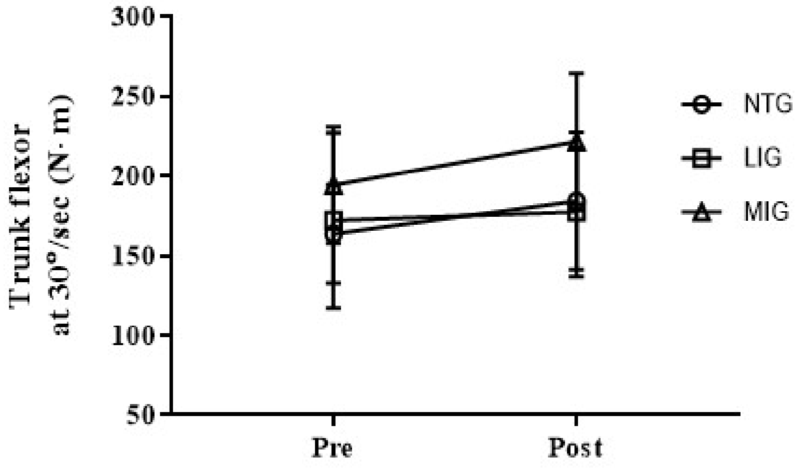

Figure 49. Change of absolute value of peak torque in trunk after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

④ Relative value of peak torque in trunk flexor

<Table 108>, <Table 109>, and <Figure 50> show the results of changes in relative value of peak torque in trunk flexor in obese adult women according to the exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 108. Descriptive statistics and one-way ANOVA results of relative value of peak torque in trunk flexor (%BW)

Variables	Pre	Post	Total
NTG[a]	264.50±24.34	297.00±40.50	280.75±32.42
LIG[b]	266.17±70.03	274.17±44.62	270.17±57.33
MIG[c]	304.14±55.34	343.14±49.91	323.64±52.62
Total	279.63±54.02	306.79±52.34	293.21±53.18
F	1.163	3.918	
p	.338	.041	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 109. The result of two-way repeated measures ANOVA for relative value of peak torque in trunk flexor

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	21201.185	2	10600.592	2.487	.115	.237	.426
Error	68206.131	16	4262.883				
Within Subject							
Period	6636.263	1	6636.263	9.877	.006	.382	.839
Group×Period	1677.513	2	838.757	1.248	.313	.135	.233
Error	10750.750	16	671.922				

<Table 108> shows the mean and standard deviation of the change in relative value of peak torque in trunk flexor by measurement period according to exercise intensity during 4 weeks of detraining. <Table 109> shows the results of two-way repeated measures

analysis of variance to confirm statistical differences in relative value of peak torque in trunk flexor changes.

In <Table 109>, there was no significant difference between the groups (F=2.487, p=.115), but a significant difference was found in the measurement period within the group (F=9.877, p=.006). On the other hand, there was no significant difference in the interaction effect between groups and measurement period (F=1.248, p=.313).

As a result of one-way ANOVA to confirm differences between groups according to the measurement period, there was no significant difference between before detraining (F=1.163, p=.338) and 4 weeks after detraining (F=3.918, p=.041).

As a result of a paired-sample t-test to confirm the change within the group, the mean change in relative value of peak torque in trunk flexor of the NTG was 32.50±22.57 (%BW), showing a significant difference (t=-3.527, p=.017). The mean change in relative value of peak torque in trunk flexor of the LIG was 5.33±30.24 (%BW), showing a no significant difference (t=-.419, p=.693). In addition, the mean change in relative value of peak torque in trunk flexor of the MIG was 39.00±36.55 (%BW), showing a no significant difference (t=-2.823, p=.030).

Summarizing the changes in relative value of peak torque in trunk flexor, in <Figure 50>, there was no significant difference in the prior values of relative value of peak torque in trunk flexor between the groups. After detraining, in NTG, relative value of peak torque in trunk flexor decreased significantly from the previous value, and in MIG, relative value of peak torque in trunk flexor increased significantly from the previous value.

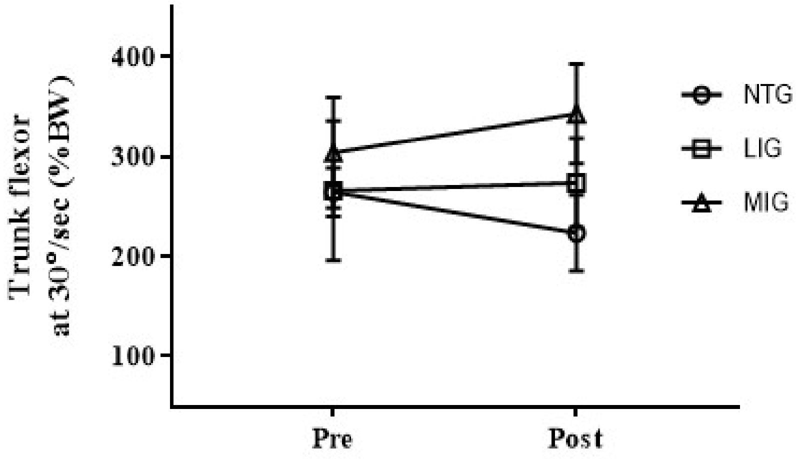

Figure 50. Change of relative value of peak torque in trunk flexor after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

⑤ Relative value of F:E ratio in trunk

<Table 110>, <Table 111>, and <Figure 51> present the results of changes in relative value of F:E ratio in trunk in obese adult women according to exercise intensity (low, moderate) performed during the detraining period (4 weeks).

Table 110. Descriptive statistics and one-way ANOVA results of relative value of F:E ratio in trunk (%)

Variables	Pre	Post	Total
NTG[a]	264.50±24.34	297.00±40.50	280.75±32.42
LIG[b]	266.17±70.03	274.17±44.62	270.17±57.33
MIG[c]	304.14±55.34	343.14±49.91	323.64±52.62
Total	279.63±54.02	306.79±52.34	293.21±53.18
F	1.154	.132	
p	.340	.878	
Scheffe	-	-	

NTG[a], non-training group; LIG[b], low-intensity exercise group; MIG[c], moderate-intensity exercise group

Table 111. The result of two-way repeated measures ANOVA for relative value of F:E ratio in trunk

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	342.292	2	171.146	.510	.610	.060	.119
Error	5366.024	16	335.376				
Within Subject							
Period	3.086	1	3.086	.080	.780	.005	.058
Group×Period	220.347	2	110.174	2.873	.086	.264	.483
Error	613.548	16	38.347				

<Table 110> shows the mean and standard deviation of the change in relative value of F:E ratio in trunk by measurement period according to exercise intensity during 4 weeks of detraining. <Table 111> shows the results of two-way repeated measures analysis of variance to confirm statistical differences in bilateral balance ratio of knee extensor

changes.

In <Table 111>, there was no significant difference between the groups (F=.510, p=.610), and no significant difference was found in the measurement period within the group (F=.080, p=.780). In addition, there was no significant difference in the interaction effect between groups and the measurement period (F=2.873, p=.086).

