Recent research in exercise and type 2 DM

Health and Exercise Science Laboratory
Institute of Sports Science

Wook Song, Ph.D.

연구 1
(김지연)

8주간의 저항성 운동이 제 2형 당뇨 쥐(Zucker rat)의 근섬유 조성과 GLUT4 발현에 미치는 영향

서울대학교 스포츠과학연구소

건강운동과학연구실

Skeletal muscle plasticity in T2DM

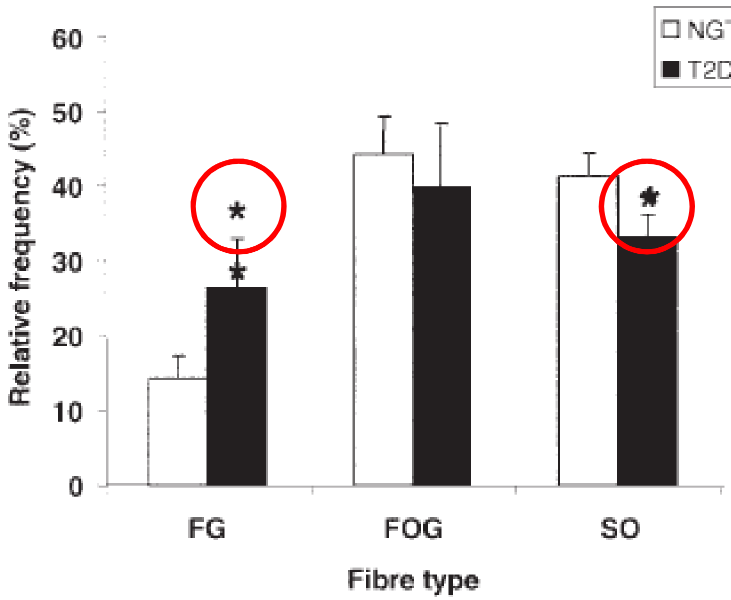
MHC type I
Oxidative phenotype

Electrical stimulation
Exercise training
Pharmacological stimuli
Genetic manipulations

Fiber type conversion

MHC type II
Glycolytic phenotype

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)

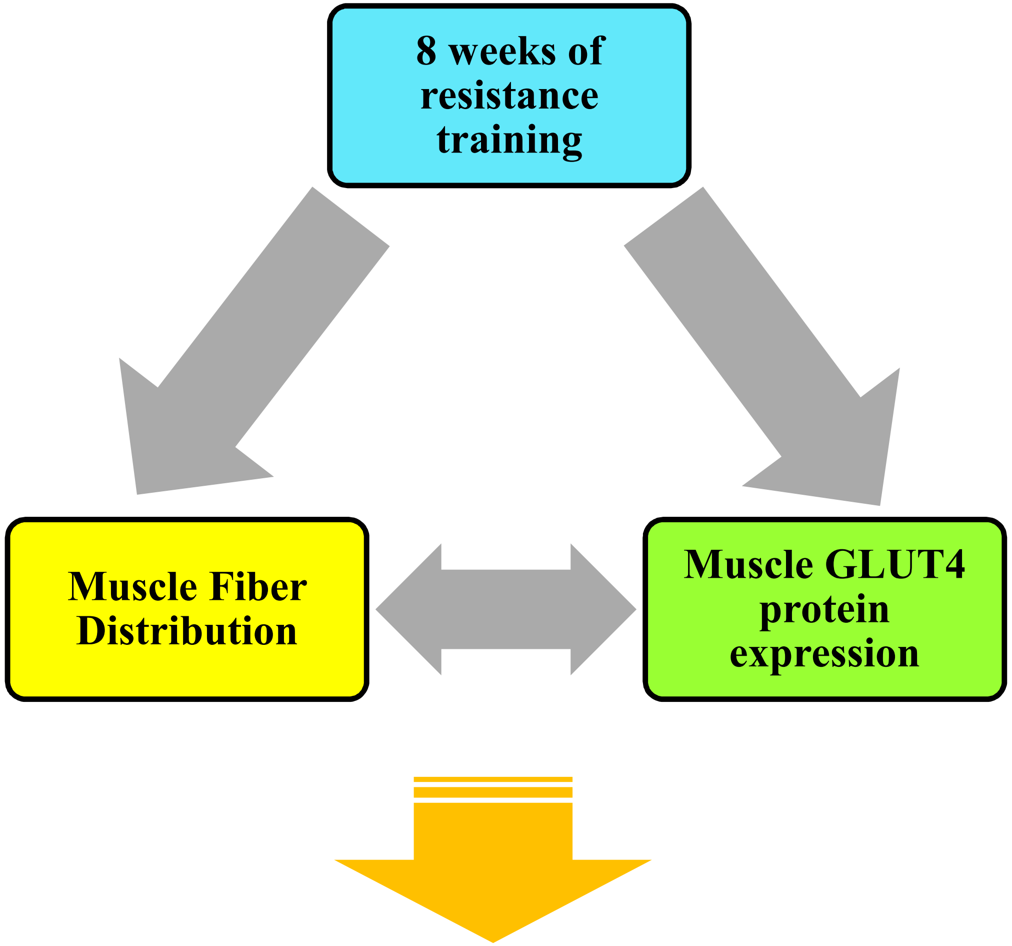
The effects of resistance training on type 2 DM

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 → slow oxidative)**

Purpose of Study

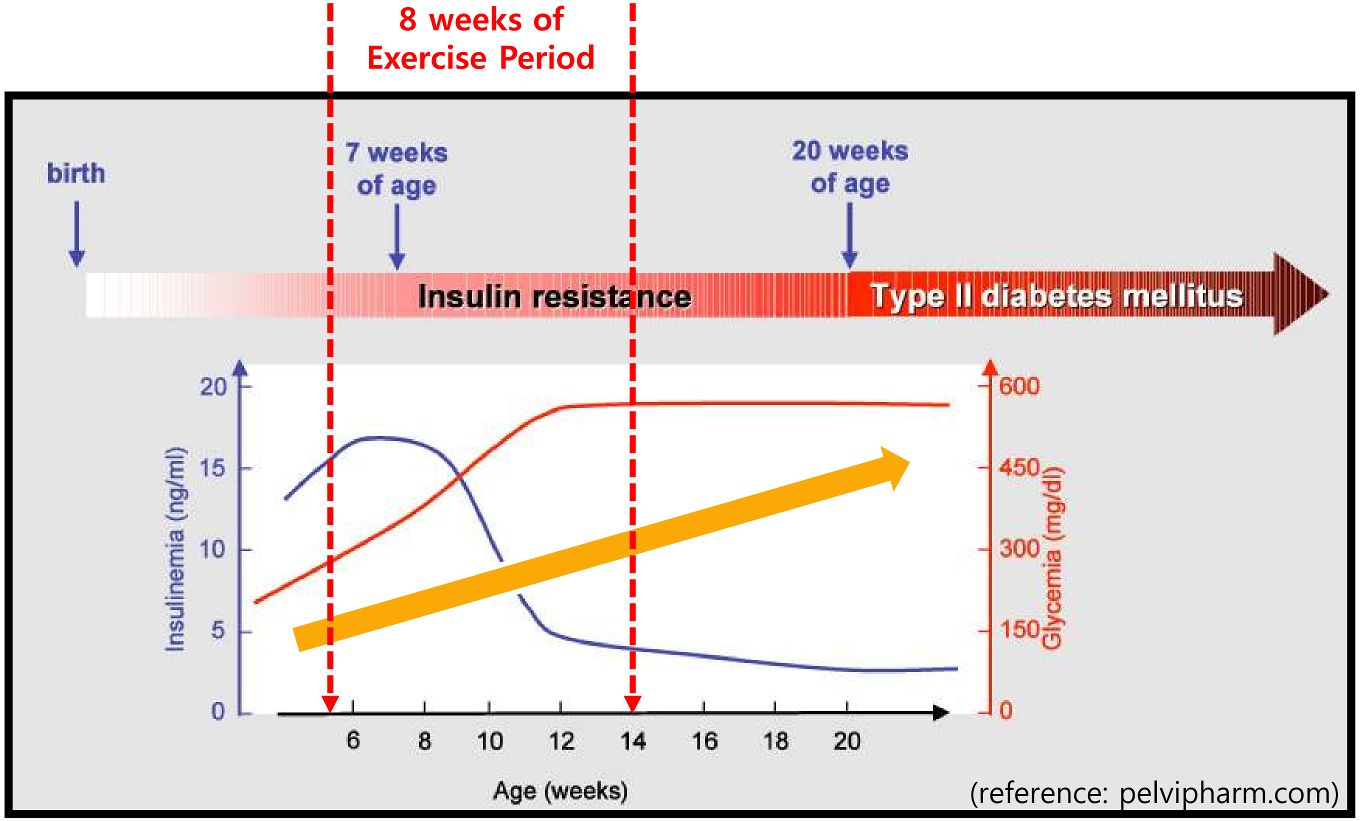
ZUCKER rat
Type 2 diabetic model



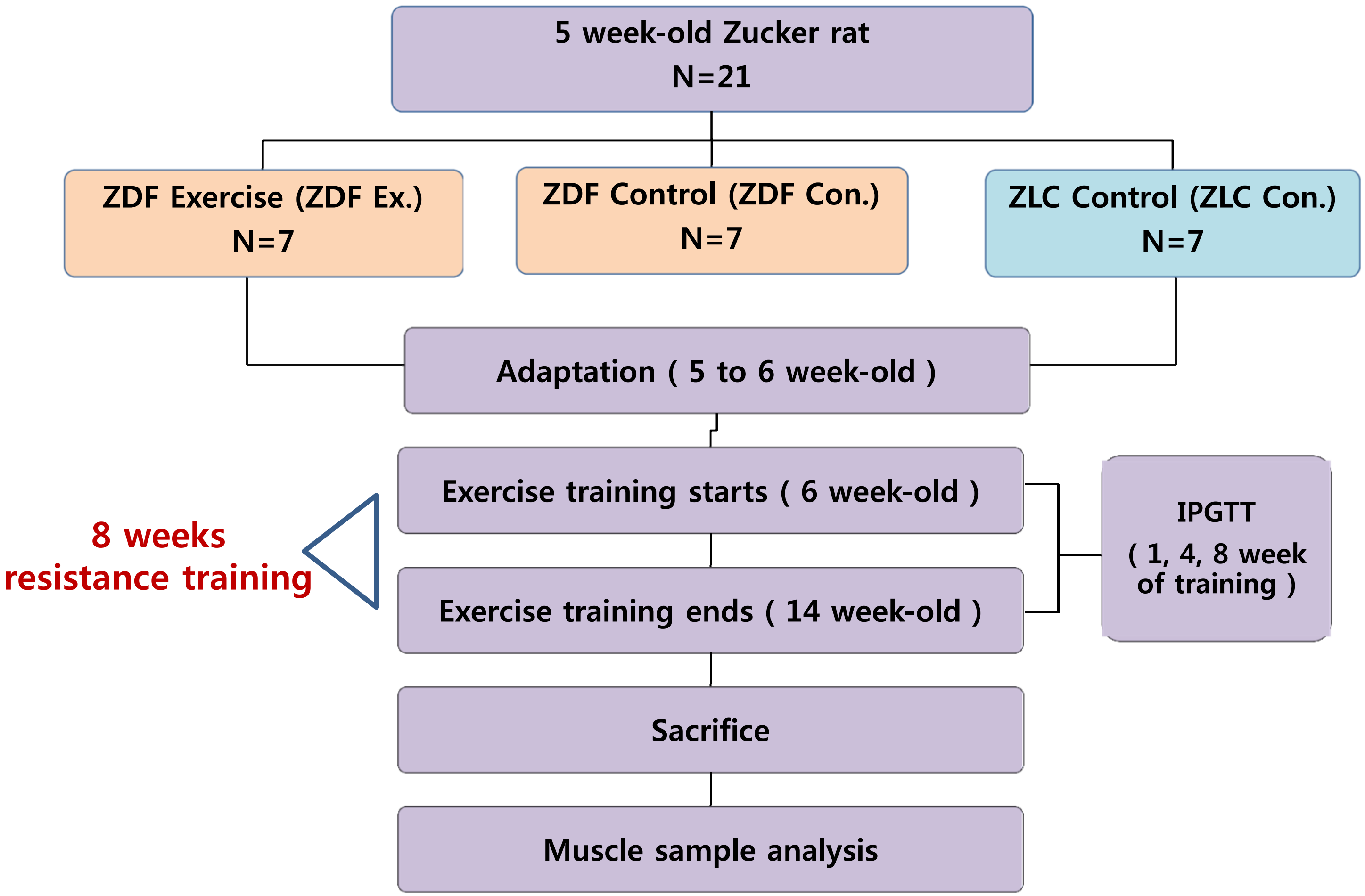
To test whether 8 weeks of resistance training could convert muscle fiber type distribution and enhance glucose metabolism including GLUT4 protein expression in Zucker diabetic fatty(ZDF) rats.

Animal Model

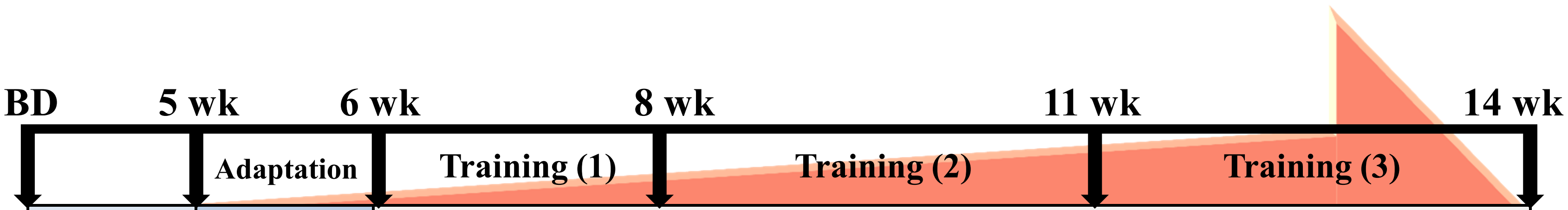
ZDF (Zucker Diabetic Fatty) vs. ZLC (Zucker Lean Control)



Experimental Design



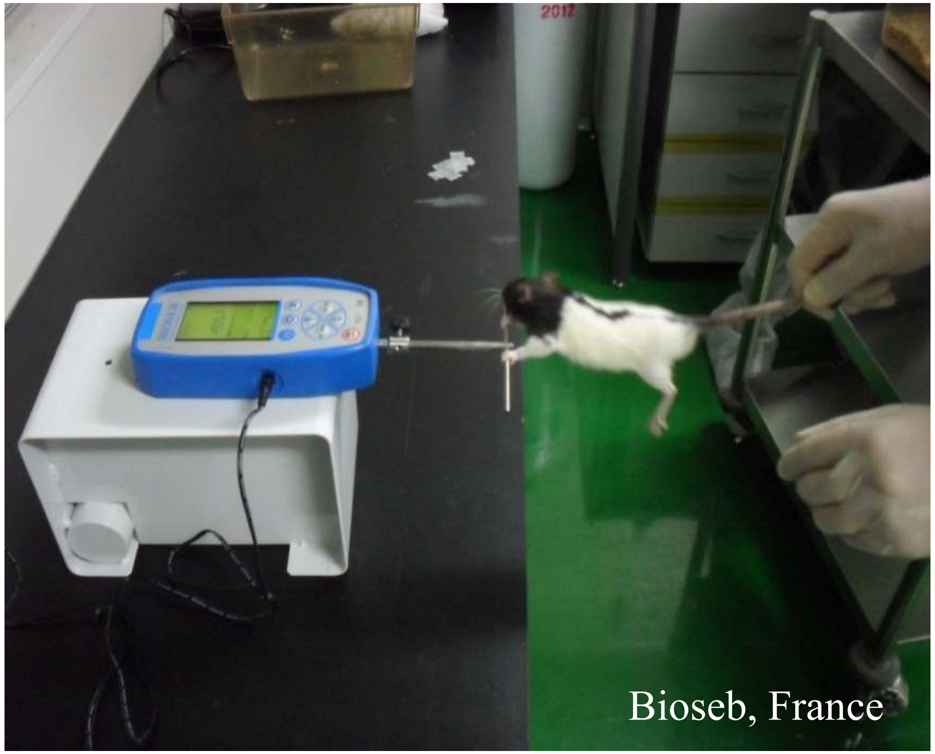
Exercise protocol



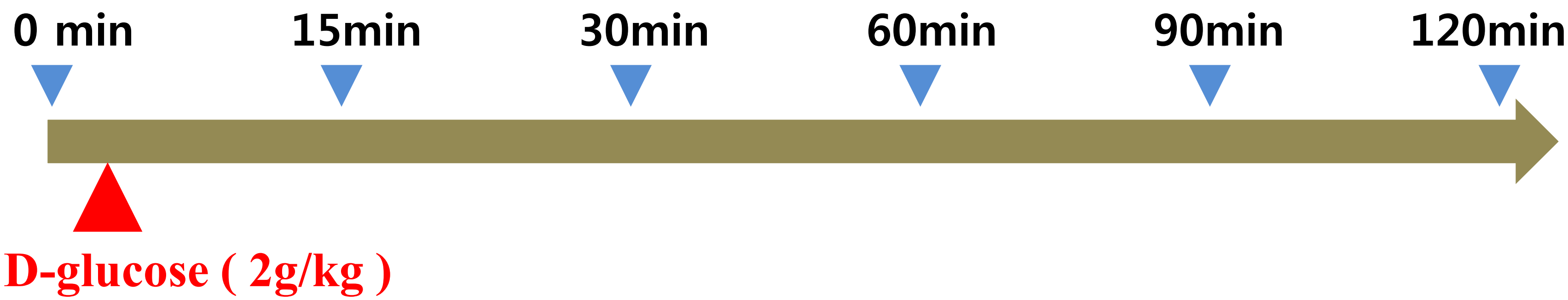
	Adapt-ation (1week)	Exercise Period							
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Reps.	Max.3	Max.10 repetitions							
Load	0g	50% BW / Every trial +20g		70% MW / Every trial +20g			80% MW / Every trial +20g		
Rest	2 mins								
Frequ-ency	3 days/week								

