Recent research in exercise and type 2 DM

Health and Exercise Science Laboratory
Institute of Sports Science

Wook Song, Ph.D.
8주간의 저항성 운동이 제 2형 당뇨 쥐(Zucker rat)의 근섬유 조성과 GLUT4 발현에 미치는 영향

서울대학교 스포츠과학연구소
건강운동과학연구실
Skeletal muscle plasticity in T2DM

MHC type I
Oxidative phenotype

MHC type II
Glycolytic phenotype

Electrical stimulation
Exercise training
Pharmacological stimuli
Genetic manipulations

Fiber type conversion

Myotonia
Neuromuscular dystrophies
Type 2 diabetes
Skeletal muscle disuse

Figure. Different skeletal muscle fiber type distribution in the normal glucose tolerant (NGT) group and type 2 diabetic group.

In patients with type 2 diabetes, the slow oxidative (SO) fiber fraction was reduced by 16%, whereas the fast glycolytic (FG) fiber fraction was increased by 49%. *P 0.05 for NGT vs. type 2 diabetic subjects.

(Andreas Oberbach et al., 2006)
The effects of resistance training on type 2 DM

**Resistance training can...**

- Enhance insulin sensitivity
- Increase in the activity and content of mitochondria
- Increase oxidative capacity
- Lower body fat mass, fat distribution and increase lean body mass which lead to ameliorate insulin resistance
- Improve glucose uptake capacity
- Make fiber type shift (fast glycolytic $\rightarrow$ slow oxidative)
To test whether 8 weeks of resistance training could convert muscle fiber type distribution and enhance glucose metabolism including GLUT4 protein expression in Zucker diabetic fatty (ZDF) rats.
Animal Model

ZDF (Zucker Diabetic Fatty) vs. ZLC (Zucker Lean Control)

[Graph showing insulin resistance and type II diabetes mellitus progression over age (weeks)]

(Reference: pelvipharm.com)
Experimental Design

- 5 week-old Zucker rat
  - N=21
- ZDF Exercise (ZDF Ex.)
  - N=7
- ZDF Control (ZDF Con.)
  - N=7
- ZLC Control (ZLC Con.)
  - N=7
- Adaptation (5 to 6 week-old)
- Exercise training starts (6 week-old)
- Exercise training ends (14 week-old)
- IPGTT (1, 4, 8 week of training)
- Sacrifice
- Muscle sample analysis

8 weeks resistance training
## Exercise protocol

<table>
<thead>
<tr>
<th>BD</th>
<th>5 wk</th>
<th>6 wk</th>
<th>8 wk</th>
<th>11 wk</th>
<th>14 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adaptation (1 week)</td>
<td>Training (1)</td>
<td>Training (2)</td>
<td>Training (3)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reps.</th>
<th>Max.3</th>
<th>Max.10 repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>0g</td>
<td>50% BW / Every trial +20g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70% MW / Every trial +20g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80% MW / Every trial +20g</td>
</tr>
<tr>
<td>Rest</td>
<td></td>
<td>2 mins</td>
</tr>
<tr>
<td>Frequent</td>
<td></td>
<td>3 days/week</td>
</tr>
</tbody>
</table>

- BD: Birth Day, BW: Body Weight, MW: Maximal Weight
Laddering exercise & Grip strength
Intraperitoneal glucose tolerance test (IPGTT)

D-glucosex(x2g/kgx)

0 min          15min          30min          60min          90min        120min

Accu-check, Germany
RESULTS
## RESULTS (1)

### Body weight and muscle weight

> **Table 1. Body weight and gastrocnemius muscle characteristics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>ZLC-Con</th>
<th>ZDF-Con</th>
<th>ZDF-Ex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± S.E.M.</td>
<td>Mean ± S.E.M.</td>
<td>Mean ± S.E.M.</td>
</tr>
<tr>
<td>Body weight (g)</td>
<td>272 ± 5.35</td>
<td>364 ± 13.57* (.002)</td>
<td>371.5 ± 17.42 (.925)</td>
</tr>
<tr>
<td>Muscle wet weight (mg)</td>
<td>586.25 ± 17.60</td>
<td>505 ± 15.14 (.070)</td>
<td>556.25 ± 30.85 (.285)</td>
</tr>
<tr>
<td>Muscle wet weight/body weight (mg/g)</td>
<td>2.16±0.09</td>
<td>1.39±0.03** (.000)</td>
<td>1.50±0.18 (.512)</td>
</tr>
</tbody>
</table>