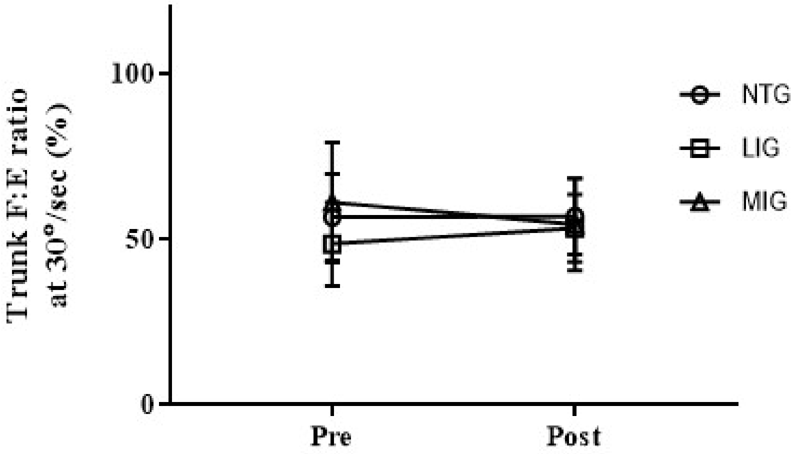

Figure 51. Change of relative value of F:E ratio in trunk after exercise

NTG, non-training group; LIG, low-intensity exercise group; MIG, moderate-intensity exercise group

IV. Study Ⅱ: Effects of different exercise intensities during the detraining period on HIT-induced aerobic and anaerobic metabolism in the flexor pollicis longus and soleus muscles.

1. Research significance

Skeletal muscle in the human body is sensitively changed according to the amount of physical activity including exercise, sports injury, detraining and disease. In other words, frequency, intensity, exercise time and rest time of physical exercise regulates an adaptation process of molecular, histological and functional characteristics of muscle fibers, resulting in muscle hypertrophy or atrophy (Phillips, 2009). This adaptation of skeletal muscle is closely associated with accelerating specific protein signaling pathway (Glass, 2003; Goldspink, 2003; Gunasekra et al., 2003), and it is necessary to understand the metabolic adaptation occurring in skeletal muscles.

In general, it has been reported that resistance exercise improves skeletal muscle hypertrophy and function by activation of the I3K/Akt/mTOR, MAPK, and CaMk signaling pathways (Goldspink, 2003). In Akt-mTOR signaling pathway, phosphorylation of Akt increases mTOR activity, a downstream molecule of Akt, and promotes differentiation in satellite cells and muscle fibers of skeletal muscle (Glass, 2003). Also, increase in insulin-like growth factor (IGF-1), a upstream molecule of Akt, after regular HIT facilitates the rate of protein synthesis in skeletal muscle for hypertrophy and/or hyperplasia (Yang & Goldspink, 2002). These synthesis process in muscle fibers after resistance exercise is rapidly activated at the early stage of training, and then it is gradually decreased over time (Ogasawara et al., 2013, Philp et al., 2011).

Aerobic exercise has been known to be effective in reducing body weight by promoting fat oxidation in adipose tissues, and this phenomenon occurs due to an increase in mitochondrial biogenesis regulatory cascade such as PGC1-α (Liang and Ward, 2006). Scarpulla (2011) suggested that inhibition of PGC1-α decreased exercise capacity along with acute inflammation and mitochondrial dysfunction (Tiraby and Langin, 2005). PGC1-α is a downstream protein of AMPK (adenosine monophosphate-activated protein kinase), regular aerobic exercise accelerates the AMPK-PGC1-α pathway to positively regulate mitochondrial biogenesis in the skeletal muscle (Coffey and Hawley, 2007).

Considering previous studies related to skeletal muscle adaptation to exercise, any continuously performing aerobic and/or anaerobic exercise improves skeletal muscle hypertrophy and metabolism. But modern people require a special strategy to maintain the effects of prior exercise during the period of training cessation (Glass, 2003; Goldspink, 2003).

Detraining is defined as phenomenon in which enhanced physiological and physical elements (VO_2max, glycogen storage and lactate threthold) after long-term training return to the pre-exercise state (Mujika & Padilla, 2000). In previous studies on the changes in physiological characteristics during detraining, Sheibani et al. (2020) found that the weight and size of soleus muscle and myocardium were decreased within 7 days after stopping training, and activation of FoxO3a and MAFbx transcription factors prevented proliferation and hypertrophy in cardiomyocytes. Omidi & Yousefi, (2019) reported that the improvement of fasting blood glucose, insulin sensitivity and glycated hemoglobin in diabetic rats after 8-week of aerobic treadmill exercise were rapidly decreased to the pre-exercise state within 4 weeks after stopping exercise, suggesting that effect of exercise in diabetic rats could not be keep up for 3 days.

Taken together, previous studies have only focused on the effect of differences in exercise type and frequency on physiological variables during detraining (Applegate et al., 1984; Radak et al., 2006). Reliable studies on role of the exercise intensity and intramuscular signaling metabolism during the period of detraining are lacking. Therefore, the purpose of this study is to confirm whether different exercise intensities during the detraining period can maintain HIT-induced aerobic and anaerobic metabolism in the flexor pollicis longus and soleus muscles of the rats.

2. Research purpose

The purpose of this study 2 was to confirm the cell biological changes related to aerobic and anaerobic muscle metabolism in the flexor pollicis longus and soleus muscles after 8 weeks of high-intensity exercise and 2 weeks of exercise intensity during the detraining period. Based on this, we want to identify the minimum exercise intensity to maintain the effect of regular exercise.

3. Materials and Methods

1) Experimental animals

The experimental animals in this study were SD (Sprague-Dawley) rats (5 weeks old, male, N=30). In order to generalize the breeding environment of laboratory animals, they were consigned to the Jeju National University Laboratory Animal Center where the temperature was 22℃, the humidity was 60%, and day and night were controlled at 12-hour intervals for 10 weeks. The use of rats in this study was approved by Ethical committee of Jeju National University (approval number: 2022-2026).

Table 112. Grouping of the experimental animal

non-exercise	Training for 8 weeks	Detraining for 2 weeks			Total
NEG (n=6)	EG (n=6)	CD2 (n=6)	LID2 (n=6)	MID2 (n=6)	n=30

NEG, non-exercise group; EG, Finished high-intensity exercise group; CD2, Rest group; LID2, Low-intensity exercise group; MID2, Moderate-intensity exercise group

2) Experimental design

This study is an experimental design to investigate the effect of the exercise intensity (low, moderate) of the exercise performed during the detraining period (2 weeks) after 8 weeks of high-intensity exercise for SD-type rats on the effect of the previous exercise.

The experimental design of this study is shown in <Figure 52>.