- BD: Birth Day, BW: Body Weight, MW: Maximal Weight

Laddering exercise & Grip strength



Intraperitoneal glucose tolerance test (IPGTT)



RESULTS

RESULTS (1)

Body weight and muscle weight

Table 1. Body weight and gastrocnemius muscle characteristics

Variable	ZLC-Con	ZDF-Con	ZDF-Ex
	Mean ± S.E.M.		
Body weight (g)	272 ± 5.35	364.5 ± 13.57***(.002)**	371.5 ± 17.42(.925)
Muscle wet weight (mg)	586.25 ± 17.60	505 ± 15.14(.070)	556.25 ± 30.85(.285)
Muscle wet weight/body weight (mg/g)	2.16±0.09	1.39±0.03****(.000)**	1.50±0.18(.512)

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

Variable	1 wk	2 wk	3 wk	4wk	5wk	6wk	7wk	8wk
	Mean ± S.E.M.							
Maximal weight lifted (g)	240 ± 12.25	330 ± 21.21	420 ± 46.19	497.5 ± 36.14	625 ± 31.75	670 ± 34.88	745 ± 26.3	785 ± 2.89
Maximal weight lifted / body weight (g/g)	1.77 ± 0.18	1.62 ± 0.08	1.77 ± 0.10	1.83 ± 0.07	2.12 ± 0.03	2.13 ± 0.02	2.15 ± 0.01	2.13 ± 0.09

Values are mean± S.E.M.; n=4/group

RESULTS (3)

Grip strength

Table 3. Grip strength test

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

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)

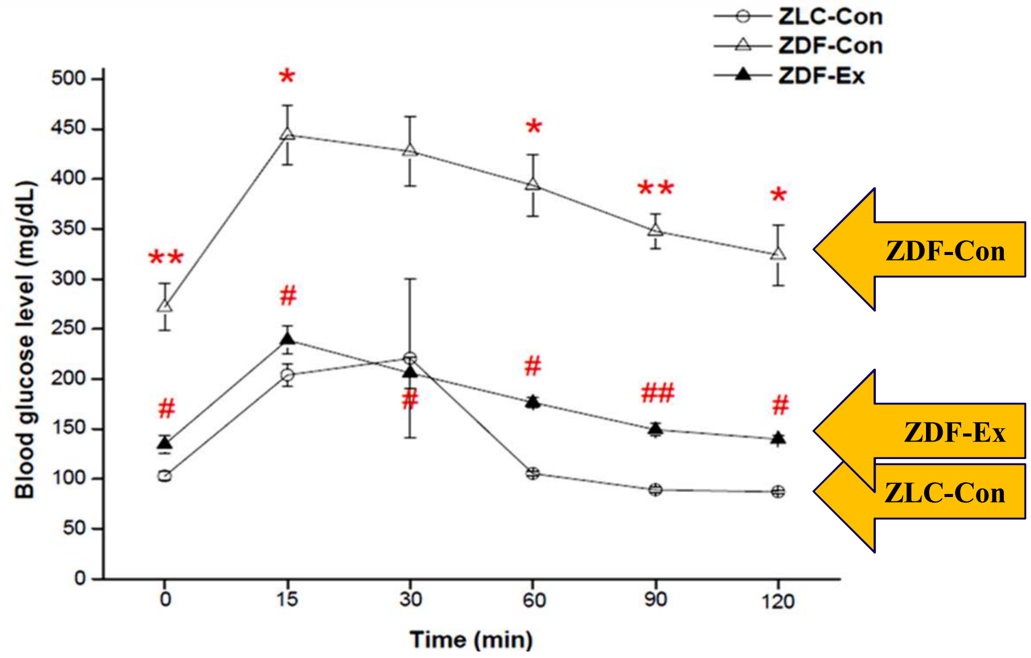
Glucose tolerance (IPGTT)

▶ **Table 4. Changes of fasting blood glucose level**

Variable (mg/dL)	ZLC-Con	ZDF-Con	ZDF-Ex
	Mean ± S.E.M.		
Fasting blood glucose level of 1st week of training	97 ± 3.03	108.5 ± 12.71(.564)	111.5 ± 2.87(.959)
Fasting blood glucose level of 4st week of training	100.25 ± 3.54	217.25 ± 71.69(.169)	115.75 ± 2.63(.247)
Fasting blood glucose level of 8st week of training	102.75 ± 4.48	272 ± 23.56**(.000)**	134.75 ± 8.87††**(.000)**

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)

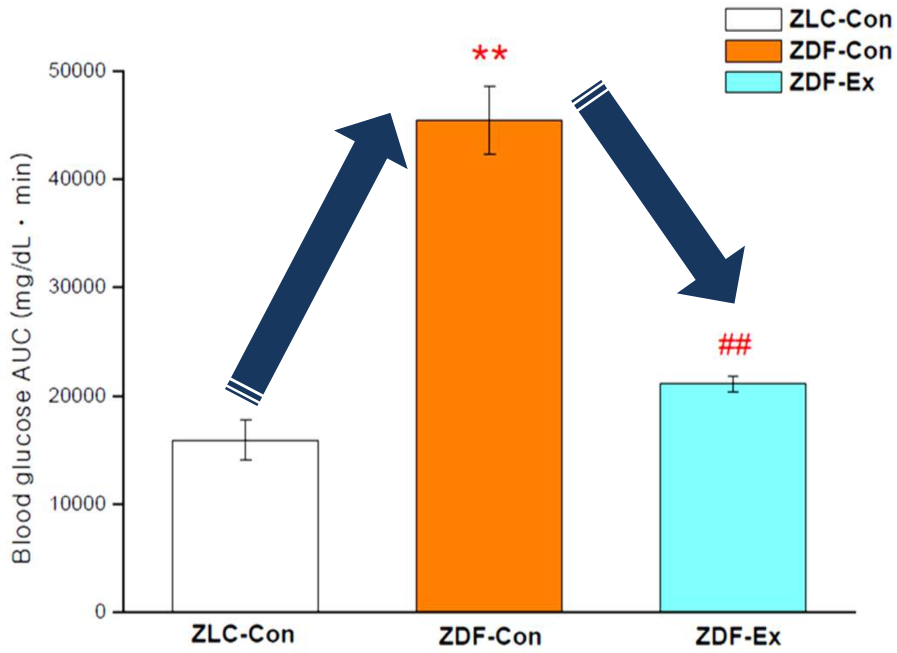
Glucose tolerance (AUC)

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

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

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 ($p<0.001$).

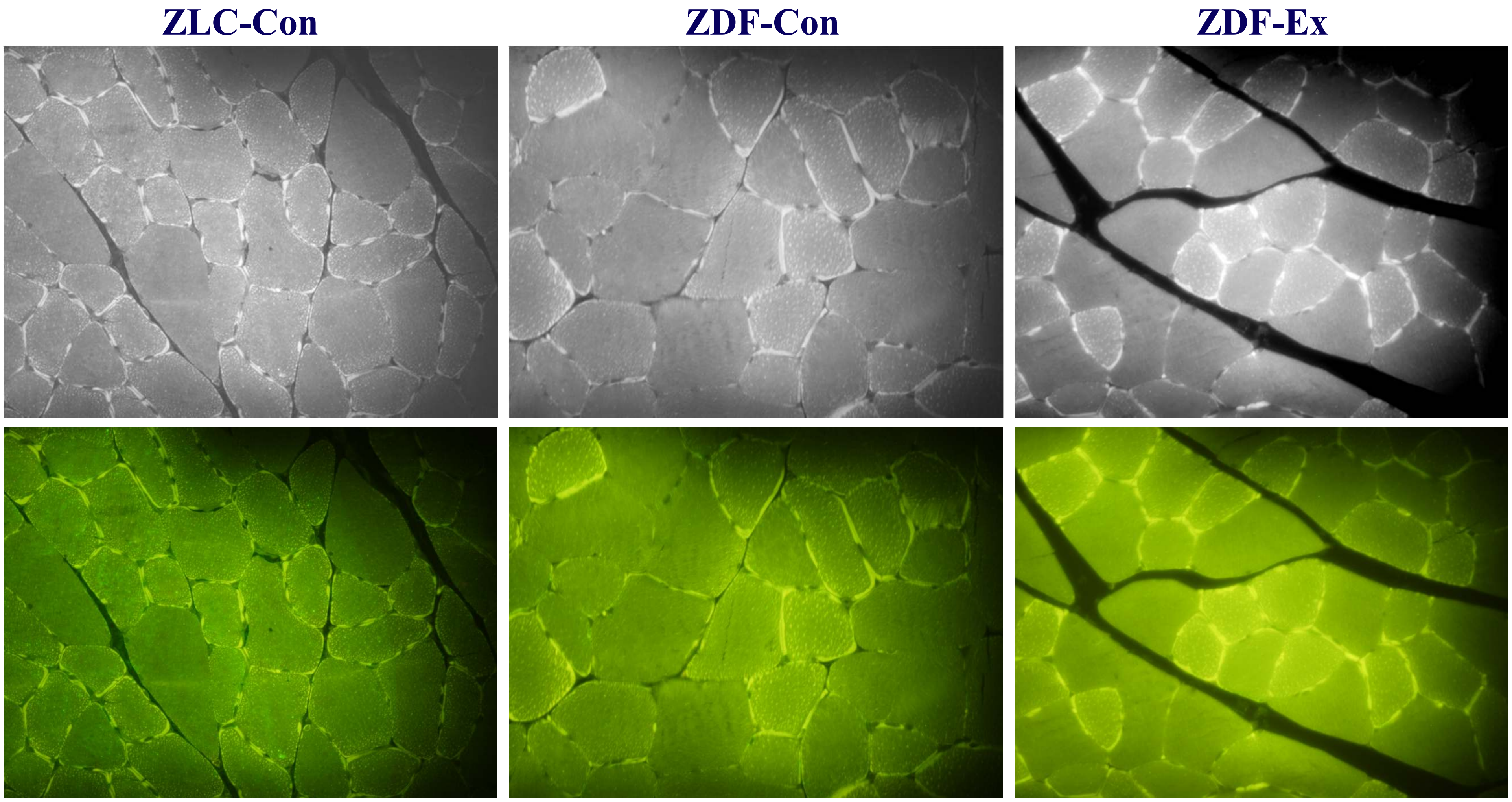
Figure 2. Blood glucose AUC



RESULTS (5)

Immunofluorescence staining – GLUT4

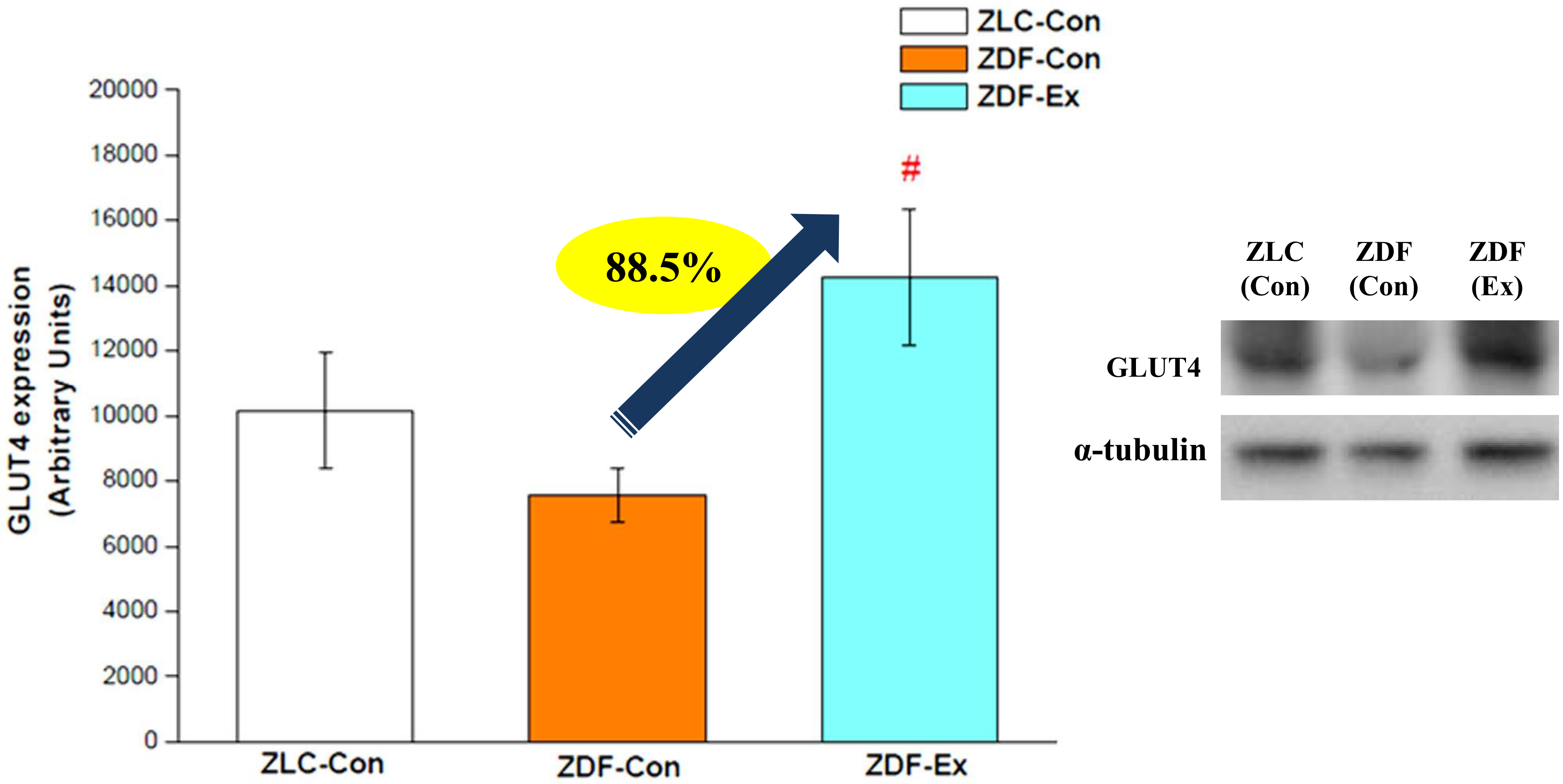
Figure 3 . Immunofluorescence staining for medial gastrocnemius muscle GLUT4 protein



RESULTS (6)

Western blot

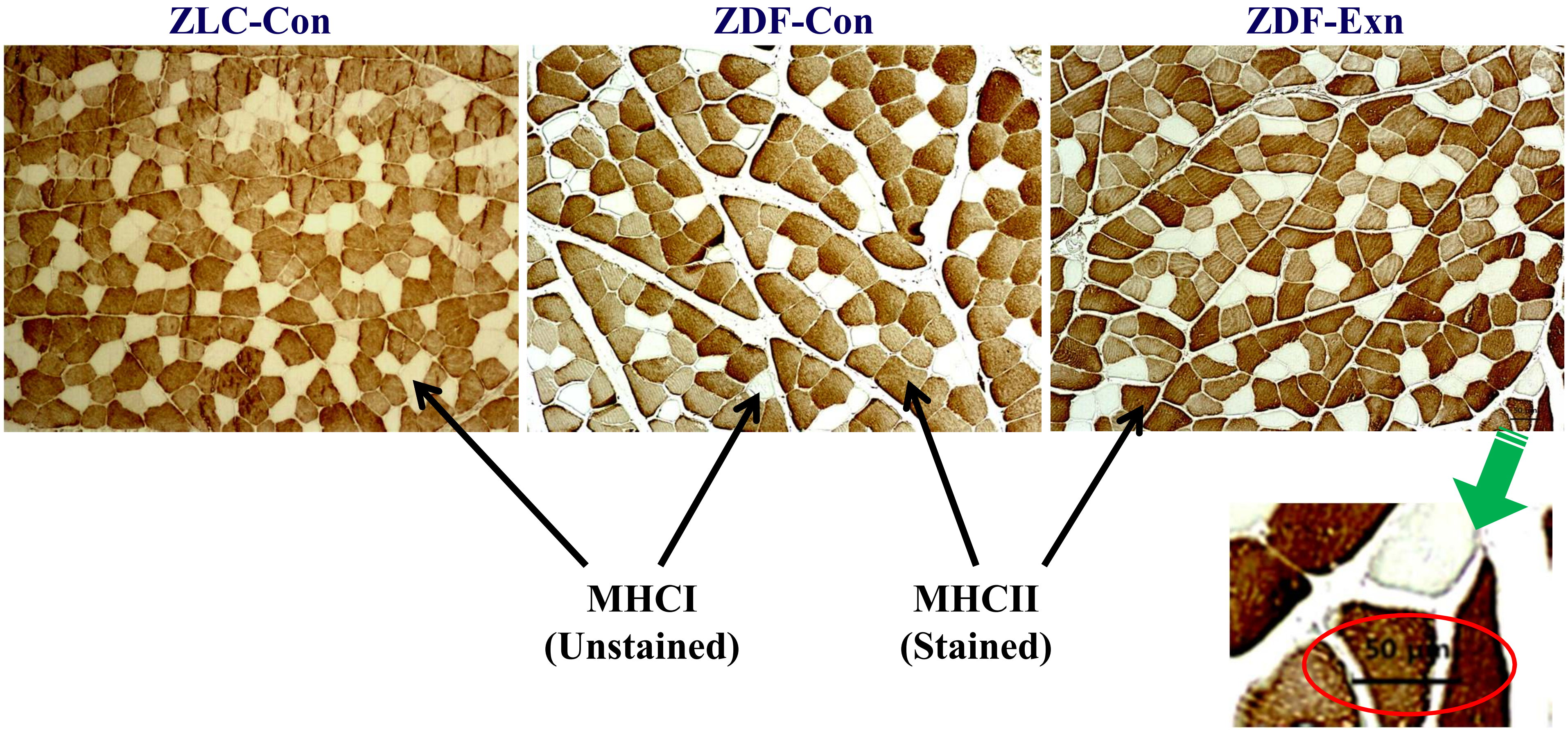
Figure 4. GLUT4 protein expression in gastrocnemius muscle