Values are mean± S.E.M.; n=4/group; * significantly different from ZLC-Con group (p<0.05); ** significantly different from ZLC-Con group (p<0.001).
## RESULTS (2)

Exercise performance

### Table 2. Weekly exercise performance changes

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 wk</th>
<th>2 wk</th>
<th>3 wk</th>
<th>4 wk</th>
<th>5 wk</th>
<th>6 wk</th>
<th>7 wk</th>
<th>8 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal weight lifted (g)</td>
<td>240 ± 12.25</td>
<td>330 ± 21.21</td>
<td>420 ± 46.19</td>
<td>497.5 ± 36.14</td>
<td>625 ± 31.75</td>
<td>670 ± 34.88</td>
<td>745 ± 26.3</td>
<td>785 ± 2.89</td>
</tr>
<tr>
<td>Maximal weight lifted / body weight (g/g)</td>
<td>1.77 ± 0.18</td>
<td>1.62 ± 0.08</td>
<td>1.77 ± 0.10</td>
<td>1.83 ± 0.07</td>
<td>2.12 ± 0.03</td>
<td>2.13 ± 0.02</td>
<td>2.15 ± 0.01</td>
<td>2.13 ± 0.09</td>
</tr>
</tbody>
</table>

Values are mean ± S.E.M.; n=4/group
## RESULTS (3)

### Grip strength

**Table 3. Grip strength test**

<table>
<thead>
<tr>
<th>Variable</th>
<th>ZLC-Con Mean ± S.E.M.</th>
<th>ZDF-Con Mean ± S.E.M.</th>
<th>ZDF-Ex Mean ± S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip strength (g)</td>
<td>1099.48 ± 50.55</td>
<td>704.74 ± 53.73* (.009)</td>
<td>918.09 ± 99.05 (.141)</td>
</tr>
<tr>
<td>Grip strength/muscle weight (g/g)</td>
<td>1877.39 ± 78.67</td>
<td>1389.86 ± 64.22 (.072)</td>
<td>1671.94 ± 210.02 (.344)</td>
</tr>
<tr>
<td>Grip strength/body weight (g/g)</td>
<td>4.04 ± 0.18</td>
<td>1.93 ± 0.08** (.000)</td>
<td>2.52 ± 0.37 (.248)</td>
</tr>
</tbody>
</table>

Values are mean ± S.E.M.; n=4/group; * significantly different from ZLC-Con group (p<0.05); ** significantly different from ZLC-Con group (p<0.001).
## RESULTS (4)
**Glucose tolerance (IPGTT)**

### Table 4. Changes of fasting blood glucose level

<table>
<thead>
<tr>
<th>Variable (mg/dL)</th>
<th>ZLC-Con</th>
<th>ZDF-Con</th>
<th>ZDF-Ex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting blood glucose level of 1&lt;sup&gt;st&lt;/sup&gt; week of training</td>
<td>97 ± 3.03</td>
<td>108.5 ± 12.71(0.564)</td>
<td>111.5 ± 2.87(0.959)</td>
</tr>
<tr>
<td>Fasting blood glucose level of 4&lt;sup&gt;th&lt;/sup&gt; week of training</td>
<td>100.25 ± 3.54</td>
<td>217.25 ± 71.69(0.169)</td>
<td>115.75 ± 2.63(0.247)</td>
</tr>
<tr>
<td>Fasting blood glucose level of 8&lt;sup&gt;th&lt;/sup&gt; week of training</td>
<td>102.75 ± 4.48</td>
<td>272 ± 23.56**(.000)**</td>
<td>134.75 ± 8.87***(.000)**</td>
</tr>
</tbody>
</table>

Values are mean ± S.E.M.; n=4/group; * significantly different from ZLC-Con group (p<0.05); ** significantly different from ZLC-Con group (p<0.001); †† significantly different from ZDF-Con group (p<0.001).