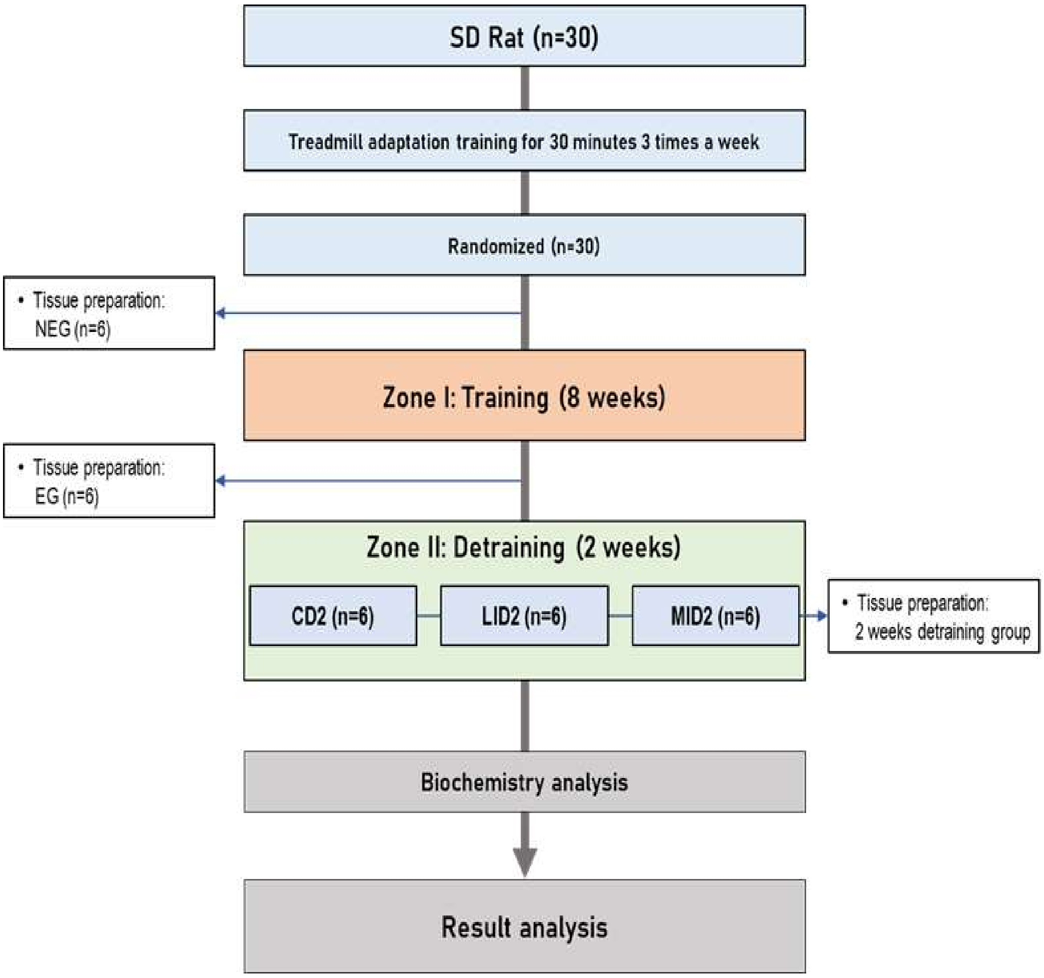

Figure 52. The experimental study design for study Ⅰ

NEG, non-exercise group; EG, Finished high-intensity exercise group; CD2, Rest group; LID2, Low-intensity exercise group; MID2, Moderate-intensity exercise group

3) Exercise protocol

For exercise application in this study, adaptive exercise was gradually performed at a speed of 10～24m/min on a treadmill for 1 week before treadmill exercise for 8 weeks. During high-intensity exercise for 8 weeks, the treadmill incline was 0% at a speed of 24m/min for 30 min once, 3 times a week.

During the detraining period (2 weeks) after 8 weeks of high-intensity exercise on the treadmill, the low-intensity exercise group reduced 60% from high-intensity exercise intensity to 8m/min, and the moderate-intensity exercise group reduced 30% from high-intensity exercise intensity to 16m/min once. It was performed 3 times a week for 30 min, and the complete rest group did not apply any other exercise other than daily life control (Wisløff et al., 2001).

The exercise programs of Zone I and Zone II of this experiment are shown in <Table 113>.

Table 113. Exercise protocol

Zone	Type	Frequency (day/week)	Intensity	Time (min)	Degree (°)
	Treadmill exercise	3/8	High(24m/min)	30	0
Ⅱ	Treadmill exercise	3/2	Low(8m/min)	30	0
			Moderate(16m/min)		

4) Sacrifice and tissue preparation

To perform histological and biochemical analyses on the tissues, the rat was sacrificed and excised 48 hours after the end of exercise. This study used the flexor pollicis longus and soleus muscles.

Experimental animals were sacrificed in a CO_2 chamber and pretreated with OCT combined (Tissue Tek; Sakura Finetek Europe B.V, Zoeterwoude, Netherlands) for the morphological analysis of muscles. The flexor pollicis longus and soleus muscles were stored at -80°C for further biochemical analyses.

5) Western blot

Protein lysates were extracted from the dissected flexor pollicis longus and soleus muscles. The tissues were introduced into triton lysis buffer, and the nucleus and cytoplasm were separated using the nuclear extraction and cytosol extraction buffers, respectively. Denatured proteins were separated on sodium dodecyl sulphate-polyacrylamide gel and then transferred onto polyvinylidene difluoride membrane on ice at 200mA for 2 hours. The membranes were blocked with 5% skim milk and washed with 0.1% Tween 20 in tris buffered saline for 30 min at room temperature. The membranes were incubated overnight at 4°C with primary antibodies.

Protein (20㎍) was used for Western blot analysis. Anti-PI3K mouse polyclonal antibody (1:1,000, Cell Signaling Biotechnology, Danvers, MA, USA), anti-phosphorylated mTOR rabbit polyclonal antibody (1:1,000, Cell Signaling Biotechnology, Danvers, MA, USA), anti-phosphorylated Akt rabbit polyclonal antibody (1:1,000, Cell Signaling Biotechnology), anti-phosphorylated ERK1/2 rabbit monoclonal antibody (1:1,000, Cell Signaling Biotechnology), anti-GAPDH mouse monoclonal antibody (1:1,000, Santa Cruz Biotechnology), anti-phosphorylated AMPK mouse polyclonal antibody (1:1,000, Cell Signaling Biotechnology), anti-PGC-1α mouse monoclonal antibody (1:1,000, Cell Signaling Biotechnology), anti-FNDC5 mouse polyclonal antibody (1:1,000, Cell Signaling Biotechnology), and goat anti-mouse or goat anti-rabbit horseradish peroxidase-conjugated secondary antibody (1:1,000, GeneTex Inc., Irvine, CA, USA) were used. The blotting proteins were detected using Westar ECL substrates (Cyanagen, Bologna, Italy). The protein density was analyzed using Chemidoc (Bio-Rad, Hercules, CA, USA). <Table 114> provides information on the types and ratios of primary and secondary antibodies used in this study.

Table 114. Skeletal muscle metabolism related protein and ratio

	Primary		Secondary	
	Antibody	Ratio	Antibody	Ratio
Mitochondria biogenesis	p-AMPK	1:1000	anti-Mouse	1:2000
	PGC1α	1:1000	anti-Mouse	1:2000
	Irsin/FNDC5	1:1000	anti-Mouse	1:2000
Muscle hypertrophy	PI3K	1:1000	anti-Mouse	1:2000
	p-ERK	1:1000	anti-Rabbit	1:2000
	p-Akt	1:1000	anti-Rabbit	1:2000
	p-mToR	1:1000	anti-Rabbit	1:2000
	GAPDH	1:1000	anti-Rabbit	1:2000

4. Statistical analysis

All the data were presented as mean ± standard. Statistical analysis was performed using one-way ANOVA analysis of all variances followed by Tukey post-hoc test. The significance level was set at $P<0.05$. All graphs were drawn using Prism 6 (GraphPad, La Jolla, CA, USA).