RESULTS (7)

Immunohistochemical staining – Myosin Heavy Chain (MHC)

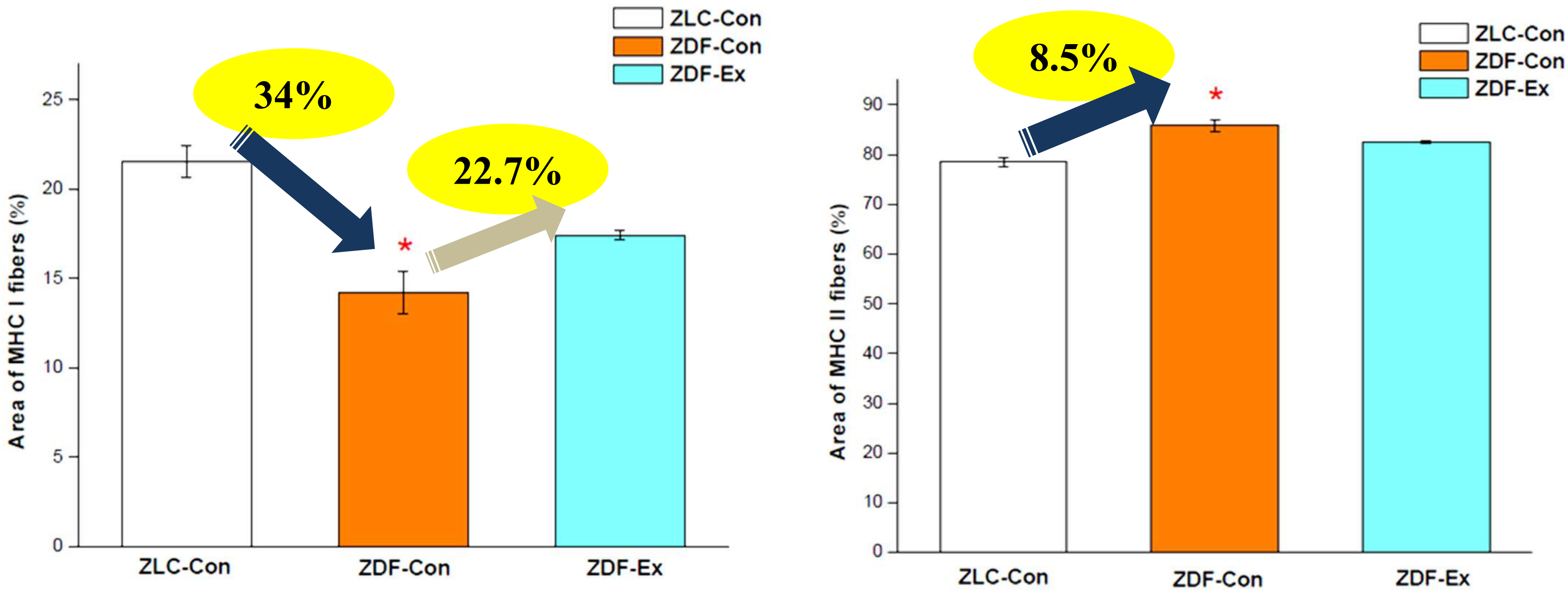
▶ **Figure 5. Immunohistochemical staining on cross sectional area of gastrocnemius muscles**



RESULTS (8)

Immunohistochemical staining – Myosin Heavy Chain (MHC)

Figure 6. Area of muscle fiber type



연구 2

(김희재)

동물 당뇨모델 (Zucker)에서 운동에 따른 Myokine의 변화

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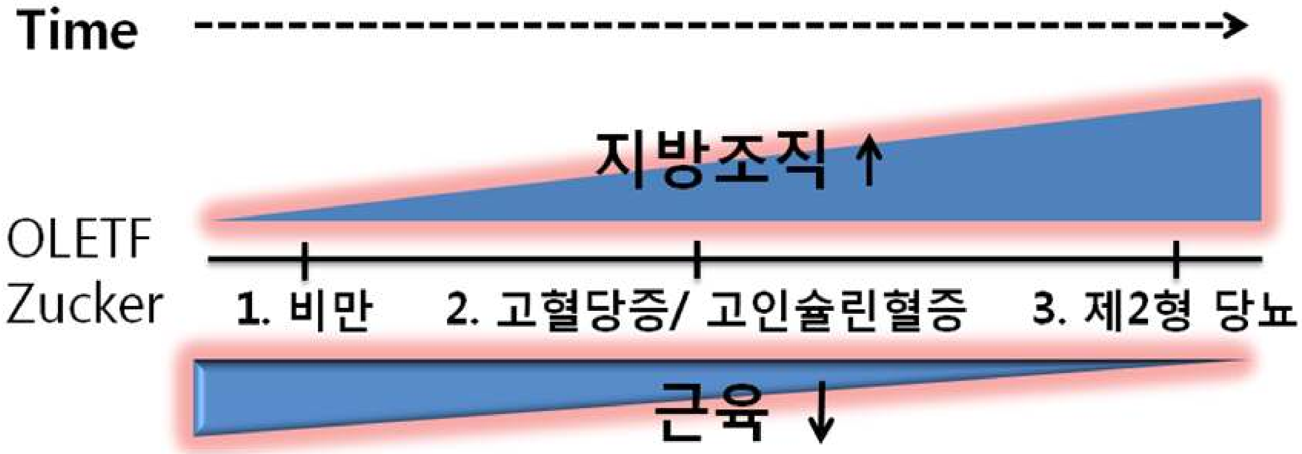
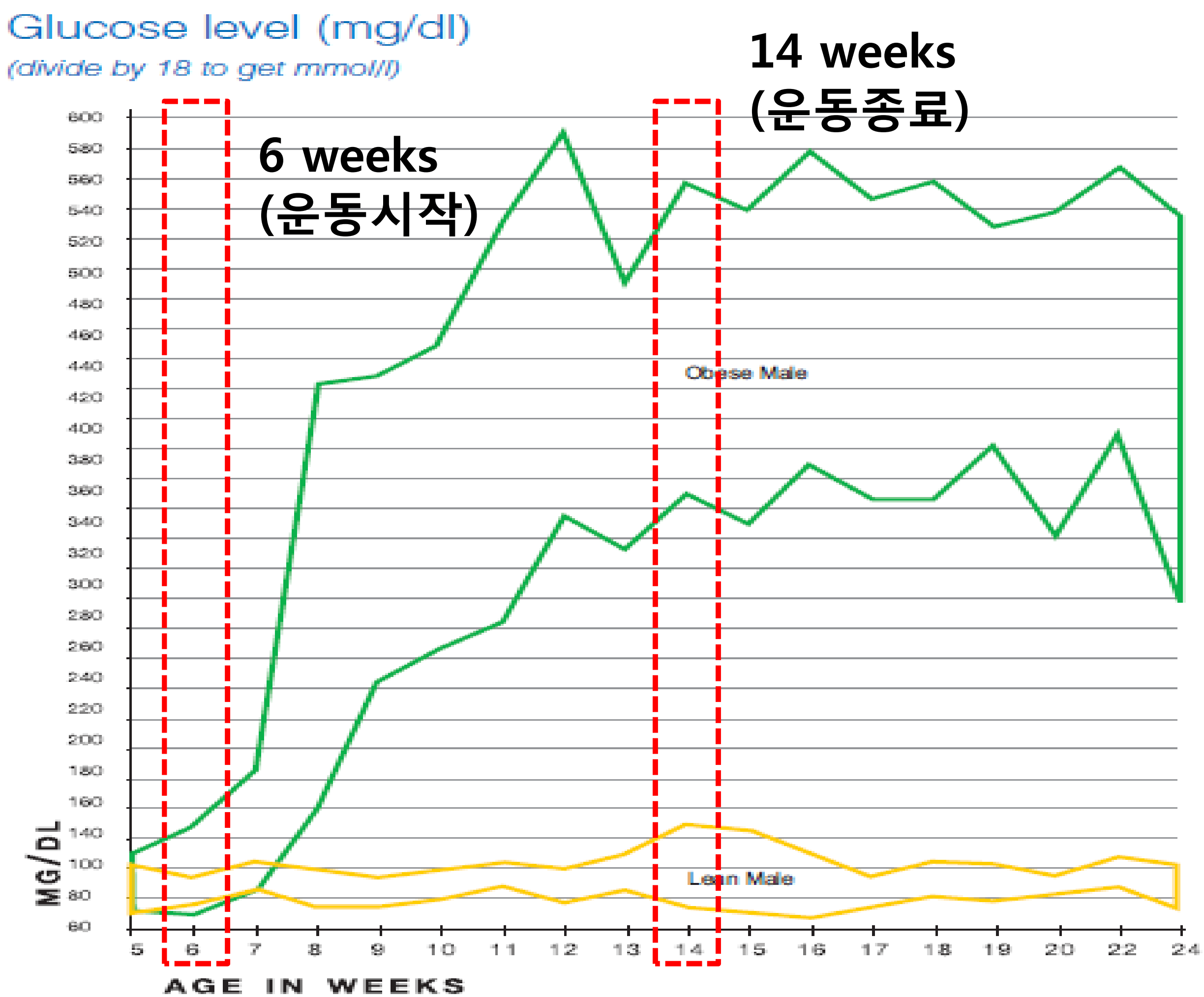
건강운동과학연구실

Animal study (Zucker)

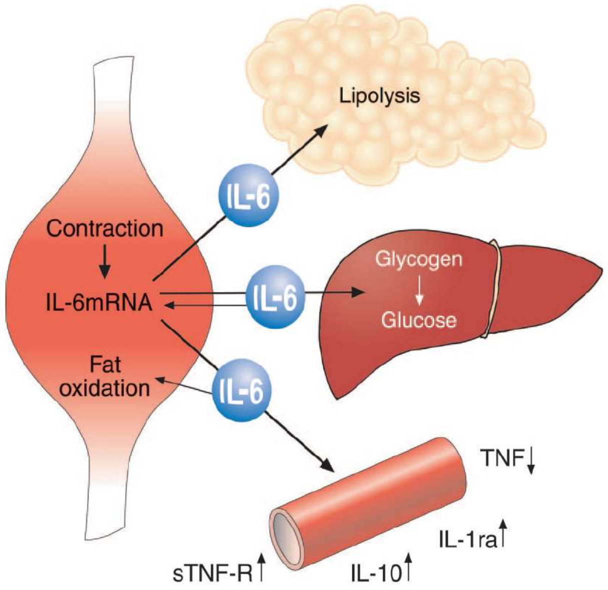


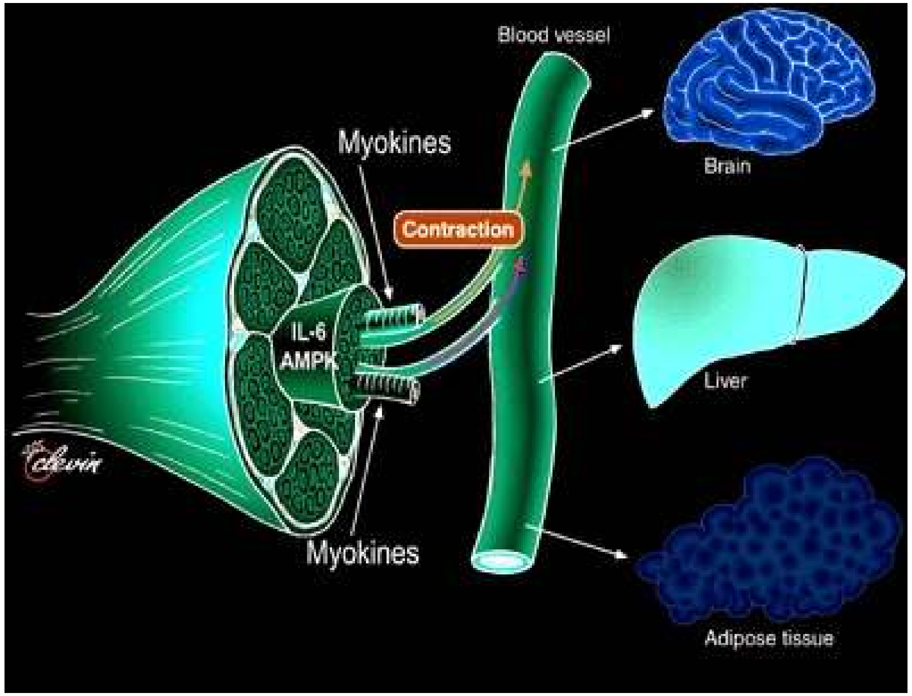
Animal study (Zucker)



Myokine

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

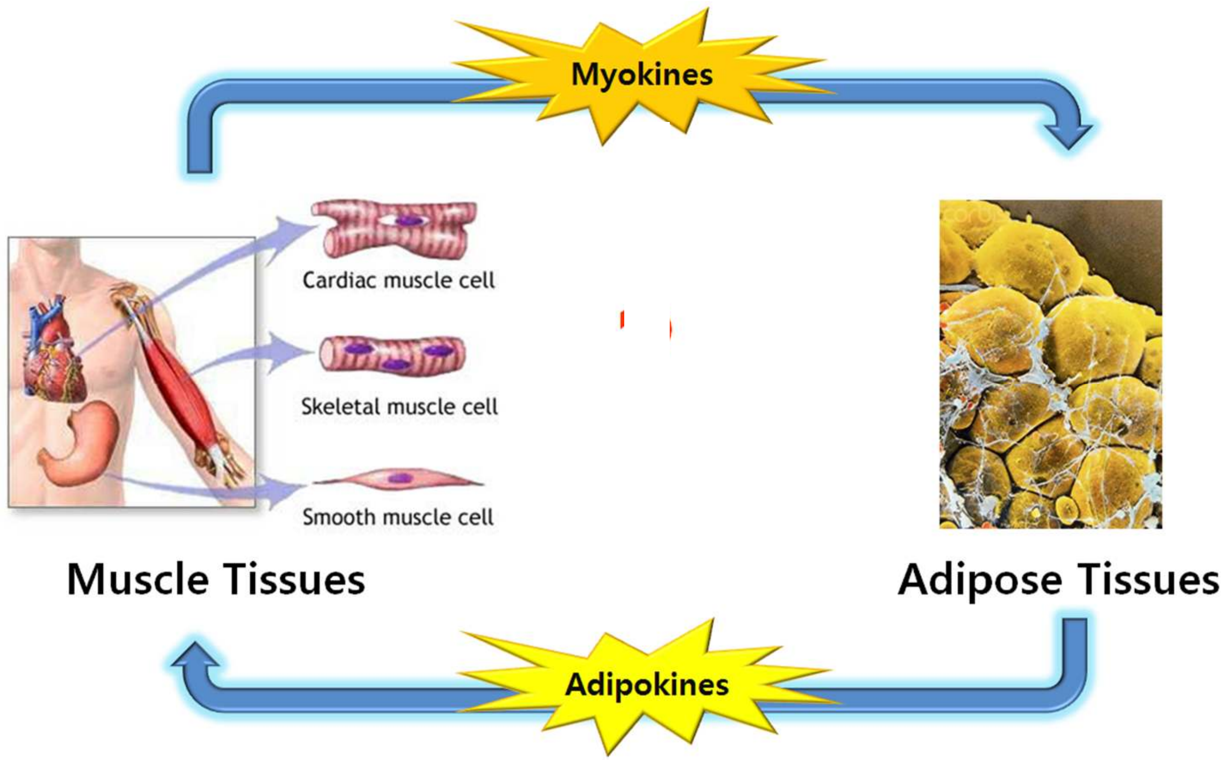




Bente K. Pedersen (2012)

IL-15: A role in muscle-fat cross talk

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.