### Figure 1. Blood glucose level during IPGTT
## RESULTS (4)

### Glucose tolerance (AUC)

Table 5. Changes of glucose area under the curve (AUC)

<table>
<thead>
<tr>
<th>Variable (mg/dL-min)</th>
<th>ZLC-Con</th>
<th>ZDF-Con</th>
<th>ZDF-Ex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± S.E.M.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUC of 1st week of training</td>
<td>13310.63 ± 418.66</td>
<td>19282.5 ± 2203.49* (.027)</td>
<td>14814.38 ± 468.36 (.094)</td>
</tr>
<tr>
<td>AUC of 4th week of training</td>
<td>13957.5 ± 268.49</td>
<td>28005 ± 3180.01* (.001)</td>
<td>19556.25 ± 844.31 † (.029)</td>
</tr>
<tr>
<td>AUC of 8th week of training</td>
<td>15931.88 ± 1880.11</td>
<td>45429.38 ± 3099.8** (.000)</td>
<td>21099.38 ± 701.63 †† (.000)</td>
</tr>
</tbody>
</table>

Values are mean ± S.E.M.; n=4/group; * significantly different from ZLC-Con group (p<0.05); ** significantly different from ZLC-Con group (p<0.001); † significantly different from ZDF-Con group (p<0.05); †† significantly different from ZDF-Con group (p<0.001).

Figure 2. Blood glucose AUC
RESULTS (5)
Immunofluorescence staining – GLUT4

Figure 3. Immunofluorescence staining for medial gastrocnemius muscle GLUT4 protein
RESULTS (6)

Western blot

Figure 4. GLUT4 protein expression in gastrocnemius muscle

88.5%
RESULTS (7)
Immunohistochemical staining – Myosin Heavy Chain (MHC)

Figure 5. Immunohistochemical staining on cross sectional area of gastrocnemius muscles

ZLC-Con  ZDF-Con  ZDF-Exn

MHCI (Unstained)  MHCII (Stained)
RESULTS (8)
Immunohistochemical staining – Myosin Heavy Chain (MHC)

Figure 6. Area of muscle fiber type

![Graph showing area of MHC fibers with 34%, 22.7%, and 8.5% comparisons.](image-url)
동물 당뇨모델 (Zucker)에서 운동에 따른 Myokine의 변화

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건강운동과학연구실
Animal study (Zucker)
Animal study (Zucker)

6 weeks (운동시작) 14 weeks (운동종료)

Glucose level (mg/dl) (divide by 18 to get mmol/l)

AGE IN WEEKS

MG/DL
Myokine

Cytokines and other peptides that are produced, expressed, and released by muscle fibers and exert autocrine, paracrine or endocrine effects.

Bente K. Pedersen (2012)
There are several reports about IL-15 as a potent regulator of fat mass and muscle-fat cross-talk. So, IL-15 is thought to be a principal myokine to prevent metabolic syndrome involving obesity and diabetes.
IL-15 seems to play a role in reducing adipose tissue mass

When IL-15 was administered to adult rats for 7 days, it resulted in a 33% decrease in white adipose tissue mass.

(Biochimica et Biophysica Acta 1526 (2001) 17~24)
Change of IL-15 protein following resistance exercise

Plasma IL-15 protein concentration before and after resistance exercise at the beginning (session 1) and end (session 30) of the resistance exercise training intervention ($n = 124$).

*P<0.05

Effect of Treadmill Exercise on Interleukin-15 Expression and Glucose Tolerance in Zucker Diabetic Fatty Rats

1) Hee-jae Kim, 2) Jae Young Park, 1) Seung Lyul Oh, 1) Yong-An Kim, 1) Byunghun So, 3) Je Kyung Seong and 1, 4) Wook Song

1) Health and exercise science laboratory, Institute of Spots Science, Seoul National University
2) Department of sport, Kyungil University
3) Department of anatomy and cell biology, College of Veterinary Medicine and Research Institute for Veterinary Science, Seoul National University
4) Institute of Aging, Seoul National University

- **Endurance training (treadmill exercise)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Intensity</th>
<th>Duration</th>
<th>Frequency</th>
<th>Contents</th>
</tr>
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<tbody>
<tr>
<td>Endurance Exercise</td>
<td>15 ~ 20 m/min</td>
<td>60 min</td>
<td>5 times/week</td>
<td>Exercise Group</td>
</tr>
</tbody>
</table>

DMJ, 2013 Accepted
Effect of treadmill exercise on IL-15 in Zucker rats

Fig. 1 (A) **Body weight** and (B) **fasting glucose levels** were **reduced** following treadmill exercise.