5. Results

Cell biological changes related to aerobic and anaerobic hypertrophy of the flexor pollicis longus and soleus muscles were confirmed by the difference in exercise intensity (low, moderate) during the 2 weeks of detraining after high-intensity exercise (8 weeks). Based on this, it is intended to identify the minimum exercise intensity to prevent muscle atrophy and mitochondrial function deterioration during detraining after high-intensity exercise.

1) Muscle hypertrophy signaling pathway in flexor pollicis longus muscle

(1) Changes in muscle hypertrophy-related protein expression according to exercise intensity during the detraining period

① Expression of PI3K in the flexor pollicis longus muscle

The results of PI3K expression in the flexor pollicis longus muscle according to exercise intensity during the detraining period are shown in <Table 115>, <Table 116>, and <Figure 53>.

<Table 115> shows the descriptive statistics of PI3K expression in the flexor pollicis longus muscle according to exercise intensity during the detraining period. As a result of one-way ANOVA to confirm the difference between groups, PI3K showed a statistically significant difference (F=6.020, p=.010). As a result of the post-hoc test, the expression level of PI3K was significantly increased in EG and LID2 than in NEG <Table 116>.

Table 115. Descriptive statistics of PI3K/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
PI3K	.59±.06	.70±.01	.68±.04	.72±.04	.62±.02	.66±.02

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 116. One-way ANOVA of PI3K/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	*F*	*p*	*Tukey*
PI3K	.59±0.06	.70±.01	.68±.04	.72±.04	.62±.02	.66±.02	6.020	.010	a<b,d

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

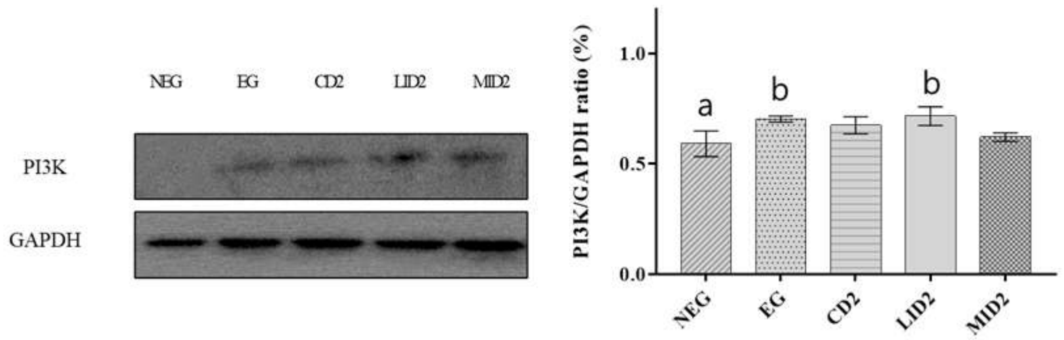

Figure 53. Change of PI3K expression levels in flexor pollicis longus muscle 2 weeks after detraining

NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

② Expression of p-ERK1/2 in the flexor pollicis longus muscle

The expression results of p-ERK1/2 in the flexor pollicis longus muscle according to exercise intensity during the detraining period are shown in <Table 117>, <Table 118>, and <Figure 54>.

<Table 117> shows the descriptive statistical values of the p-ERK1/2 expression level in the flexor pollicis longus muscle according to the exercise intensity during the detraining period. 2 showed no statistically significant difference (F=1.435, p=.292) <Table 118>.

Table 117. Descriptive statistics of p-ERK1/2/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
p-ERK1/2	.74±0.04	.80±0.04	.76±.05	.72±.04	.72±.04	.75±.04

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 118. One-way ANOVA of p-ERK1/2/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	*F*	*p*	*Tukey*
p-ERK1/2	.74±.04	.80±.04	.76±.05	.72±.04	.72±.04	.74±.05	1.435	.292	-

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

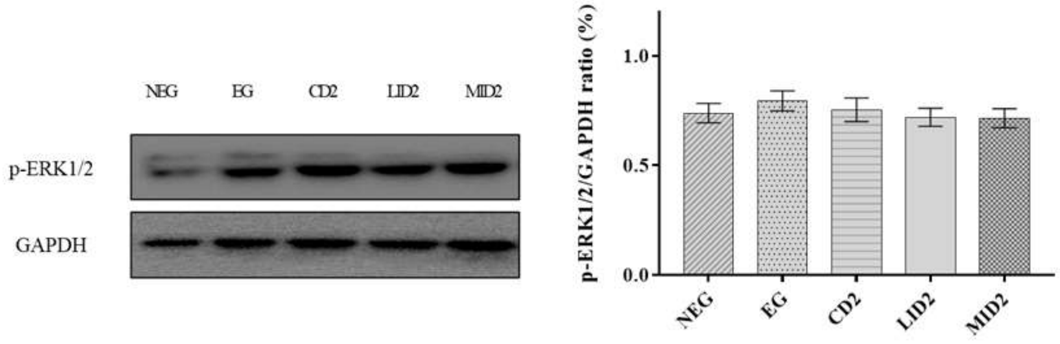

Figure 54. Change of p-ERK1/2 expression levels in flexor pollicis longus muscle 2 weeks after detraining.

NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

③ Expression of p-Akt in the flexor pollicis longus muscle

The results of p-Akt expression in the flexor pollicis longus muscle according to exercise intensity during the detraining period are shown in <Table 119>, <Table 120>, and <Figure 55>.

<Table 119> shows the descriptive statistics of p-Akt expression in the flexor pollicis longus muscle according to exercise intensity during the detraining period. As a result of one-way ANOVA to confirm the difference between groups, p-Akt showed a statistically significant difference (F=32.091, p=.001). As a result of the post-hoc test, the expression level of p-Akt was significantly increased in MID2 than in EG, and more significantly in EG than in NEG, CD2, and LID2 <Table 120>.

Table 119. Descriptive statistics of p-Akt/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
p-Akt	.35±.02	.45±.02	.38±.02	.39±.03	.54±.03	.42±.03

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 120. One-way ANOVA of p-Akt/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	F	p	*Tukey*
p-Akt	.35±.02	.45±.02	.38±.02	.39±.03	.54±.03	.42±.07	32.091	.001	a,c,d<b<e

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

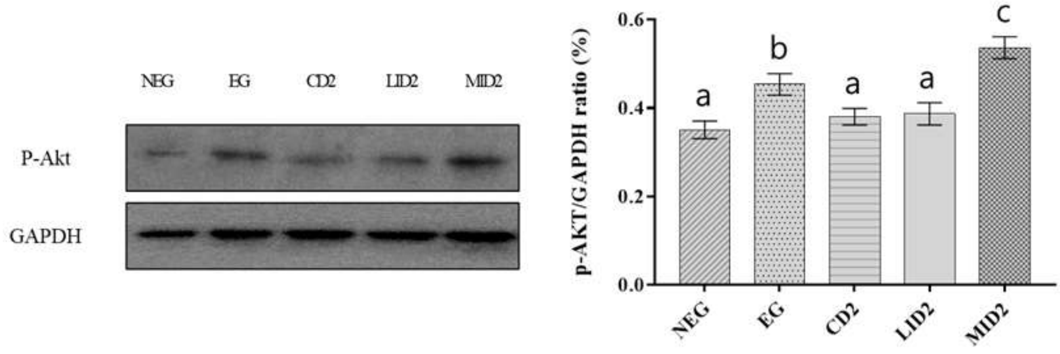

Figure 55. Change of p-Akt expression levels in flexor pollicis longus muscle 2 weeks after detraining.

NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

④ Expression of p-mTOR in the flexor pollicis longus muscle

The expression results of p-mTOR in the flexor longus muscle according to exercise intensity during the detraining period are shown in <Table 121>, <Table 122>, and <Figure 56>.

<Table 121> presents the descriptive statistics of p-mTOR expression in the flexor pollicis longus muscle according to exercise intensity during the detraining period. As a result of one-way ANOVA to confirm the difference between groups, p-mTOR showed a statistically significant difference (F=14.445, p=.001). As a result of the post-hoc test, the expression level of p-mTOR increased significantly in EG and MID2 than in NTG, CD2, and LID2 <Table 122>.

Table 121. Descriptive statistics of p-mTOR/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
p-mTOR	.35±.02	.43±.02	.35±.01	.35±.02	.43±.02	.38±.02

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 122. One-way ANOVA of p-mTOR/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	*F*	*p*	*Tukey*
p-mTOR	.35±.02	.43±.02	.35±.01	.35±.02	.43±.02	.38±.04	14.445	.001	a,c,d<b,e

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

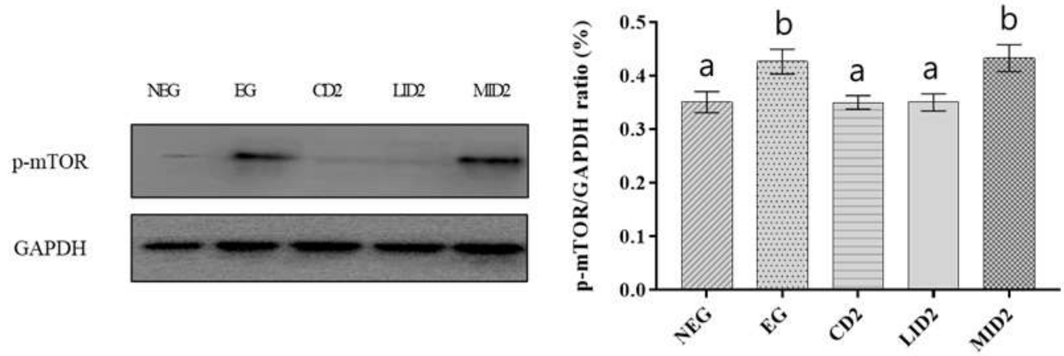

Figure 56. Change of p-mTOR expression levels in flexor pollicis longus muscle 2 weeks after detraining.

NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

2) Mitochondrial biogenesis signaling pathway in soleus muscle

(1) Changes in mitochondrial biogenesis-related protein expression according to exercise intensity during detraining

① Expression of p-AMPK in soleus muscle

<Table 123>, <Table 124>, and <Figure 57> show the results of p-AMPK expression in the soleus muscle according to exercise intensity during the detraining period.

<Table 123> shows the descriptive statistical values of the p-AMPK expression level in the soleus muscle according to the exercise intensity during the detraining period. As a result of one-way ANOVA to confirm the difference between groups, p-AMPK showed a statistically significant difference. appeared (F=5.053, p=.017). As a result of the post-hoc test, the expression level of p-AMPK was significantly increased in CD2 and MID2 than in NTG <Table 124>.

Table 123. One-way ANOVA of p-AMPK/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	*F*	*p*	*Tukey*
p-AMPK	.46±.02	.55±.06	.60±.01	.52±.06	.59±.01	.54±.03	5.053	.017	a<c,e

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 124. Descriptive statistics of p-AMPK/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
p-AMPK	.46±.02	.55±.06	.60±.01	.52±.06	.59±.01	.54±.03

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

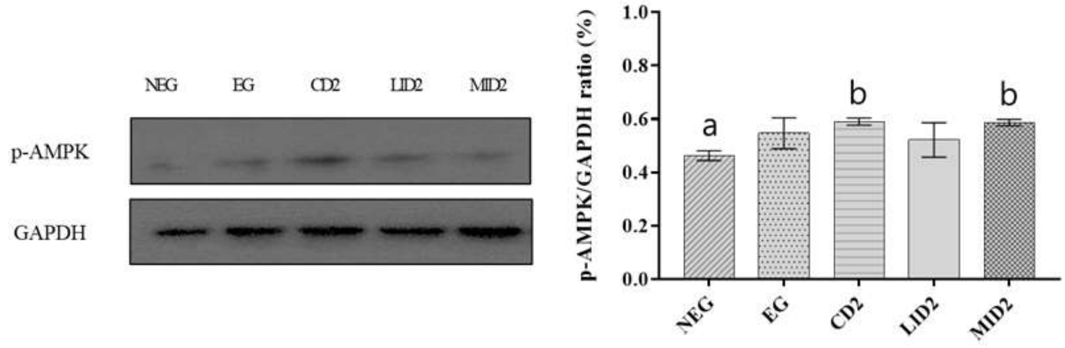

Figure 57. Change of p-AMPK expression levels in soleus muscle 2 weeks after detraining.

NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

② Expression of PGC1-α in the soleus muscle

The results of PGC1-α expression in the soleus muscle according to exercise intensity during the detraining period are shown in <Table 125>, <Table 126>, and <Figure 58>.

<Table 125> presents the descriptive statistical values of the PGC1-α expression level in the soleus muscle according to the exercise intensity during the detraining period. As a result of one-way ANOVA to confirm the difference between groups, PGC1-α showed a statistically significant difference. did not appear (F=3.267, p=.059) <Table 126>.

Table 125. Descriptive statistics of PGC1-α/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
PGC1-α	.72±.02	.74±.10	.77±.10	.92±.06	.86±.10	.80±.07

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 126. One-way ANOVA of PGC1-α/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	*F*	*p*	*Tukey*
PGC1-α	.72±.02	.74±.10	.77±.10	.92±.06	.86±.10	.80±.11	3.267	.059	-

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

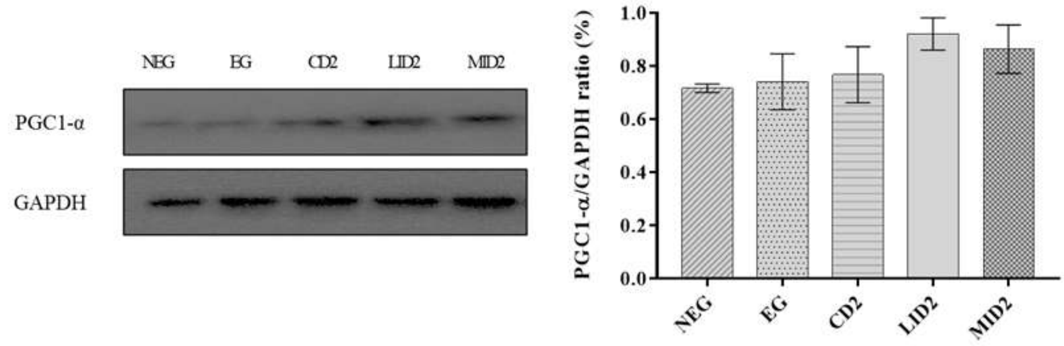

Figure 58. Change of PGC1-α expression levels in soleus muscle 2 weeks after detraining.

NTG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

③ Expression of FNDC5 in the soleus muscle

<Table 127>, <Table 128>, and <Figure 59> show the results of FNDC5 expression in the soleus muscle according to exercise intensity during the detraining period.