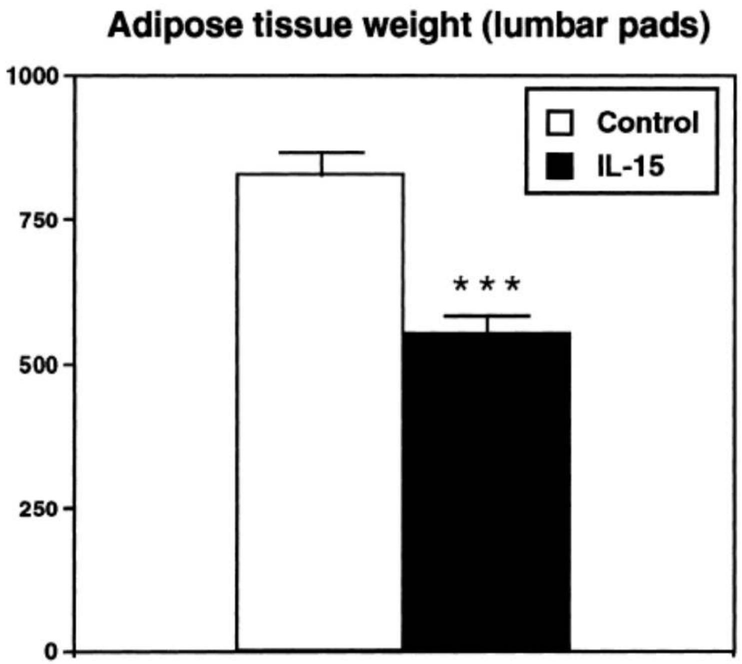


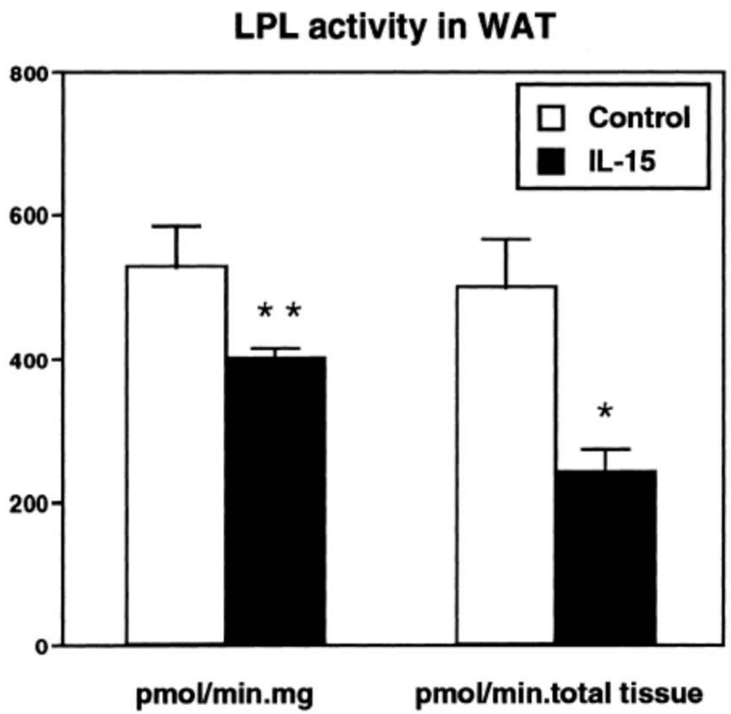
Interleukin-15

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.

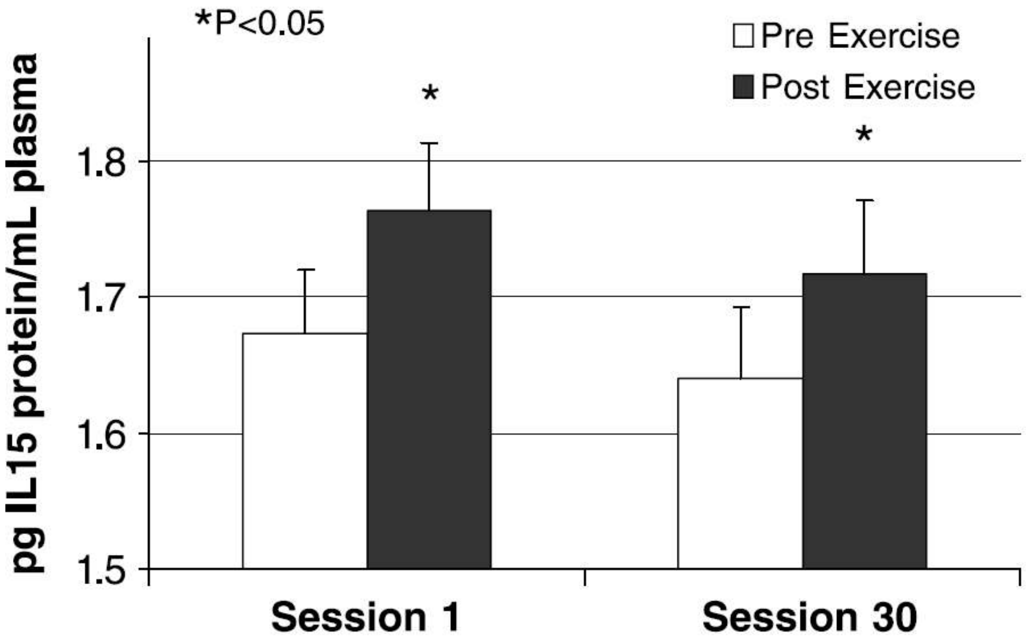
(Biochimica et Biophysica Acta 1526 (2001) 17~24)





Interleukin-15

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).*

J Appl Physiol. 2004 Dec;97(6):2214-9.

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)

Type	Intensity	Duration	Frequency	Contents
Endurance Exercise	15 ~ 20 m/min	60 min	5 times/week	Exercise Group

DMJ, 2013 Accepted

Effect of treadmill exercise on IL-15 in Zucker rats

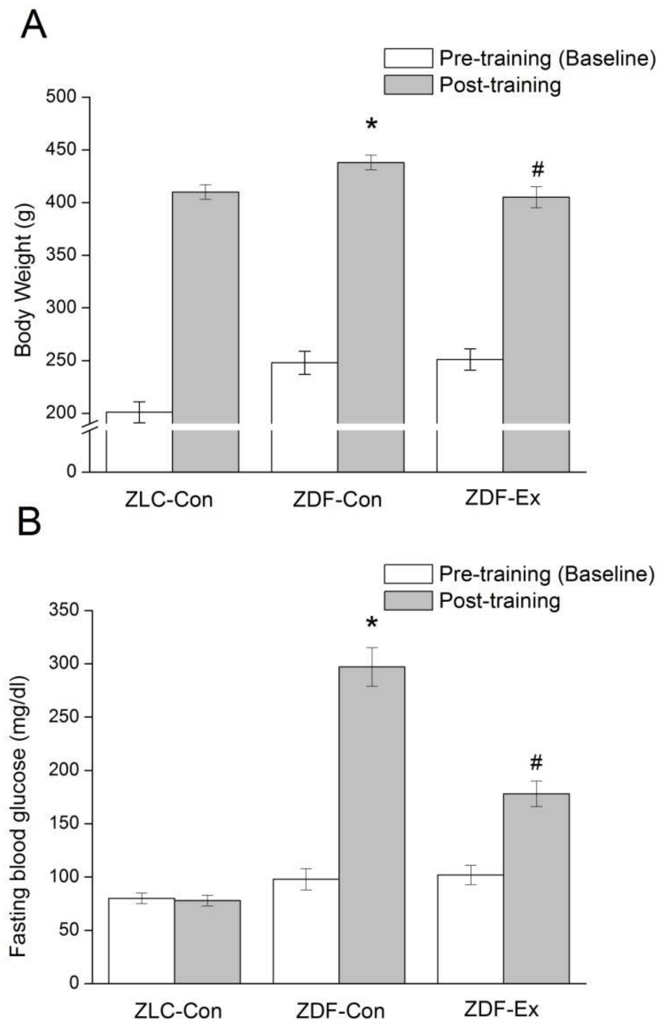


Fig. 1 (A) **Body weight** and (B) **fasting glucose levels** **were reduced** following treadmill exercise

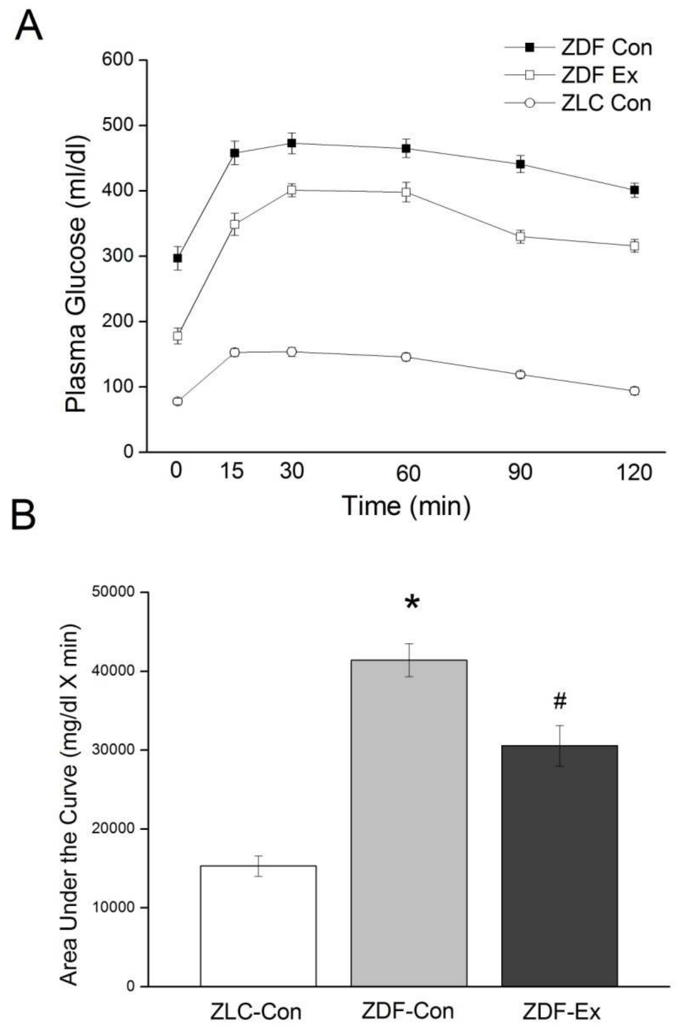


Fig. 2 **Glucose tolerance** was **significantly improved** following treadmill exercise

DMJ, 2013 Accepted

Effect of treadmill exercise on IL-15 in Zucker rats

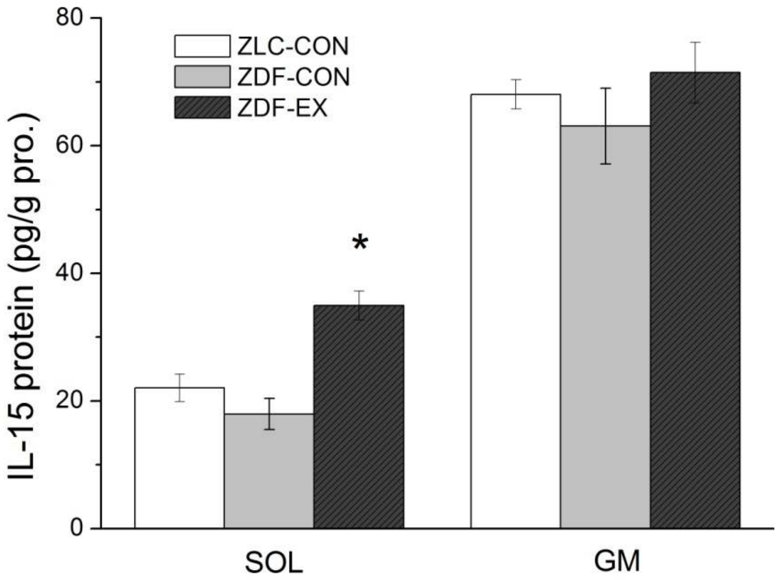


Fig. 3. **IL-15 protein expression** was increased in SOL of ZDF rats

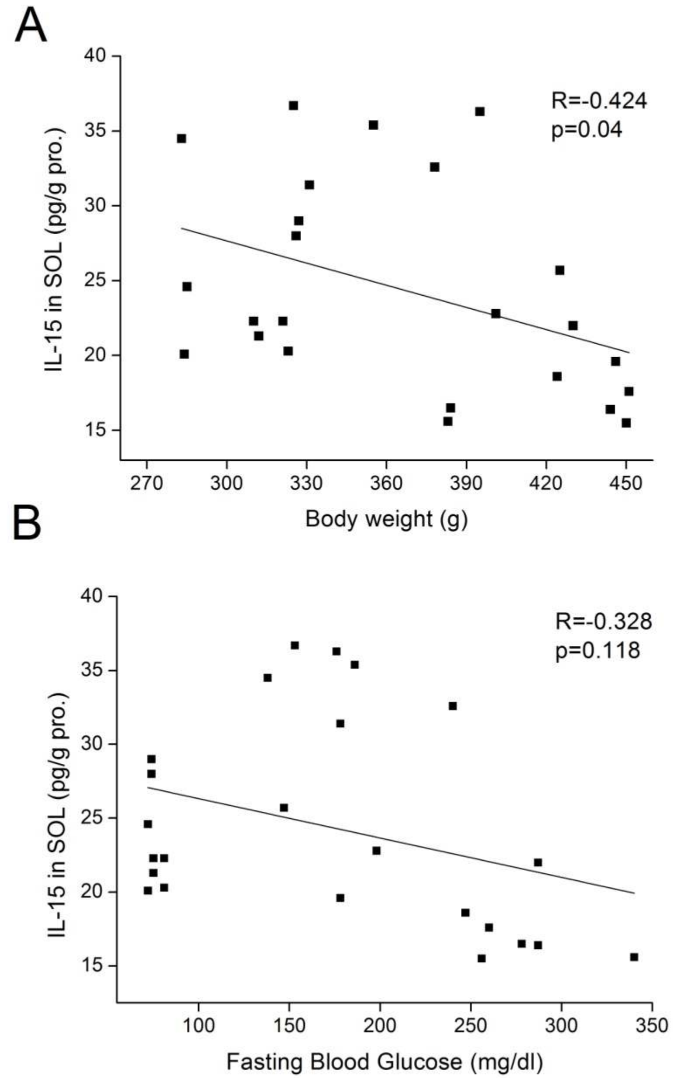
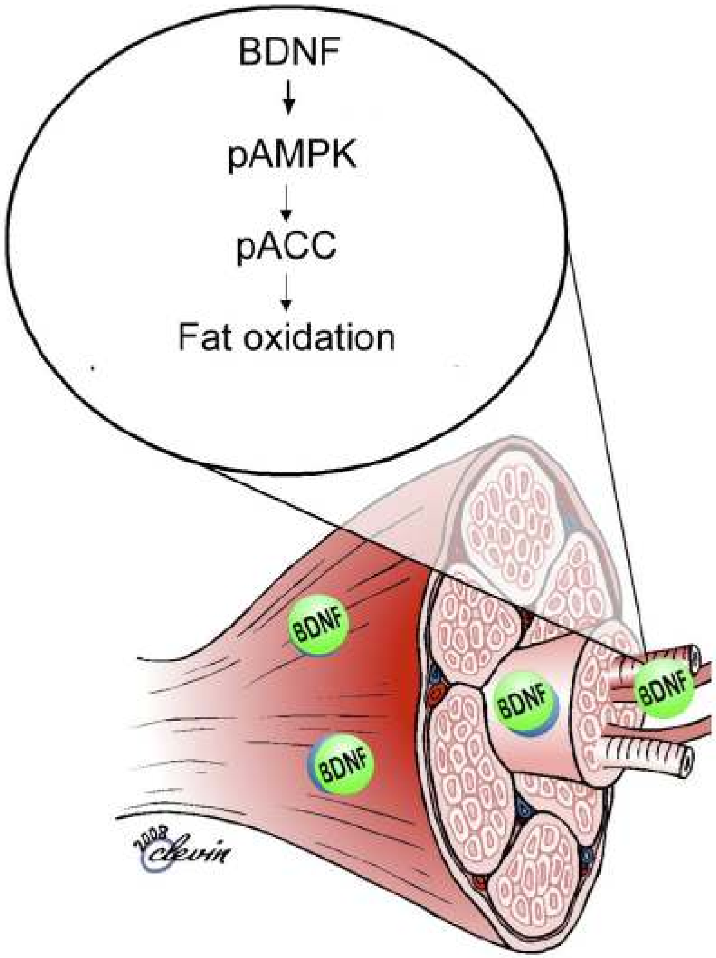


Fig. 4. **Body weight** and **fasting glucose levels** were **negatively correlated with IL-15** protein expression in SOL of ZDF rats

DMJ, 2013 Accepted

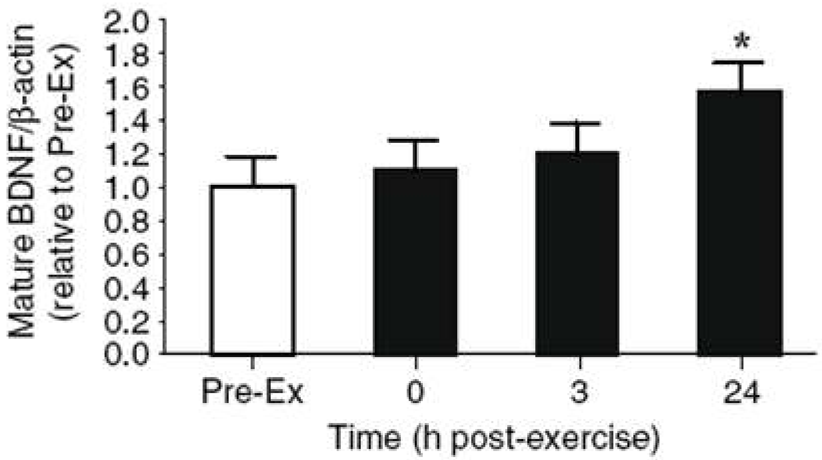
BDNF: A role in neurobiology and metabolism



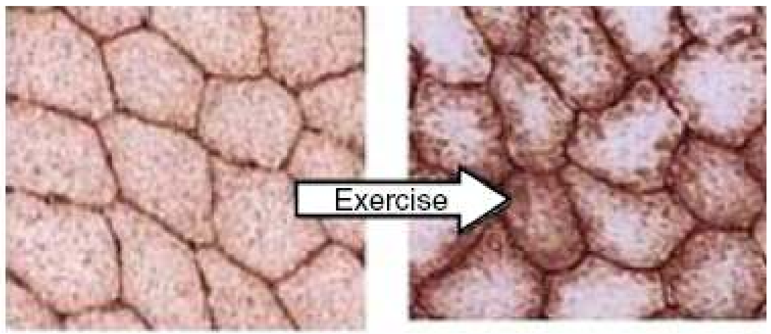
In response to muscle contractions, **BDNF mRNA** and **protein** expression are markedly increased in human skeletal muscle after exercise.