Fig. 2 **Glucose tolerance** was **significantly improved** following treadmill exercise.

DMJ, 2013 Accepted
Effect of treadmill exercise on IL-15 in Zucker rats

**Fig. 3.** IL-15 protein expression was increased in SOL of ZDF rats

**Fig. 4.** Body weight and fasting glucose levels were negatively correlated with IL-15 protein expression in SOL of ZDF rats
BDNF: A role in neurobiology and metabolism

In response to muscle contractions, BDNF mRNA and protein expression are markedly increased in human skeletal muscle after exercise.
BDNF mRNA and protein expression were increased in human skeletal muscle after exercise; however, muscle derived BDNF appears not to be released into the circulation.
**Muscle BDNF and Type 2 DM**

**BDNF mRNA levels are up-regulated** in hindlimb skeletal muscle of diabetic rats: effect of denervation  
*(Exp Neurol. 1996; 141(2):297-303)*

Altered neurotrophin mRNA levels in peripheral nerve and skeletal muscle of experimentally diabetic rats.  
*(J Neurochem. 1995;64:2131-7)*
Effect of resistance training on BDNF expression in diabetic skeletal muscles: relation to muscle quality

Experimental group

- ZLC control (ZLC con, n= 6)
- ZDF control (ZDF con, n=6)
- ZDF exercise (ZDF ex, n=5)

1 week adaptation

8 weeks training

IPGTT, Grip-strength test
PET-CT
Tissue collection

In Preparation: unpublished data
Changes of body weight, grip-strength and plasma glucose

<table>
<thead>
<tr>
<th></th>
<th>Body weight</th>
<th>Grip-strength</th>
<th>Plasma glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Ex</td>
<td>Post-Ex</td>
<td>Pre-Ex</td>
</tr>
<tr>
<td>ZLC Con</td>
<td>110.16 ± 2.04</td>
<td>256.33 ± 5.07</td>
<td>3023.4 ± 125.4</td>
</tr>
<tr>
<td>ZDF Con</td>
<td>116.66 ± 2.29</td>
<td>370.04 ± 9.87*</td>
<td>2975.3 ± 105.3</td>
</tr>
<tr>
<td>ZDF Ex</td>
<td>116.96 ± 2.21</td>
<td>341.4 ± 1.21#</td>
<td>3004.3 ± 98.43</td>
</tr>
</tbody>
</table>

*: ZLC Con vs. ZDF Con
#: ZDF Con vs. ZDF Ex
Glucose tolerance test (IPGTT, AUC)

*: ZLC Con vs. ZDF Con
#: ZDF Con vs. ZDF Ex
Muscle Volume, Muscle Quality
(measured by PET-CT)

A

B

*: ZLC Con vs. ZDF Con
#: ZDF Con vs. ZDF Ex
BDNF expression in skeletal muscle
Relation of BDNF to FBG & muscle strength

A

Blood glucose

BDNF (pg/ml)

R = 0.512
p = 0.008

B

Grip-strength/Body weight

BDNF (pg/ml)

R = -0.657
p = 0.004
유산소 및 저항성 운동이 비만인의 혈중 Irisin에 미치는 영향

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건강운동과학연구실
Irisin is a PGC1-α dependent myokine that drives brown fat like development of whit fat.
Introduction of irisin

**ARTICLE**

A PGC1-α-dependent myokine that drives brown-fat-like development of white fat and thermogenesis

Pontus Boström¹, Jun Wu¹, Mark P. Jedrychowski², Anisha Korde¹, Li Ye¹, James C. Lo¹, Kyle A. Rasbach¹, Elisabeth Almer Boström³, Jang Hyun Choi¹, Jonathan Z. Long¹, Shingo Kajimura⁴, Maria Cristina Zingaretti⁵, Birgitte F. Vind⁶, Hua Tu⁷, Saverio Cinti⁵, Kurt Højlund⁶, Steven P. Gygi² & Bruce M. Spiegelman¹