<Table 127> presents the descriptive statistical values of FNDC5 expression level in the soleus muscle according to exercise intensity during the detraining period. As a result of one-way ANOVA to confirm the difference between groups, a statistically significant difference was found in FNDC5 (F =31.310, *p*=.001). As a result of the post-hoc test, the expression level of FNDC5 was significantly increased in LID2 than in EG and CD2, and higher in EG and CD2 than in NTG <Table 128>.

Table 127. Descriptive statistics of FNDC5/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total
FNDC5	.79±.02	.86±.02	.87±.03	.99±.03	.84±.02	.87±.02

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

Table 128. One-way ANOVA of FNDC5/GAPDH ratio in flexor pollicis longus muscle 2 weeks after detraining (%)

Group	NEG[a]	EG[b]	CD2[c]	LID2[d]	MID2[e]	Total	*F*	*p*	*Tukey*
FNDC5	.79±.02	.86±.02	.87±.03	.99±.03	.84±.02	.87±.07	31.310	.001	a<b,c<d

Mean±standard deviation
NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

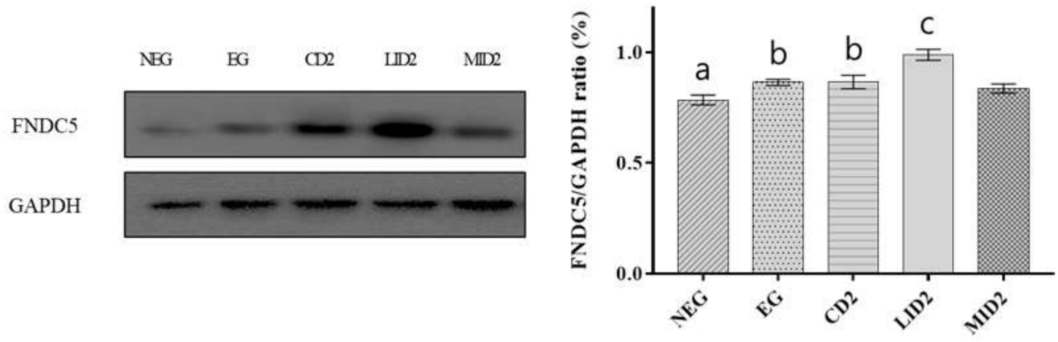

Figure 59. Change of FNDC5 expression levels in soleus muscle 2 weeks after detraining.

NEG[a], non-exercise group; EG[b], Finished exercise group; CD2[c], Rest group; LID2[d], Low-intensity exercise group; MID2[e], Moderate-intensity exercise group

V. Discussion

The present study consisted of two subjects to analyze that different exercise intensities applied during the detraining period can maintain the changed body composition, cardiovascular risk factors, physical strength, and isokinetic muscle function after 8-week HIT. One was a study to confirm whether different exercise intensities during detraining period could maintain the improved body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function in obese adult women after HIT, the other was to confirm whether different exercise intensities during the detraining period could keep up HIT-induced aerobic and anaerobic metabolism in the flexor pollicis longus and soleus muscles of the rats. Based on the results in the present study, the discussion will proceed as follows.

Study Ⅰ: Effects of different exercise intensities during detraining period on HIT-improved body composition, cardiovascular risk factor, physical fitness, and isokinetic muscle function in obese adult women.

Study I identified the minimum exercise intensity during 4-week detraining period to maintain HIT-changed physiological adaptation of obese adult women. It has been known that high-intensity circuit exercise applied in this study can be configured in various programs according to the physical fitness level of the subjects. Recently, Gibala or Tabata interval exercise that consists of short term high-intensity exercise and a relatively longer rest periods has been introduced as an effective exercise method for obese and busy people (Gillen et al., 2014; Gibala & Little, 2020). Many previous studies have verified that high-intensity circuit exercise has positive effect on body composition and physical fitness such as improvement of cardiovascular and muscular functions (Gripp et al., 2021; Miguet et al., 2020; Lanzi et al., 2015). In the present study, Eight-week high-intensity circuit training significantly increased body composition, physical fitness, and isokinetic muscle function, except for cardiovascular disease risk factors in all obese women compared to pre-exercise test. The study of Gripp et al. (2021) and Su et al. (2019) that short term circuit training improved cardiovascular fitness and muscle function support the present findings.

On this wise, many previous studies have obviously proven effect of regular circuit exercise, but there is as lack of study on how to sustain improved cardiovascular and muscle functions during the period of training cessation. Some previous studies on changes in physiological variables during detraining period provided meaningful data that aerobic capacity was decreased within 2 weeks after stopping high-intensity exercise, and maximum muscle strength might be maintained up to about 4 weeks later (Mujika & Padila, 2000). Since these research findings in detraining were analyzed for elite athletes, there are limitations in applying them to obese people. Thus, the present study involved obese women, and investigated effect of different exercise intensities during detraining to maintain improved physiological characteristics and physical movement in women with obesity after 8-week high-intensity circuit training. As a result, unlike other groups, only the MIG during the period of detraining kept up advancement in BW, BFM, BMI, %BF, WC, HC, SMM and LM in obese women after HIT. WC, HC and WHR were significantly decreased in MIG compared to those in NTG. According to a previous study by Joo (2018), changed body composition after high-intensity exercise did not deteriorate within 2 weeks after training cessation. And Ormsbee & Arciero. (2012) confirmed that moderate-intensity exercise might prevent aggravation in BW and %BF during 6-week detraining period, which is consistent with the results of this study. Moreover, we believe that moderate-intensity exercise during detraining might be most useful because MIG significantly reduced in WC, HC and WHR in obese women.

Among cardiovascular disease risk factors, TG is a water-insoluble energy-rich lipid derived from glycerol and three fatty acid, and LDL-C plays a role in transporting cholesterol to peripheral tissues as well as HDL-C transports cholesterol to the liver and excretes it out of the body. An abnormal increase in blood lipid concentration is determined as dyslipidemia, which causes cardiovascular disease, and causes health problems (ACSM, 2013). A sudden changes in blood TG, LDL-C and HDL-C has been reported to be a critical indicator for determining dyslipidemia (Meshsani & Adeli, 2009). In the latest previous study by Gripp et al. (2021), applying intermittent high-intensity or moderate-intensity training to obese people led to a positive improvement in cardiovascular parameters, and they suggested that only sustained high-intensity training during the detraining period could maintain these findings, whereas moderate-intensity exercise during detraining quickly reversed the changes in high-intensity exercise to the pre-exercise state. These results suggest the present study that 8-week high-intensity circuit training influenced cardiovascular factors, but moderate-intensity exercise applied during detraining did not affect the positive improvement of cardiovascular parameters.

Regular physical exercise has been known to be very effective in preventing and improving various metabolic syndromes including cardiovascular disease and diabetes, and a high level of physical fitness by exercise is a major index for predicting these metabolic diseases (Bouchard et al., 1993; Shaw et al., 2006; Batrakoulis et al., 2022). The present study demonstrated that MID for 4-week detraining period meaningfully sustained muscular endurance, power and cardiovascular fitness improved by high-intensity exercise compared to CG. According to a study by Mujika & Padilla (2000), detraining resulted in a fast decrease in maximum cardiac output, capillary density in skeletal muscle, and respiratory exchange rate within 4 weeks after the end of exercise. However, the present study proved that LID and MID showed statistically higher cardiorespiratory capacity than CG during the period of detraining after the end of exercise. This reason is thought to be that cardiorespiratory function was maintained because low- and moderate-intensity exercise prevented the decrease in VO_2max, cardiac output, skeletal muscle capillary density, and respiratory exchange rate that increased after exercise. Also, since the present study indirectly analyzed cardiovascular fitness through the Harvard step test, scientific verification using graded exercise testing (GXT) and specific hormone analysis is needed in future research.