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.**

High intensity Cycle exercise



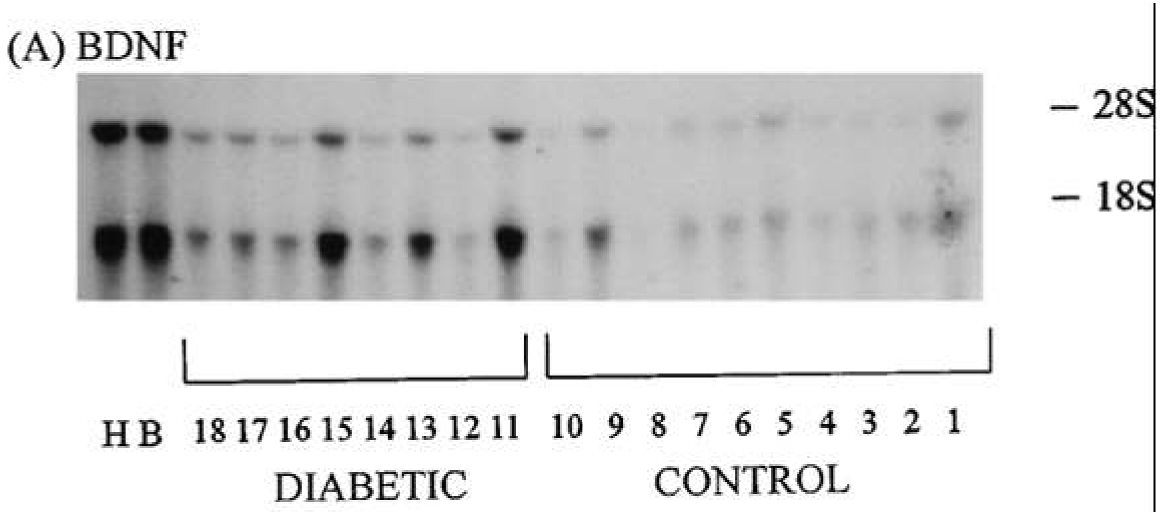
24 h

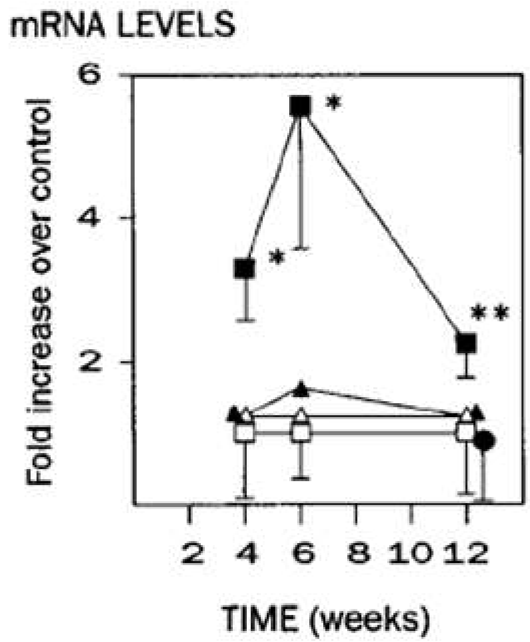


Muscle BDNF and Type 2 DM

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)*



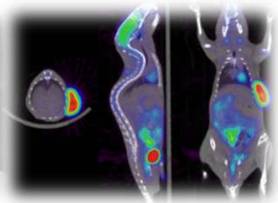


Effect of resistance training on BDNF expression in diabetic skeletal muscles: relation to muscle quality

Experimental group

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






1 week adaptation

IPGTT, Grip-strength test
PET-CT
Tissue collection

8 weeks training

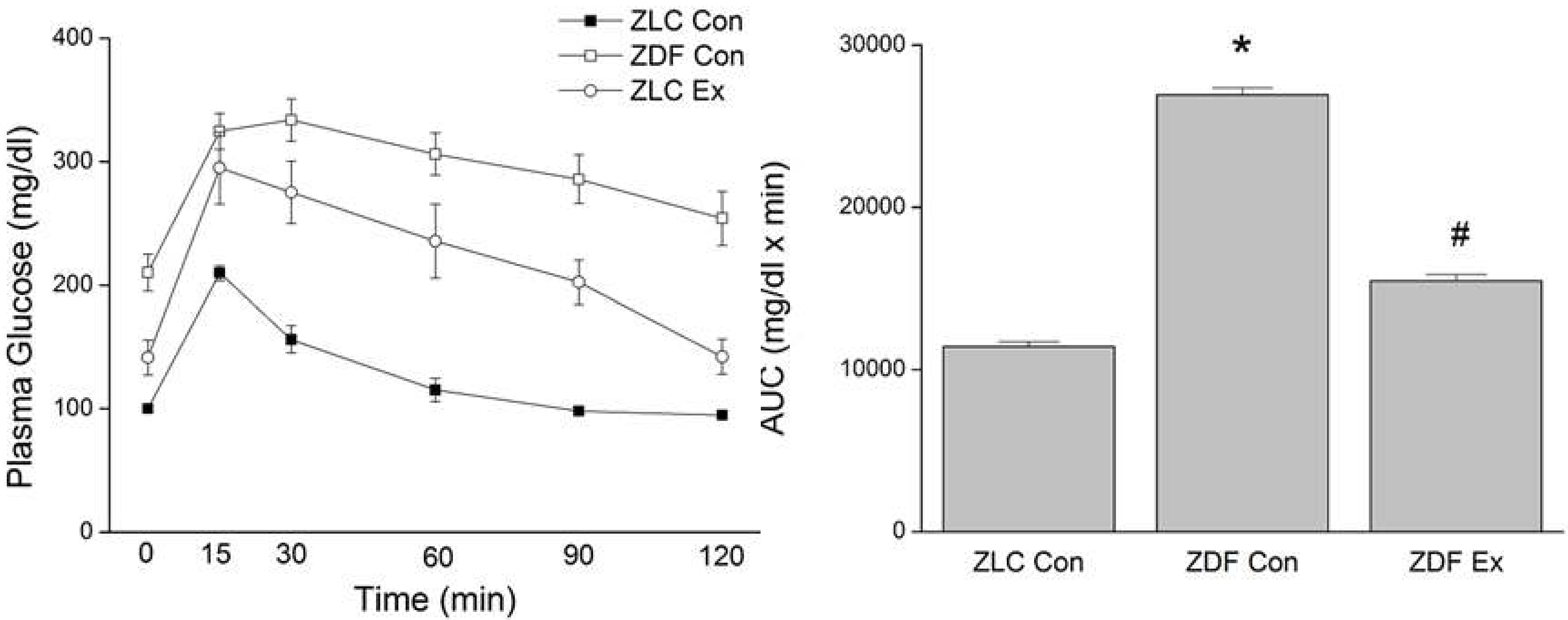
In Preparation: unpublished data

Changes of body weight, grip-strength and plasma glucose

	Body weight		Grip-strength		Plasma glucose	
	Pre-Ex	Post-Ex	Pre-Ex	Post-Ex	Pre-Ex	Post-Ex
ZLC Con	110.16 ± 2.04	256.33 ± 5.07	3023.4 ± 125.4	3231.84 ± 132.3	105.43 ± 2.54	100.33 ± 2.75
ZDF Con	116.66 ± 2.29	370.04 ± 9.87*	2975.3 ± 105.3	2760.14 ± 98.4*	110.33 ± 2.98	210.33 ± 34.97*
ZDF Ex	116.96 ± 2.21	341.4 ± 1.21#	3004.3 ± 98.43	3191.23 ± 100.3#	109.43 ± 0.92	141.63 ± 24.19#

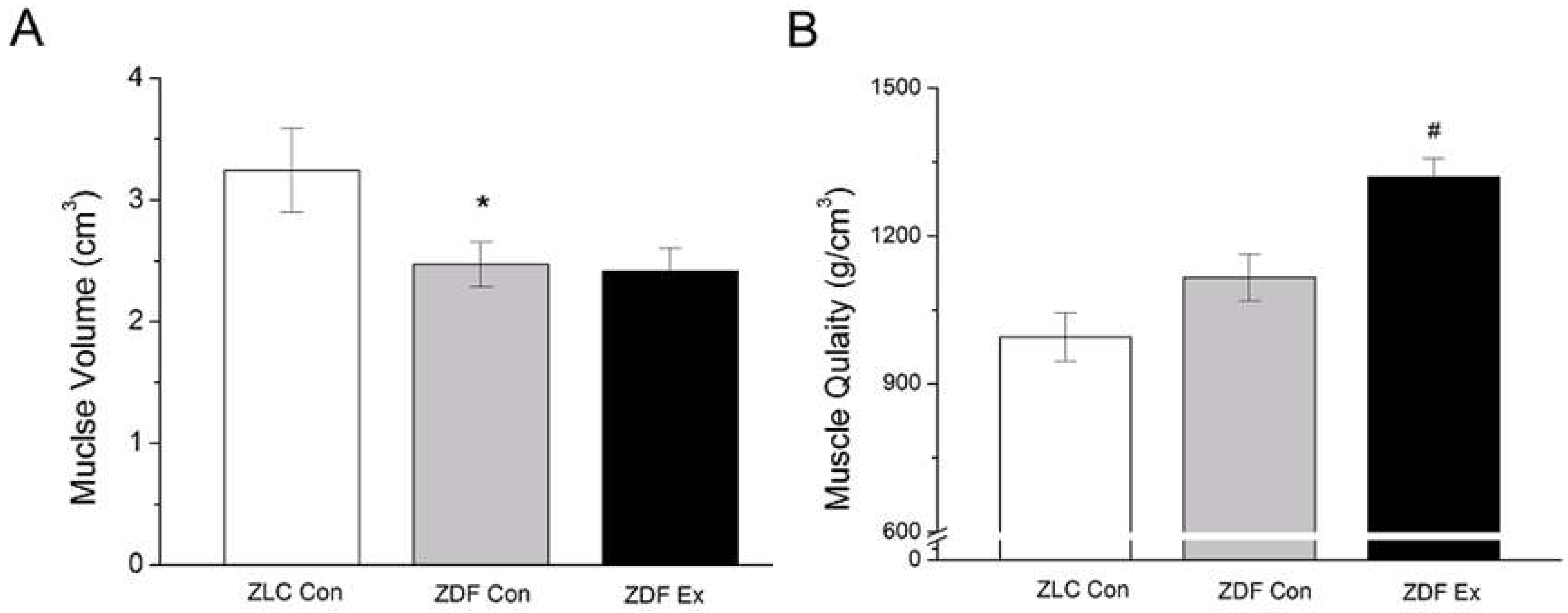
*: ZLC Con vs. ZDF Con
#: ZDF Con vs. ZDF Ex

Glucose tolerance test (IPGTT, AUC)



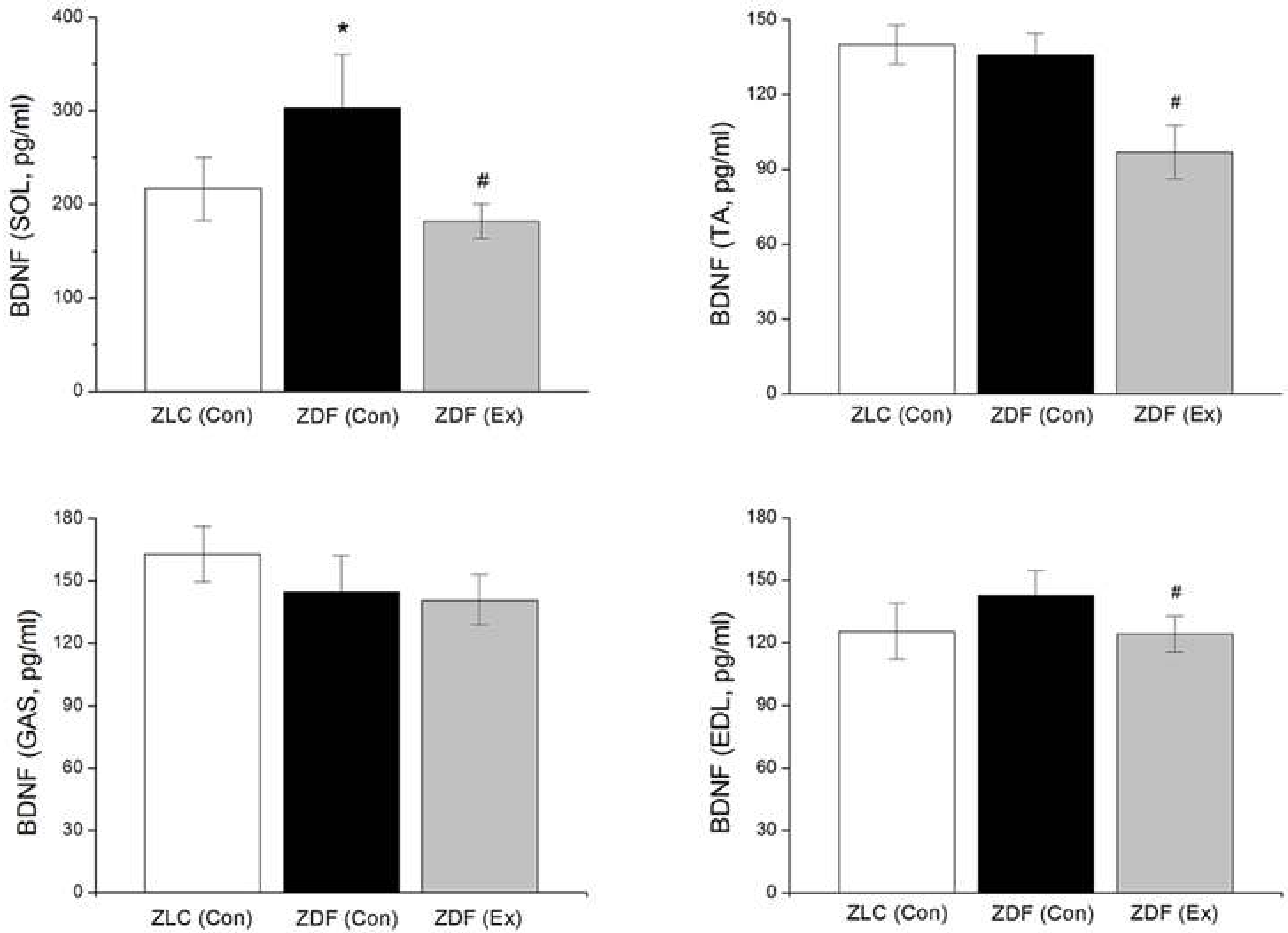
*: ZLC Con vs. ZDF Con
#: ZDF Con vs. ZDF Ex

Muscle Volume, Muscle Quality
(measured by PET-CT)