Nature 2012, Pontus Boström et al

doi:10.1038/nature10777
Major findings from irisin paper
Nature 2012, Pontus Boström et al

- Muscle-specific PGC1-a transgenic mice have increased brown/beige fat cells in the subcutaneous depot
- FNDC5 is induced with forced PGC1-a expression or exercise, and turns on brown/beige fat gene expression
- FNDC5 is a potent inducer of the brown/beige fat gene program
- FNDC5 is proteolytically cleaved and secreted from cells
- Detection of irisin in mouse and human plasma
- Irisin induces browning of white adipose tissues in vivo and protects against diet-induced obesity and diabetes
Irisin induces browning of white adipose tissues in vivo and protects against diet-induced obesity and diabetes.
Irisin is not routinely activated by exercise in humans

Irisin expression is not related to diabetes status in humans

Nature 2012, Timmons et al
Controversial results regarding irisin and clinical parameters

- Irisin levels showed a **positive correlation with body weight and BMI** (Joo Young Huh, 2012; Andreas Stengel, 2013).
Controversial results regarding irisin and clinical parameters

- Irisin was positively correlated with circulating insulin and glucose (Andreas Stengel, 2013).
Controversial results regarding irisin and clinical parameters

- Irisin levels were negatively associated with obesity (Jose Maria, 2013; Yeon Kyung Choi, 2013).
Circulating irisin level with exercise

**Metabolism, Huh et al., 2012**
8 week training program involving 3 training sessions per week.
2 or 3 set of runs on an indoor track with two 80m sprint runs in each set. A resting period of 20 min between sets.

**Nature, Timmons et al, 2012**
6 week of endurance cycle training program involving four times a week (45min) at 75% of peak aerobic capacity (peak VO$_2$).
Irisin is a potent metabolic regulator for obesity.

There is small evidence of effects of exercise on circulating irisin in obesity.

In particular, there is no evidence of resistance training on circulating irisin.
Purpose of study

8 weeks of exercise training

To investigate the effects of aerobic and resistance exercise on expression of circulating irisin level in obese adults.
Participants

- Body mass index > 25kg/m²
- Body fat percentage
  - > 25% Male
  - > 30% Female
- Stable body weight
- Sedentary lifestyle
Study Design

Allocation (N=48)
- Allocated to intervention (N=48)
  - Exercise Training Groups (N=38)
  - Control (N=10)

Follow Up
- Discontinued intervention (N=16)
  - Average attendance under 75% (N=16)

Analysis
- Analysis (N=28)
  - Excluded from analysis (N=4)
# Measurements

<table>
<thead>
<tr>
<th>Variables</th>
<th>Analysis Method</th>
<th>Model</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Composition Analysis</strong></td>
<td>BIA</td>
<td>In body 370</td>
<td>Biospace, Korea</td>
</tr>
<tr>
<td>Irisin</td>
<td>ELISA analysis</td>
<td>Irisin ELISA Kit</td>
<td>AVISCERA BIOSCIENCE</td>
</tr>
<tr>
<td>Blood Lipid profiles</td>
<td>Lipid test</td>
<td></td>
<td>The Green Cross Reference Lab, Korea</td>
</tr>
<tr>
<td>Muscle Strength</td>
<td>Isokinetic Contraction Measurement</td>
<td>Cybex Humac Norm</td>
<td>Humac Norm, USA</td>
</tr>
<tr>
<td>Cardiopulmonary Endurance</td>
<td>Treadmills Ergometers</td>
<td>Quark</td>
<td>Cosmed, USA</td>
</tr>
<tr>
<td>Subcutaneous Fat Thickness</td>
<td>Ultrasound</td>
<td>BX2000</td>
<td>Intelametrix, USA</td>
</tr>
</tbody>
</table>
Exercise Programs (aerobic)

Warm Up

Aerobic Training

65%~80% of Max HR
50min

- Treadmill
- Cycling

Cool Down
Exercise Programs (resistance)

- Warm Up
- Resistance Training: 65%~80% 1RM, 50 min
  - Leg Press
  - Bench Press
  - Leg Extension
  - Leg Curls
  - Shoulder Press
  - Seated Rows
  - Triceps Extensions
  - Crunch
- Cool Down
Descriptive Characteristics

- There were significant training effects on body composition in both exercise groups compared to control.