Maximum muscular strength, muscular endurance, and power are closely related to skeletal muscle mass. it has been reported that cross-sectional area of skeletal muscle is dramatically decreased after exercise cessation, but the decrease in muscle strength is limited (Nielsen et al., 2010; Gundersen et al., 2016). In the present study, Muscular endurance and power were significantly higher in MIG than in CG, but did not significantly affect muscle strength, isokinetic nee and trunk muscular functions. This is thought to be because the exercise program consists of circuit exercise program that improve muscular endurance and power.

Study 2: Effects of different exercise intensities during the detraining period on HIT-induced aerobic and anaerobic metabolism in the flexor pollicis longus and soleus muscles

In the present study, to find out the appropriate exercise intensity to maintain HIT-improved muscle hypertrophy and muscle metabolism, the flexor pollicis longus and soleus muscles of rats were extracted, and then these muscles were used for examining the activation of aerobic and anaerobic signaling pathway through Western blotting analysis.

The flexor pollicis longus muscle is one of three deep muscles located on the back of the leg, and the insertion site of this muscle is attached to the plantar surface of the distal phalanx of the great toe to induce plantar flexion of the ankle, which has a high distribution of fast-twitch fibers with fast and strong muscle contraction and a high rate of lactate accumulation. Therefore, the use of flexor pollicis longus muscle in the present study is suitable to identify the hypertrophy-related Akt-mTOR signaling pathway (Pan et al., 2016).

The soleus muscle is a muscle that extends from the lower part of the knee to the calcaneus, and slow twitch fibers are highly distributed to induce plantar flexion of the ankle and maintain posture for a long time (Olewnik et al., 2020). The present study extracted the soleus muscle for aerobic metabolism and mitochondria biogenesis-related signaling pathways in skeletal muscle.

Previous studies reporting the mechanism of muscle hypertrophy after resistance exercise emphasized the importance of phosphorylation of PI3K, Akt, and mTOR cascades (Fukada and Ito, 2021). Bamman et al. (2018) reported that mTOR-overexpressing transgenic mouse could accelerate hypertrophy of skeletal muscle compared to normal rats. And Sartori et al. (2021) demonstrated that mTOR, a downstream molecule of PI3K-Akt, upregulated protein synthesis in skeletal muscle after resistance exercise through activation of p70S6K and 4E-BP1.

In the present study, we investigated the flexor pollicis longus muscle to confirm activation of muscle hypertrophy-related PI3K-Akt-mTOR signaling pathway after 8-week high intensity training or during detraining period. As a result, the expression level of PI3K was significantly increased in the flexor pollicis longus muscle after 8 weeks of high-intensity training, but no statistical change was observed in the non-exercise and low-intensity exercise groups for 2 weeks after the end of high-intensity training. Activated Akt and mTOR after 8-week high-intensity training were rapidly downregulated in the non-exercise and low-intensity exercise groups during 2-week detraining period, whereas moderate-intensity exercise group considerably stimulated Akt and mTOR phosphorylation during 2-week detraining period than non-exercise group after 8-week training cessation. Looking at previous studies analyzing protein metabolism related to muscle hypertrophy, Biglari et al. (2020) found that high-intensity interval training for 8 weeks increased the expression of Akt, PI3K, and mTOR proteins to induce gastrocnemius hypertrophy, but myostatin and FoxO expression were suppressed. Liao et al. (2015) reported that not only high-intensity training but also moderate-intensity exercise for a long time can induce an increase in proliferation of satellite cells for muscle hypertrophy and hyperplasia through activation of IGF-1, Akt, and mTOR signaling pathways. These previous findings reverified the role of Akt-mTOR signaling pathway in muscle hypertrophy, and it seems to be partially consistent with the results of this study. However, in the present study, high intensity exercise-activated PI3K did not show significant changes in low-intensity and moderate-intensity exercise group during detraining period, this information is somewhat contrary to the results of previous studies. This reason is thought to be that the period of low and moderate-intensity exercise performed during detraining was not sufficient to affect the change in PI3K expression level.

ERK1/2 are protein-serine/threonine kinases that regulate the Ras-Raf-MEK-ERK signaling transduction pathway, and they stimulate various cell biological processes such as proliferation, differentiation, migration, and survival of satellite cell in skeletal muscle after regular resistance exercise (Buscà et al., 2016; Chen et al., 2020). In our study, ERK1/2 was significantly phosphorylated 8 weeks after high-intensity exercise, but no significant change was observed in non-exercise, low and moderate-intensity exercise groups during 2-week detraining period. Several previous studies reported that moderate-intensity resistance exercise (>65% 1RM) during detraining period might lead to activation of MAPK-ERK1/2 transduction cascade for muscle hypertrophy (Taylor et al., 2012; Seok, 2018; Widegren et al., 2001). These previous studies show contradictory results to data of this study. Therefore, in future studies, it is necessary to investigate how the upstream and downstream molecules that crosstalk to p-ERK1/2 can be regulated depending on the exercise intensity during detraining.

Aerobic physical exercise can prevent and treat obesity by increasing the number and density of mitochondria in skeletal muscle and facilitating aerobic energy metabolism as well as increasing BMI by converting white fat into brown fat in the body (Ross & Bradhaw, 2009; Stanford et al., 2015; Thirupathi et al., 2019). In the field of biochemistry, PGC1-α plays a role in regulating mitochondrial biogenesis in skeletal muscle, and AMPK is a major regulator of glucose metabolism and homeostasis during exercise (McConell et al., 2020). Also, FNDC5 (Irisin) is known to be an important factor in determining the amount of brown fat conversion in the body. In the present study, there was no significant difference between PGC1-α and AMPK 8 weeks after high-intensity training, and no significant changes were found in the low-intensity and moderate-intensity exercise groups during 2-week detraining period. In general, the increase in the number of mitochondria in skeletal muscle and enhancement in aerobic metabolism through activation of PGC1-α and AMPK is promoted when low-intensity exercise is performed for a long time (McConell et al., 2020; Rothschild et al., 2021). But our finding is thought to have contradictory results because high-intensity exercise was applied. Furthermore, FNDC5, and regulator of brown fat conversion, was not upregulated after 8-week high-intensity exercise, but low-intensity exercise during 2-week detraining period significantly increased expression level of FNDC5 in skeletal muscle. Xiong et al. (2019) presented that FNDC5 knockout mouse have severe obesity due to reduced brown fat conversion and BMI, and Fain et al. (2013) suggested that aerobic exercise might increase FNDC5 level to decrease body weight of pigs. These previous studies related to FNDC5 are consistent with our findings.

VI. Conclusion and recommendations

1. Conclusion

Present study analyzed the effects of different exercise intensities during 4-week detraining period could on improved body composition, cardiovascular risk factors, physical fitness, and isokinetic muscle function of obese adult female 8 weeks after HIT (study 1), and on hypertrophy and mitochondria biogenesis-related protein signaling pathway in soleus muscle of rats after HIT (study 2).