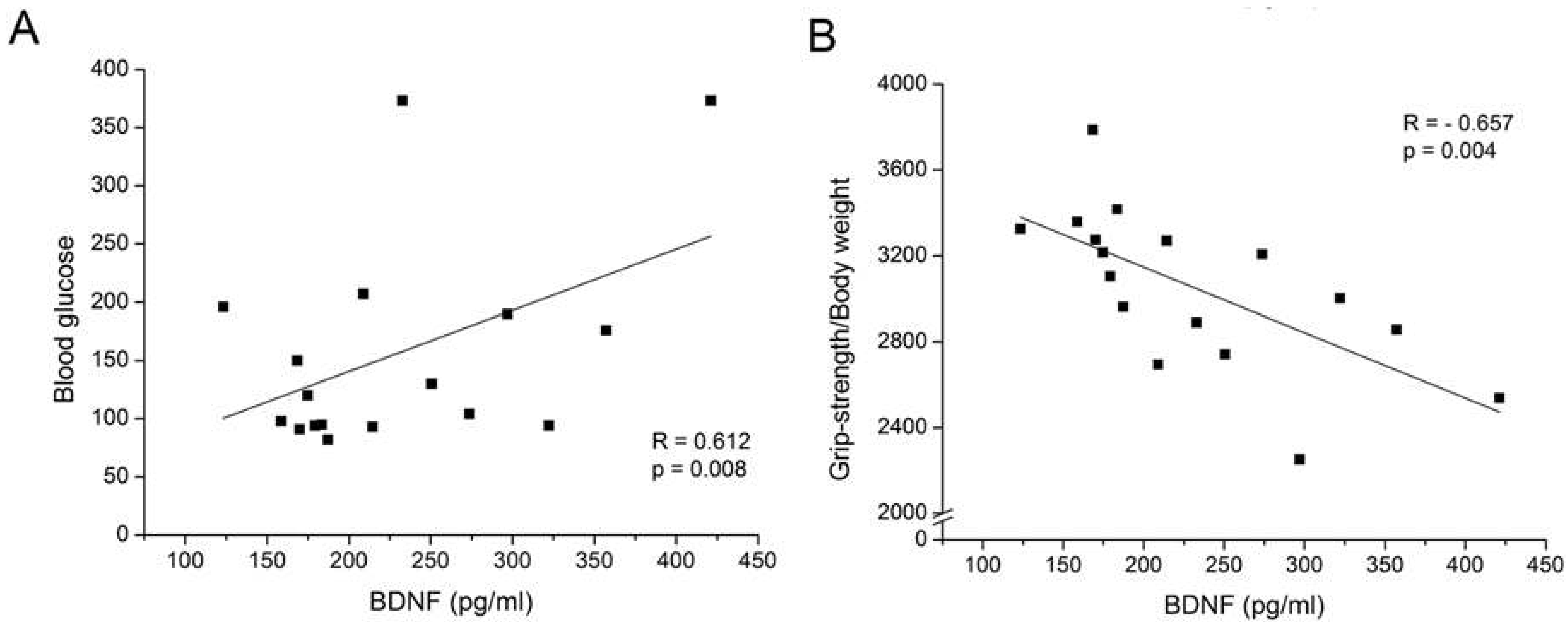


*: ZLC Con vs. ZDF Con
#: ZDF Con vs. ZDF Ex

BDNF expression in skeletal muscle



Relation of BDNF to FBG & muscle strength



연구 3
(이효주)

유산소 및 저항성 운동이 비만인의 혈중 Irisin에 미치는 영향

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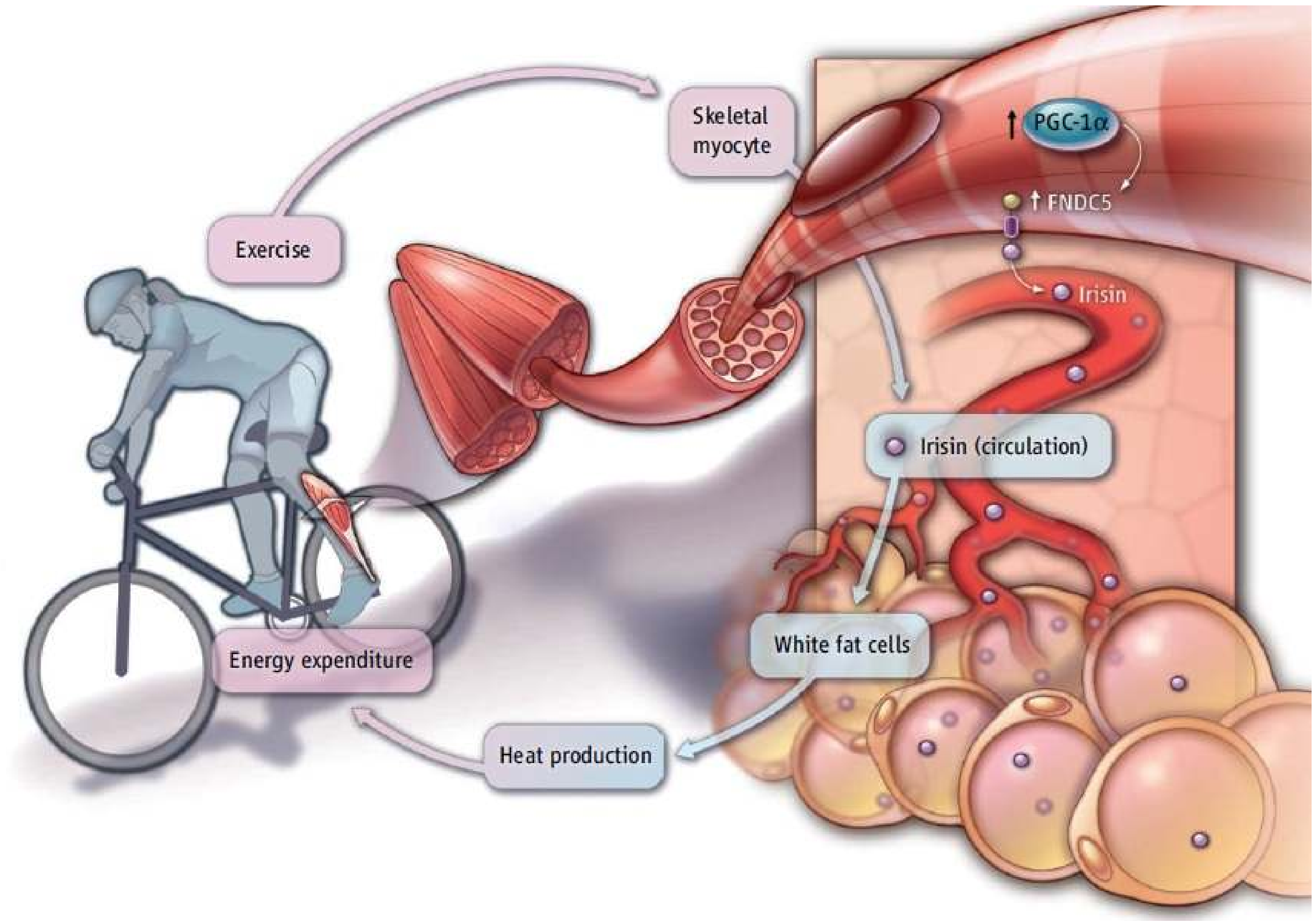
건강운동과학연구실

Irisin

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



(Kelly, Science 2012)

Introduction of irisin

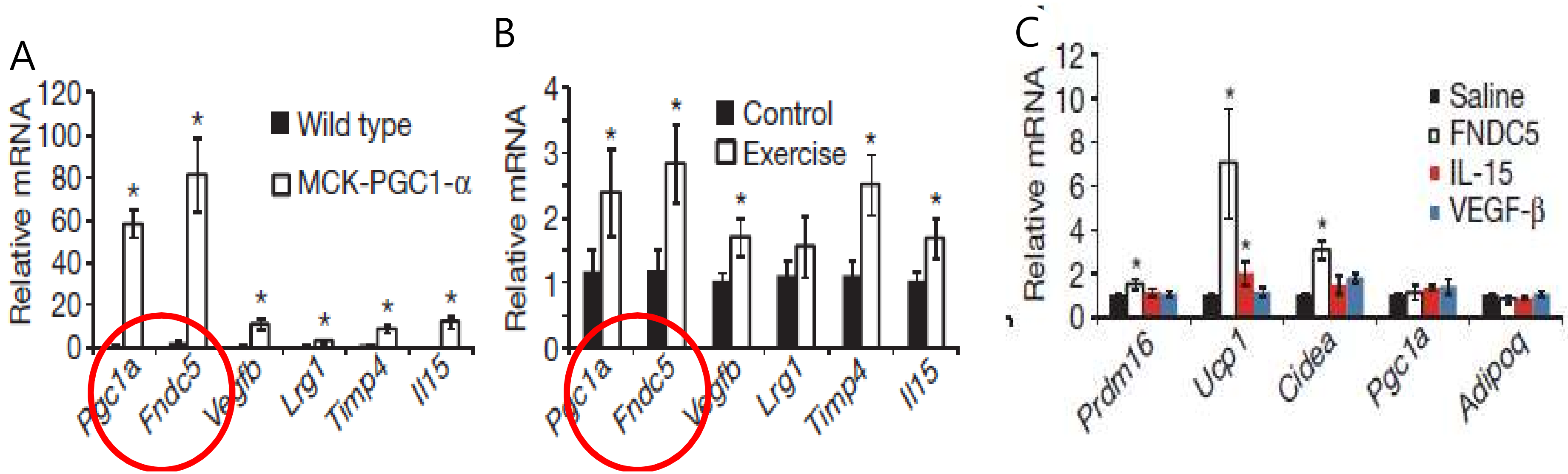
Nature 2012, Pontus Boström et al

ARTICLE

doi:10.1038/nature10777

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

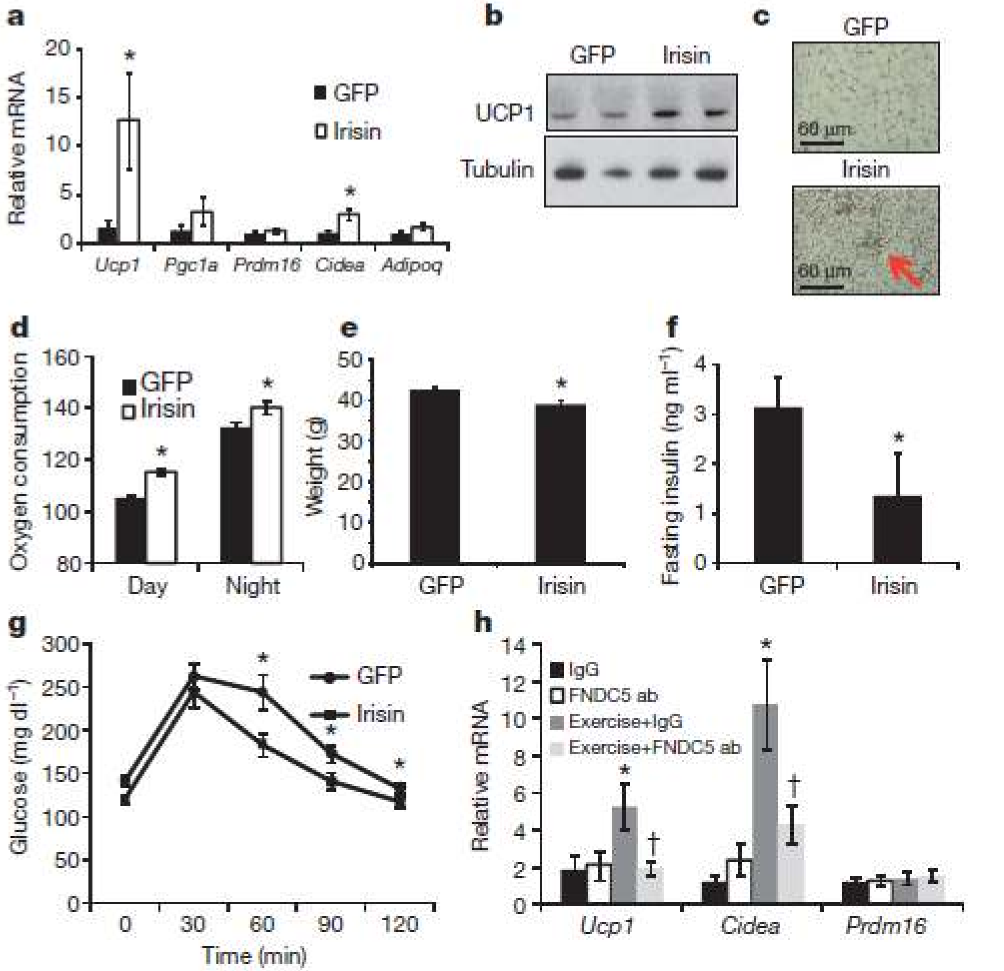
Pontus Boström[1], Jun Wu[1], Mark P. Jedrychowski[2], Anisha Korde[1], Li Ye[1], James C. Lo[1], Kyle A. Rasbach[1], Elisabeth Almer Boström[3], Jang Hyun Choi[1], Jonathan Z. Long[1], Shingo Kajimura[4], Maria Cristina Zingaretti[5], Birgitte F. Vind[6], Hua Tu[7], Saverio Cinti[5], Kurt Højlund[6], Steven P. Gygi[2] & Bruce M. Spiegelman[1]



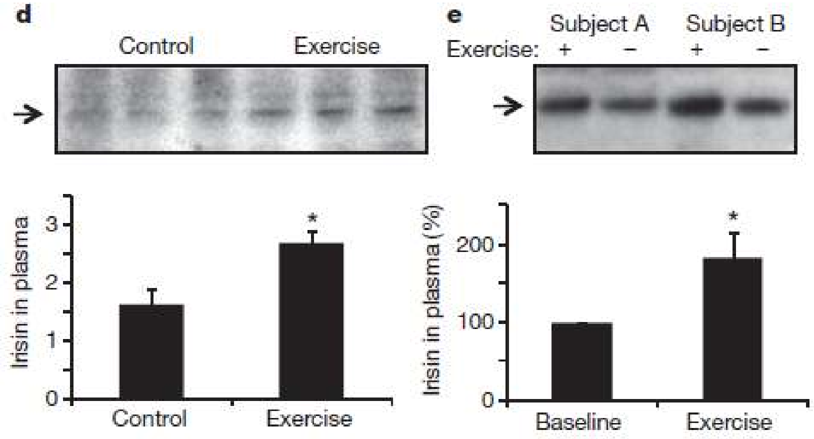
Major findings from irisin paper

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 in serum from 3 weeks exercised **mice** followed by 12 h rest

Irisin in plasma from **human** subjects before and after 10 weeks of endurance exercise

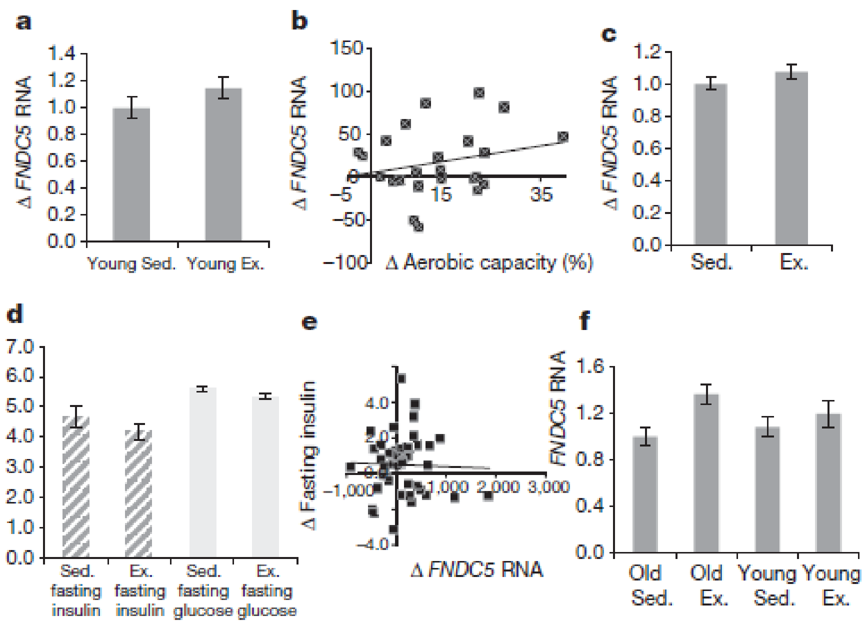
Nature 2012, Pontus Boström et al

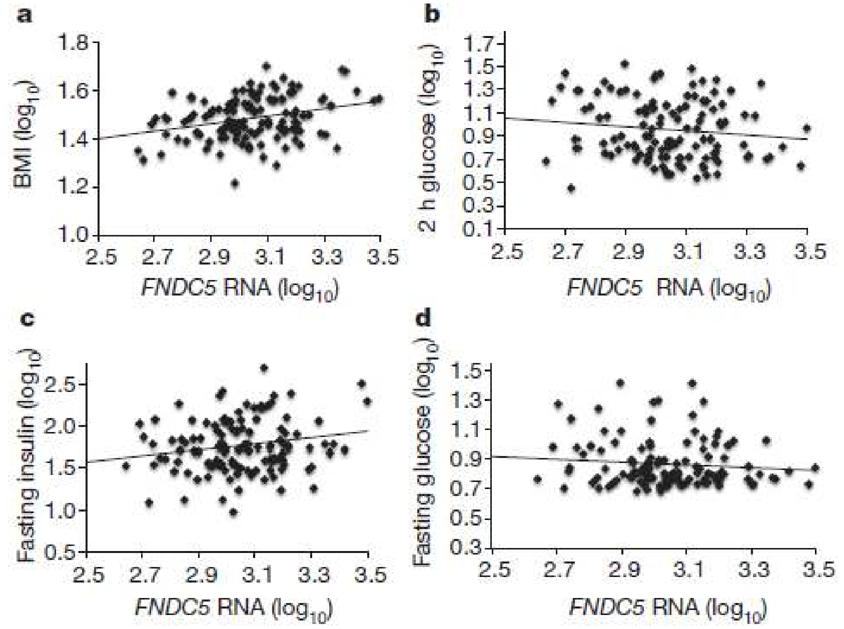
BRIEF COMMUNICATIONS ARISING

Controversial report

Is irisin a human exercise gene?