<table>
<thead>
<tr>
<th>Anthropometric Measures</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>25.8±5.5</td>
<td>25.8±5.5</td>
<td>25.7±4.1</td>
<td>25.7±4.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.2±5.4</td>
<td>167.5±5.5</td>
<td>168.3±7.7</td>
<td>168.5±7.8</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>74.1±7.6</td>
<td>74.1±7.7</td>
<td>75.3±12.7</td>
<td>73.1±13.4*</td>
</tr>
<tr>
<td>Skeletal Muscle Mass (kg)</td>
<td>32.8±4.9</td>
<td>28.2±4.8</td>
<td>28.4±6.4</td>
<td>28.4±6.5</td>
</tr>
<tr>
<td>Skeletal Muscle Mass (kg) / Body Weight (kg)</td>
<td>0.38±0.0</td>
<td>0.37±0.0</td>
<td>0.37±0.0</td>
<td>0.38±0.0*</td>
</tr>
</tbody>
</table>
### Descriptive Characteristics

<table>
<thead>
<tr>
<th>Anthropometric Measures</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Body Fat Mass (kg)</td>
<td>23.1±4.0</td>
<td>23.8±3.4</td>
<td>23.7±4.8</td>
<td>22.2±4.8*</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>31.1±5.7</td>
<td>32.1±5.2</td>
<td>32.4±4.8</td>
<td>30.6±4.8**</td>
</tr>
<tr>
<td>BMI (kg/m)</td>
<td>26.5±2.0</td>
<td>26.4±2.1</td>
<td>26.4±2.4</td>
<td>25.3±2.5**</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>89.7±4.4</td>
<td>85.5±6.7</td>
<td>90.76±6.6</td>
<td>80.9±8.8***</td>
</tr>
<tr>
<td>Hip (cm)</td>
<td>104.2±3.2</td>
<td>104.1±4.2</td>
<td>104.9±4.2</td>
<td>101.5±5.9*</td>
</tr>
<tr>
<td>WHR</td>
<td>0.86±0.0</td>
<td>0.82±0.0</td>
<td>0.86±0.0</td>
<td>0.79±0.0**</td>
</tr>
<tr>
<td>Subcutaneous Fat Thickness (mm)</td>
<td>31.9±7.9</td>
<td>33.3±3.2</td>
<td>31.3±9.1</td>
<td>27.4±6.6*</td>
</tr>
</tbody>
</table>
Total cholesterol level was changed in resistance training group.

<table>
<thead>
<tr>
<th>Blood Profiles Measures</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td><strong>Total –C (mg/dL)</strong></td>
<td>204.7±37.6</td>
<td>203.1±34.6</td>
<td>187.4±27.6</td>
<td>182.1±25.8</td>
</tr>
<tr>
<td><strong>LDL-C (mg/dL)</strong></td>
<td>124.2±28.8</td>
<td>121.7±35.0</td>
<td>112.5±29.5</td>
<td>105.5±23.2</td>
</tr>
<tr>
<td><strong>HDL-C (mg/dL)</strong></td>
<td>61.5±16.6</td>
<td>62.6±16.7</td>
<td>59.9±12.8</td>
<td>63.3±12.1</td>
</tr>
</tbody>
</table>
Exercise Capacities

- There were significant training effects on peak torque value (PK) per body weight in both exercise groups compared to control.