As a result of this study, the conclusions were as follows.

First, moderate-intensity exercise during detraining period had a positive effect on the reduction in WC, HC, and WHR in obese women (Study 1).

Second, different exercise intensities during detraining period did not have a positive effect on cardiovascular variables (systolic blood pressure, diastolic blood pressure, total cholesterol, triglyceride, high-density cholesterol, low-density cholesterol, and blood sugar) in obese women (Study 1).

Third, moderate-intensity exercise during detraining period had a positive effect on the improvement of muscular endurance, power, and cardiovascular endurance in obese women (Study 1).

Fourth, the difference in exercise intensity during detraining period did not have a positive effect on the improvement of isokinetic knee and trunk muscle function in obese women (Study 1).

Fifth, moderate-intensity exercise during detraining period positively induced changes in muscle hypertrophy-related protein signaling pathway in the flexor pollicis longus muscles of rats (Study 2).

Sixth, low-intensity exercise during detraining period positively maintained a mitochondrial biogenesis protein in the soleus muscles of rats (Study Ⅱ).

Summarizing the results of this study, regular exercise during the detraining period is necessary to maintain high intensity training-improved physiological characteristics and physical fitness. In particular, we believe that moderate-intensity exercise should be continued in order to maintain HIT-improved body composition and physical fitness during the detraining period.

2. Recommendations

During the detraining period after HIT, moderate-intensity exercise did not lead to statistically significant differences in cardiovascular risk factors and isokinetic muscle function. Therefore, it is thought that additional researche are needed to provide an exercise program and appropriate exercise intensity to improve cardiovascular index and isokinetic muscle function for obesity improvement in the future.

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국문초록

고강도 훈련프로그램 후 운동강도가 체력, 등속성 근기능 및 골격근 대사에 미치는 영향

유 주 인

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지도교수 서 태 범

본 연구의 목적은 실험동물과 비만인을 대상으로 8주간 고강도 훈련프로그램 후 운동강도 차이에 따른 비만 성인 여성의 신체 구성, 심혈관 지표, 건강 체력 및 등속성 근기능에 미치는 영향을 확인하고, 골격근의 유·무소산성 근대사 관련 단백질의 생화학적 변화를 검증하고자 하였다. 본 연구는 비만 성인 여성을 대상으로 한 인간대상연구(연구 1)과 실험동물을 이용한 동물대상연구(연구 2)로 구성되었다.

연구 1의 목적은 비만 성인 여성을 대상으로 8주 동안의 고강도 훈련프로그램 적용 후 4주 동안 완전휴식, 저, 중강도 운동강도를 적용하여 신체 구성, 심혈관 지표, 건강 체력 및 등속성 무릎과 코어 근기능에 미치는 영향을 비교, 분석하였다. 56명의 참가자 중 기준을 충족하지 못한 11명을 제외한 45명이 8주간 고강도 훈련프로그램에 참여하였으며, 코로나-19로 인하여 19명, 개인 사정 5명을 제외한 21명이 훈련프로그램을 종료하였다. 이후 완전휴식집단(NTG, n=7), 저강도 운동집단(LIG, n=7), 중강도 운동집단(MIG, n=7), 3개의 집단으로 무선배정하여 4주간 운동을 실시하였으며, 완전휴식집단 1명, 저강도 운동집단 1명이 제외되어 19명의 측정자료가 분석에 사용되었다. 고강도 훈련프로그램은 8주간 주 3회, RPE 12～18, 운동과 휴식 비율 1:1～3,

운동시간 10～30초, RPE 8～18로 적용하였으며, 4주간 저강도 운동집단은 주 3회, RPE 8～10, 운동과 휴식 비율 1:3, 운동시간 20～30초로, 중강도 운동집단은 주 3회, RPE 12～14, 운동과 휴식 비율 1:2, 운동시간 20～30초로 실시하였다. 운동의 효과를 확인하기 위해 신체 구성, 심혈관 위험인자, 건강 체력 및 등속성 근기능을 8주 운동 전, 후, 4주 운동 후에 측정하여 분석에 사용하였다. 집단과 시기 간 상호작용 효과는 이원반복측정분산분석을 사용하였으며, 집단 간의 차이는 일원분산분석을 사용하였으며, 사후검정은 Scheffe-HSD를 실시하였다. 본 연구의 결과, 신체 구성은 MIG에서 허리둘레, 엉덩이둘레, 허리·신장비율에서 유의하게 감소하였으며, 근지구력, 순발력, 심폐지구력 개선에 긍정적인 영향을 미쳤다. 그러나 모든 집단에서 심혈관 지표, 등속성 근기능 개선에는 긍정적인 영향을 미치지 못하였다. 따라서 연구 1에서는 8주간 수행한 고강도 훈련프로그램의 운동 효과를 4주간 유지하기 위해서는 저강도 이상의 지속적인 운동이 요구되며, 중강도 이상의 규칙적인 운동은 비만인의 신체 구성, 건강 체력 개선에 효과적임을 시사한다.

연구 2에서는 연구 1에서 도출된 인간대상연구의 결과를 바탕으로 골격근내 유·무산소성 근대사 관련 단백질 기전을 확인하기 위해 동물대상연구를 수행하였다. 연구 2에서는 SD계열 쥐를 대상으로 8주 동안의 고강도 훈련프로그램 적용 후 운동 중단기간(2주) 동안 운동강도를 저, 중강도로 적용하여 장무지굴근과 가자미근의 유·무산소성 근대사 관련 단백질 발현량에 미치는 영향을 확인하였다. 모든 실험 쥐(n=30)는 비운동집단(NEG, n=6), 8주 고강도 운동집단(EG, n=6), 8주 고강도 훈련프로그램 후 2주 동안의 완전 휴식집단(CD2, n=6), 8주 고강도 훈련 후 2주 동안의 저강도 지속운동집단(LIG2, n=6), 8주 고강도 훈련 후 2주 동안의 중강도 지속운동집단(MIG, n=6), 총 5개 집단으로 구성하였다. 고강도 훈련프로그램은 트레드밀 운동으로 주 3회, 24m/min의 속도, 하루 30분씩, 8주간 실시하였으며, 2주간 저강도 운동은 8m/min, 중강도 운동은 16m/min으로 주 3회, 일 30분, 트레드밀 운동을 수행하였다. 장무지굴근과 가자미근의 근비대와 미토콘드리아 생합성 관련 단백질 발현은 웨스턴 블롯 분석방법으로 확인하였다. 집단 간 차이는 일원분산분석 후 사후검정으로 Tuky-HSD를 수행하였다. 장무지굴근 내 PI3K의 발현량은 EG와 LID2가 NTG 보다 높았으며, Akt, p-mTOR은 MID2와 EG가 NEG, CD2, LID2 보다 유의하게 증가하였다. 가자미근 내 p-AMPK의 발현량은 CD2와 MID2가 NEG보다 높았으며, FNDC5는 LID2가 EG, CD2

보다 유의하게 증가하였다. 따라서 연구2에서는 고강도 훈련프로그램 후 중강도 운동은 무산소성 근비대 단백질의 변화에 긍정적인 영향을 미쳤으며, 저강도 운동은 유산소성 근비대 단백질의 변화에 긍정적인 영향을 미치는 것으로 확인되었다.