ARISING FROM P. Boström *et al. Nature* **831**, 463–468 (2012)





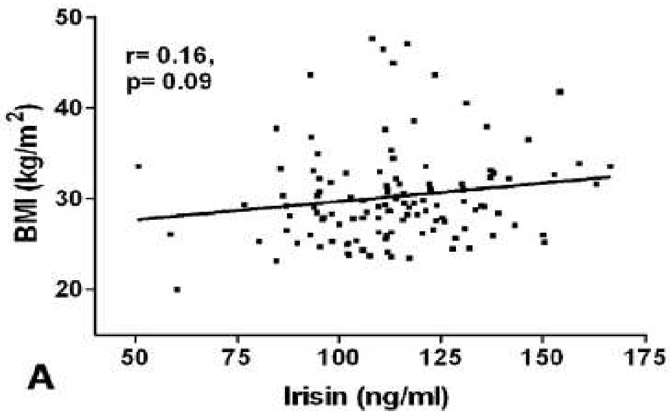
Irisin is not routinely activated by exercise in humans

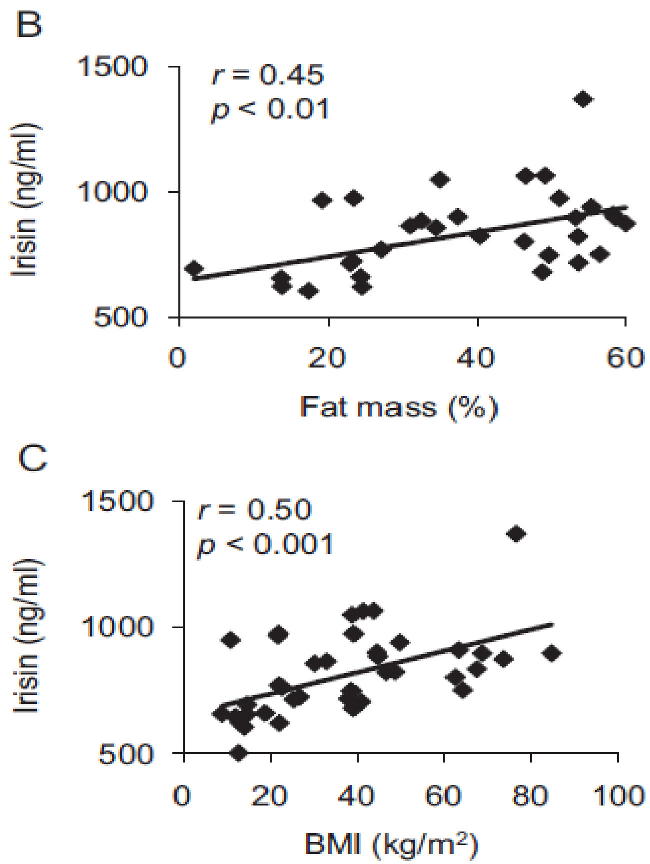
Irisin expression is not related to diabetes status in humans

Nature 2012, Timmons et al

Controversial results regarding irisin and clinical parameters

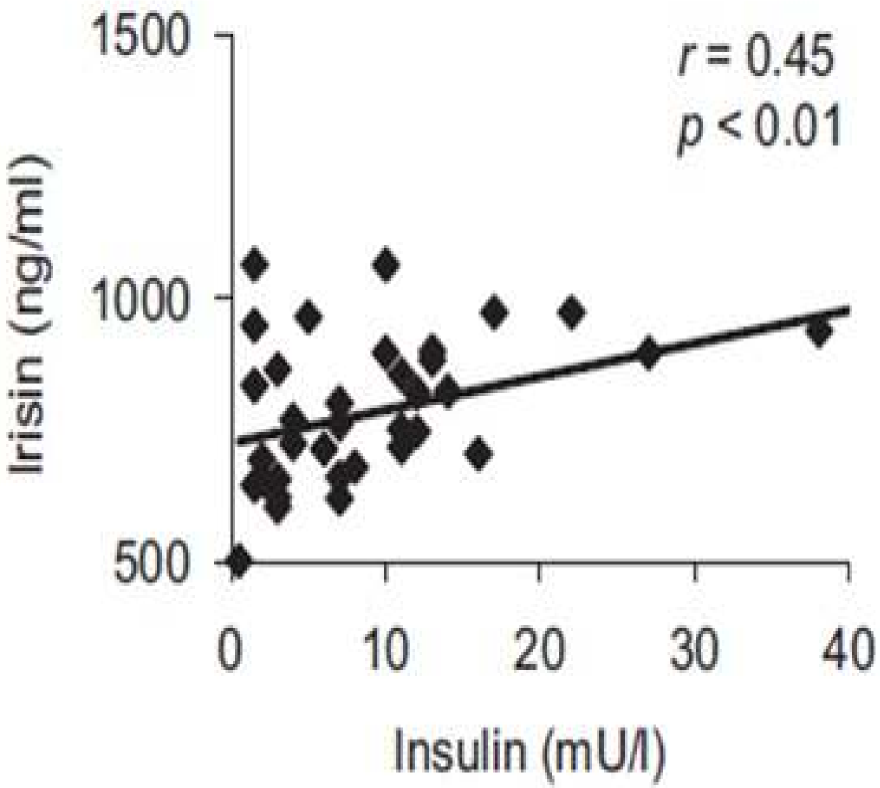
- Irisin levels showed a positive correlation with body weight and BMI(Joo Young Huh,2012 ; Andreas Stengel,2013).

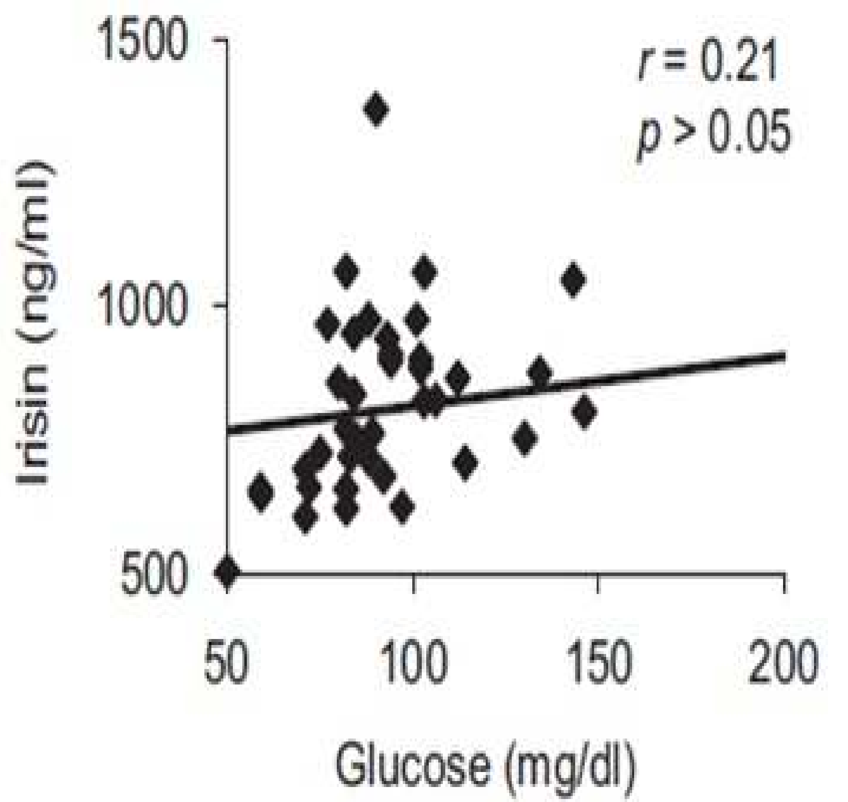




Controversial results regarding irisin and clinical parameters

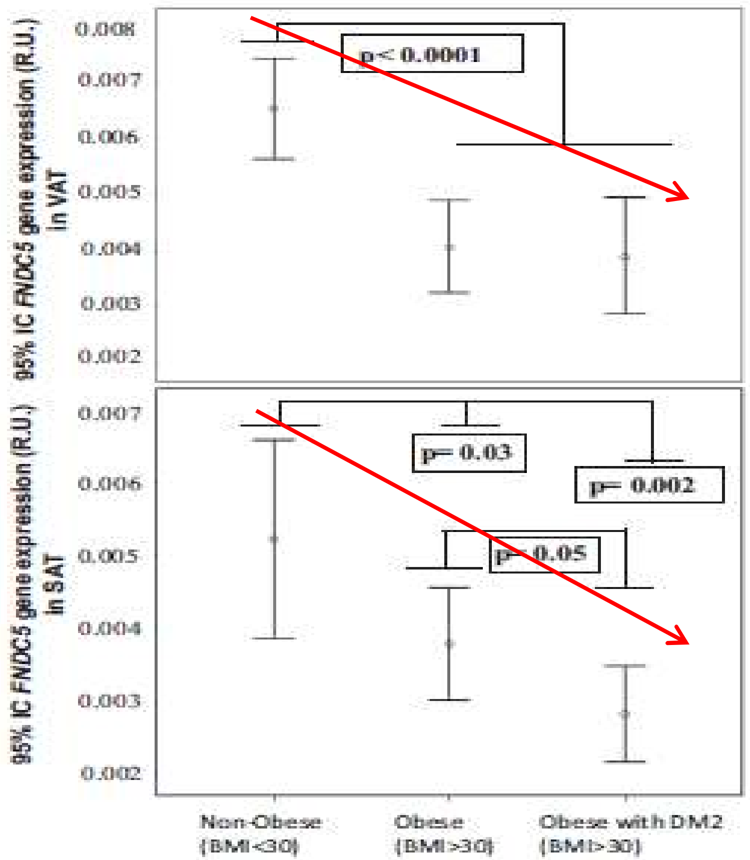
- **Irisin was positively correlated with circulating insulin and glucose (Andreas Stengel,2013).**

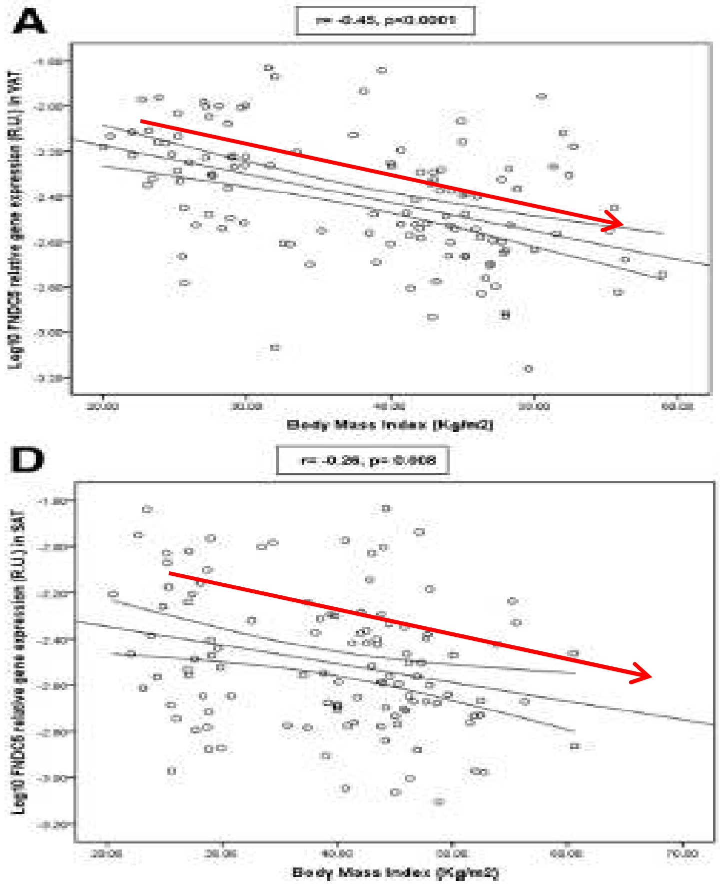




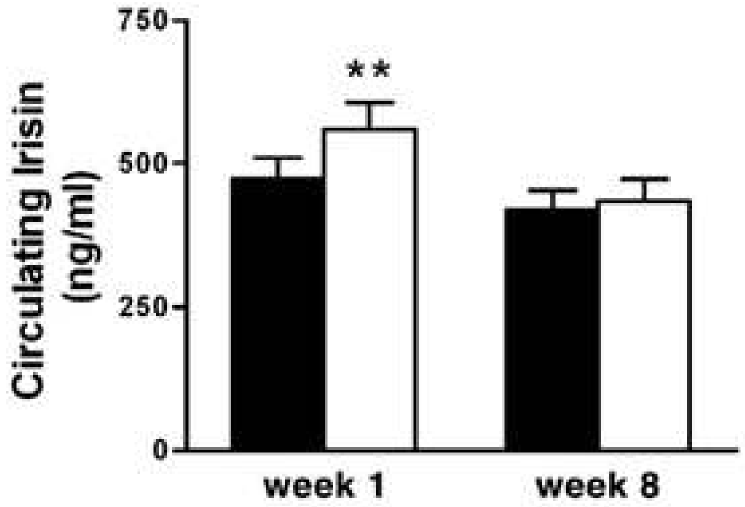
Controversial results regarding irisin and clinical parameters

- **Irisin levels were negatively associated with obesity (Jose Maria, 2013; Yeon Kyung Choi, 2013).**

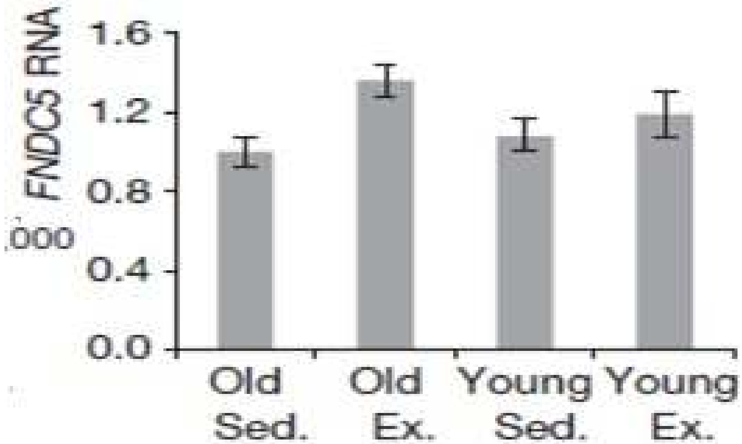




Circulating irisin level with exercise



(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).

Background

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 in tig e the effects of aero d resi e exercise on expressio cir iat irisin level in obese ad

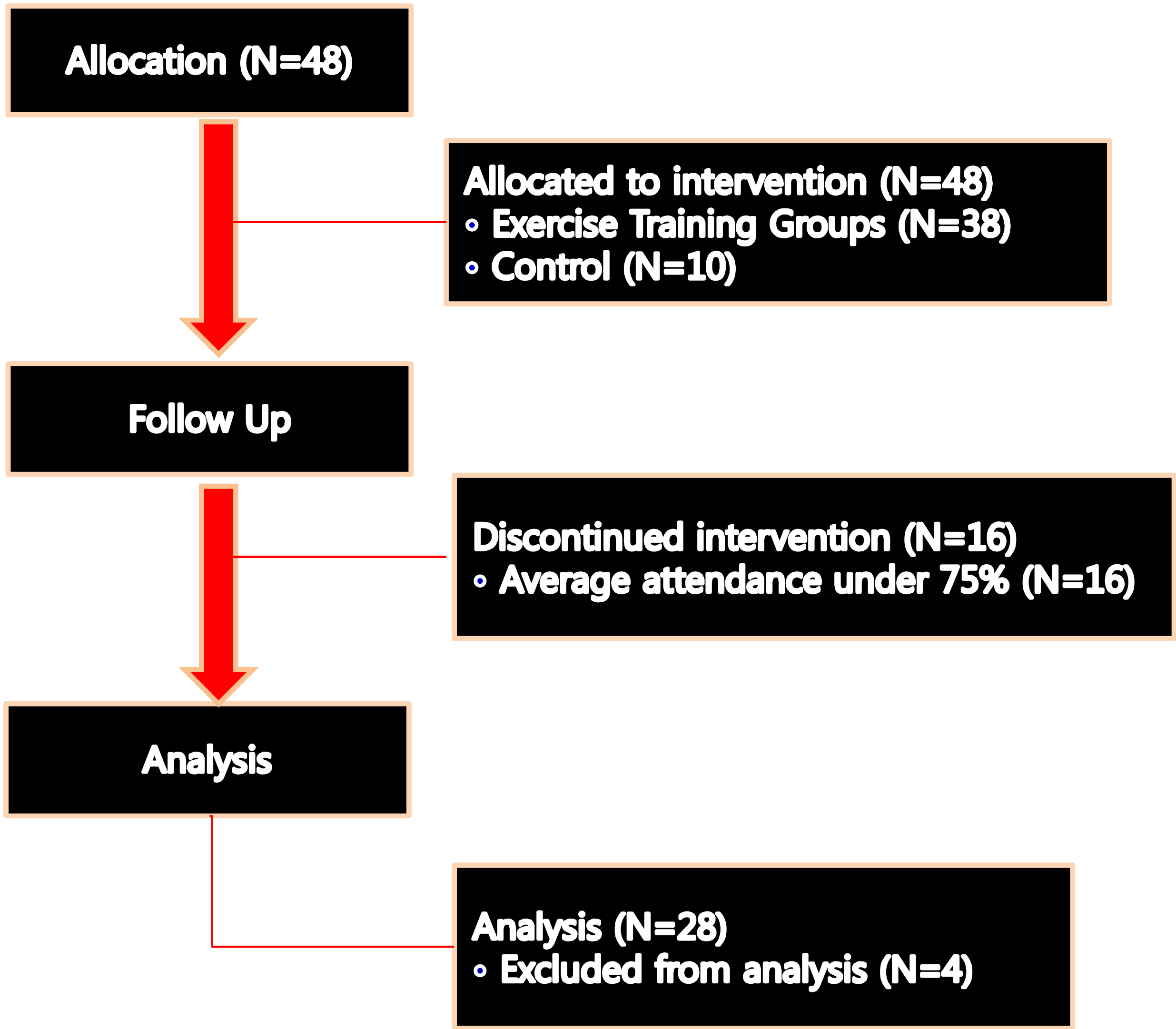
Participants

Body mass index > 25kg/㎡

Body fat percentage
> 25% Male
> 30% Female

Stable body weight
Sedentary lifestyle

Study Design



Measurements

Variables	Analysis Method	Model	Company
Body Composition Analysis	BIA	In body 370	Biospace, Korea
Irisin	ELISA analysis	Irisin ELISA Kit	AVISCERA BIOSCIENCE
Blood Lipid profiles	Lipid test		The Green Cross Reference Lab, Korea
Muscle Strength	Isokinetic Contraction Measurement	Cybex Humac Norm	Humac Norm, USA
Cardiopulmonary Endurance	Treadmills Ergometers	Quark	Cosmed, USA
Subcutaneous Fat Thickness	Ultrasound	BX2000	Intelametrix, USA

Exercise Programs (aerobic)

Exercise Programs (resistance)

Warm Up → **Resistance Training** → **Cool Down**

65%~80%
1RM
50 min

- ·Leg Press
- ·Bench Press
- ·Leg Extension
- ·Leg Curls
- ·Shoulder Press
- ·Seated Rows
- ·Triceps Extensions
- ·Crunch

Descriptive Characteristics

❖ There were significant training effects on body composition in both exercise groups compare to control.