<table>
<thead>
<tr>
<th>Peak Torque/Body Weight (Newton_Meter)</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Extensor R</td>
<td>207±55.7</td>
<td>199.8±64.3</td>
<td>232.5±44.7</td>
<td>228.6±46.3</td>
</tr>
<tr>
<td>Flexor R</td>
<td>107.0±41.4</td>
<td>109.3±30.5</td>
<td>96.7±24.2</td>
<td>112.7±25.5**</td>
</tr>
<tr>
<td>Extensor L</td>
<td>179.5±51.4</td>
<td>186.5±59.4</td>
<td>204.4±43.3</td>
<td>215.1±48.1</td>
</tr>
<tr>
<td>Flexor L</td>
<td>103.3±32.1</td>
<td>106.5±32.1</td>
<td>89.5±23.1</td>
<td>106.8±20.4*</td>
</tr>
</tbody>
</table>
# Exercise Capacities

<table>
<thead>
<tr>
<th>Peak Torque/Body Weight (Newton·Meter)</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Extensor R</td>
<td>123.1±36.3</td>
<td>127.6±33.1</td>
<td>143.9±32.8</td>
<td>145.7±31.3</td>
</tr>
<tr>
<td>Flexor R</td>
<td>64.6±30.9</td>
<td>69.6±21.1</td>
<td>65.4±14.5</td>
<td>75.6±20.0</td>
</tr>
<tr>
<td>Extensor L</td>
<td>111.5±30.5</td>
<td>120.6±39.8</td>
<td>135.5±28.1</td>
<td>141.2±26.9</td>
</tr>
<tr>
<td>Flexor L</td>
<td>60±19.8</td>
<td>65.3±24.8</td>
<td>62.3±10.4</td>
<td>65.9±11.6</td>
</tr>
</tbody>
</table>
Exercise Capacities

- There were significant increase on average power per repetition per body weight in both exercise groups compare to control.

<table>
<thead>
<tr>
<th>Average Power per Repetition / Body Weight</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Extensor R</td>
<td>124.8±35.3</td>
<td>124.6±40.9</td>
<td>147.7±27.9</td>
<td>145±27.0</td>
</tr>
<tr>
<td>Flexor R</td>
<td>80.6±30.5</td>
<td>84±23.6</td>
<td>77.3±18.9</td>
<td>88.2±19.0*</td>
</tr>
<tr>
<td>Extensor L</td>
<td>112±33.6</td>
<td>117.2±42.4</td>
<td>128.4±26.6</td>
<td>141.4±30.7*</td>
</tr>
<tr>
<td>Flexor L</td>
<td>78.6±25.8</td>
<td>82.3±26.7</td>
<td>54.2±19.2</td>
<td>62±16.2*</td>
</tr>
</tbody>
</table>
# Exercise Capacities

<table>
<thead>
<tr>
<th>Average Power per Repetition / Body Weight</th>
<th>Control (N=8)</th>
<th>Aerobic Training (N=10)</th>
<th>Resistance Training (N=10)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Extensor R</td>
<td>187.1±47.5</td>
<td>198.1±59.8</td>
<td>238.7±49.9</td>
<td>223.8±46.6</td>
</tr>
<tr>
<td>Flexor R</td>
<td>106.0±48.6</td>
<td>109.5±37.5</td>
<td>113.1±24.5</td>
<td>120.5±26.9</td>
</tr>
<tr>
<td>Extensor L</td>
<td>167.3±44.9</td>
<td>185.0±68.4</td>
<td>223.9±48.2</td>
<td>219.7±38.0</td>
</tr>
<tr>
<td>Flexor L</td>
<td>94.5±28.5</td>
<td>103.1±35.6</td>
<td>107.8±17.9</td>
<td>104.9±17.8</td>
</tr>
<tr>
<td>Grip Strength (Kg)/Body Weight(Kg)</td>
<td>0.38±0.0</td>
<td>0.37±0.0</td>
<td>0.46±0.0</td>
<td>0.47±0.0</td>
</tr>
</tbody>
</table>
Exercise Capacities

- \( \text{VO}_2\text{max} \) increased in both exercise intervention groups and the aerobic training group showed more significant improvement.
Exercise Capacities

- Change of $\text{VO}_2\text{max}$ showed negative correlation with change of WHR and glucose
Irisin

- Circulating Irisin level increased in both training group but resistance intervention showed more significant increase.
Irisin

- Change of Irisin showed positive correlation with change of muscle mass.
Irisin

- Change of Irisin showed negative correlation with change of fat mass and body fat percentage
Thanks for your attention