Anthropometric Measures	Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
	Pre	Post	Pre	Post	Pre	Post	
Age(yrs)	25.8±5.5	25.8±5.5	25.7±4.1	25.7±4.1	26.4±2.9	26.4±2.9	
Height(cm)	167.2±5.4	167.5±5.5	168.3±7.7	168.5±7.8	172.1±5.6	172.1±5.7	0.147
BodyWeight(kg)	74.1±7.6	74.1±7.7	75.3±12.7	73.1±13.4*	80.3±12.8	77.7±13.4*	0.030
Skeletal Muscle Mass(kg)	32.8±4.9	28.2±4.8	28.4±6.4	28.4±6.5	32.5±4.8	32.9±5.1	0.271
Skeletal Muscle Mass(kg) / Body Weight(kg)	0.38±0.0	0.37±0.0	0.37±0.0	0.38±0.0*	0.40±0.0	0.42±0.0**	0.000

Descriptive Characteristics

Anthropometric Measures	Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
	Pre	Post	Pre	Post	Pre	Post	
Body Fat Mass (kg)	23.1±4.0	23.8±3.4	23.7±4.8	22.2±4.8*	22.1±7.3	19.5±7.3**	0.000
Body fat (%)	31.1±5.7	32.1±5.2	32.4±4.8	30.6±4.8**	28.0±4.4	24.7±5.1***	0.000
BMI (kg/m)	26.5±2.0	26.4±2.1	26.4±2.4	25.3±2.5**	27.0±3.4	26.0±3.6*	0.035
Waist(cm)	89.7±4.4	85.5±6.7	90.76.6±	80.9±8.8***	92.8±8.8	84.6±10.6**	0.069
Hip(cm)	104.2±3.2	104.1±4.2	104.9±4.2	101.5±5.9*	105.0±5.9	102.4±6.4*	0.077
WHR	0.86±0.0	0.82±0.0	0.86±0.0	0.79±0.0**	0.88±0.0	0.82±0.0*	0.351
Subcutaneous Fat Thickness (mm)	31.9±7.9	33.3±3.2	31.3±9.1	27.4±6.6*	28.1±8.7	25.3±8.2	0.343

Descriptive Characteristics

❖ Total cholesterol level was changed in resistance training group.

Blood Profiles Measures	Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
	Pre	Post	Pre	Post	Pre	Post	
Total –C (mg/dL)	204.7±37.6	203.1±34.6	187.4±27.6	182.1±25.8	188.1±23.0	169.0±24.6*	0.300
LDL-C (mg/dL)	124.2±28.8	121.7±35.0	112.5±29.5	105.5±23.2	116.7±26.0	101.3±26.7	0.362
HDL-C (mg/dL)	61.5±16.6	62.6±16.7	59.9±12.8	63.3±12.1	55.4±8.5	54.6±13.0	0.612

Exercise Capacities

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

Peak Torque/ Body Weight (Newton_Meter)		Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
		Pre	Post	Pre	Post	Pre	Post	
Peak Torque 60°/sec	Extensor R	207±55.7	199.8±64.3	232.5±44.7	228.6±46.3	226.9±38.7	250.5±28.6**	0.036
	Flexor R	107.0±41.4	109.3±30.5	96.7±24.2	112.7±25.5**	126.5±28.1	138.8±18.2	0.289
	Extensor L	179.5±51.4	186.5±59.4	204.4±43.3	215.1±48.1	213.8±34.7	239.6±29.4*	0.421
	Flexor L	103.3±32.1	106.5±32.1	89.5±23.1	106.8±20.4*	124.1±31.4	133.7±24.2	0.384

Exercise Capacities

Peak Torque/ Body Weight (Newton_Meter)		Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
		Pre	Post	Pre	Post	Pre	Post	
Peak Torque 180° /sec	Extensor R	123.1±36.3	127.6±33.1	143.9±32.8	145.7±31.3	153.2±20.5	167.3±19.3**	0.187
	Flexor R	64.6±30.9	69.6±21.1	65.4±14.5	75.6±20.0	86.0±21.8	93.4±17.1	0.832
	Extensor L	111.5±30.5	120.6±39.8	135.5±28.1	141.2±26.9	143.3±28.9	161.9±15.7*	0.311
	Flexor L	60±19.8	65.3±24.8	62.3±10.4	65.9±11.6	82.2±19.3	86.5±14.9	0.887

Exercise Capacities

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

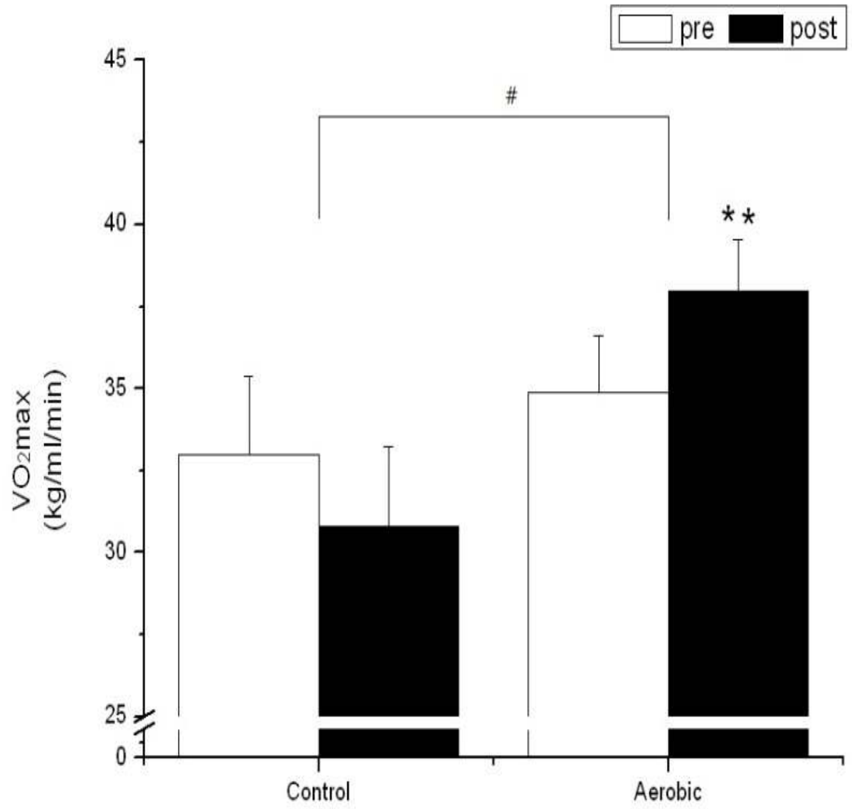
Average Power per Repetition / Body Weight		Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
		Pre	Post	Pre	Post	Pre	Post	
Average Power per Repe tition 60°/sec	Extensor R	124.8±35.3	124.6±40.9	147.7±27.9	145±27.0	146.8±25.2	165.9±21.0*	0.017
	Flexor R	80.6±30.5	84±23.6	77.3±18.9	88.2±19.0*	94.2±23.4	107.8±15.9*	0.415
	Extensor L	112±33.6	117.2±42.4	128.4±26.6	141.4±30.7*	133.7±20.6	159.3±16.6**	0.097
	Flexor L	78.6±25.8	82.3±26.7	54.2±19.2	62±16.2*	94.5±26.1	106.1±18.6	0.485

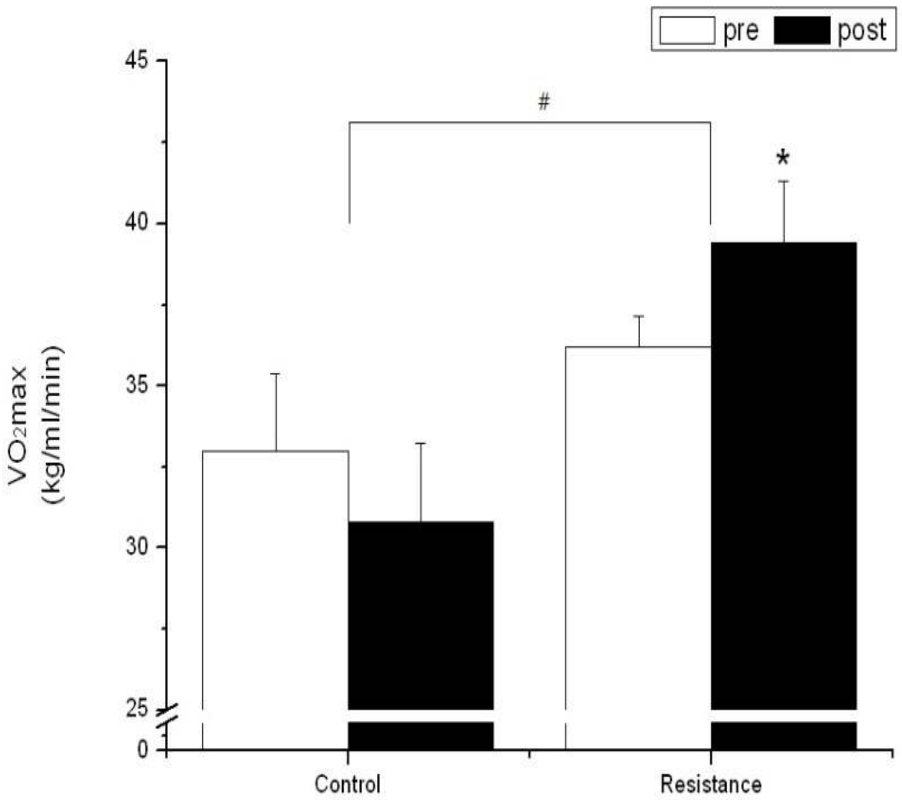
Exercise Capacities

Average Power per Repetition / Body Weight		Control (N=8)		Aerobic Training (N=10)		Resistance Training (N=10)		p-value
		Pre	Post	Pre	Post	Pre	Post	
Average Power per Repetition 180°/sec	Extensor R	187.1±47.5	198.1±59.8	238.7±49.9	223.8±46.6	262.4±34.6	298.4±112.8	0.245
	Flexor R	106.0±48.6	109.5±37.5	113.1±24.5	120.5±26.9	146.8±39.0	151.2±21.1	0.952
	Extensor L	167.3±44.9	185.0±68.4	223.9±48.2	219.7±38.0	230.9±50.2	258.4±31.8*	0.152
	Flexor L	94.5±28.5	103.1±35.6	107.8±17.9	104.9±17.8	139.4±31.6	142.9±19.7	0.463
Grip Strength (Kg)/ Body Weight(Kg)		0.38±0.0	0.37±0.0	0.46±0.0	0.47±0.0	0.46±0.0	0.52±0.0	0.038

Exercise Capacities

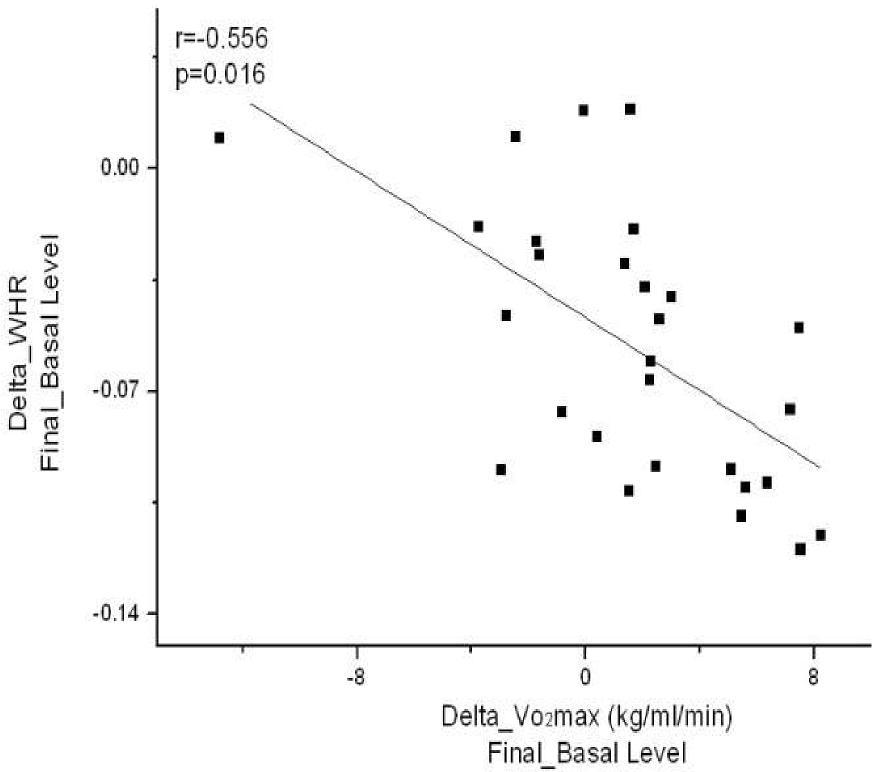
- VO₂max increased in both exercise intervention groups and the aerobic training group showed more significant improvement.

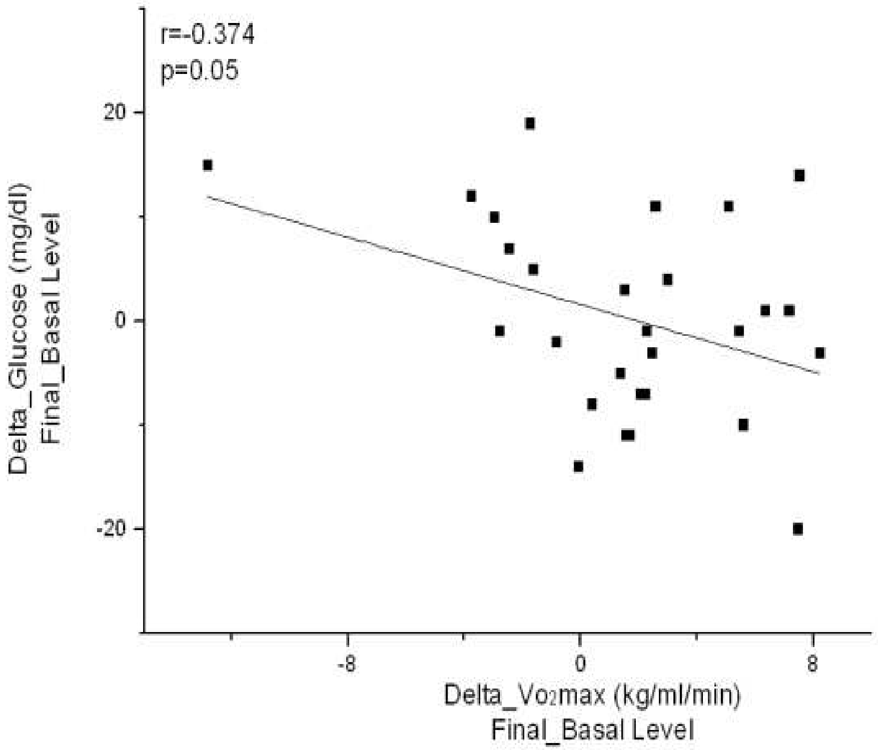




Exercise Capacities

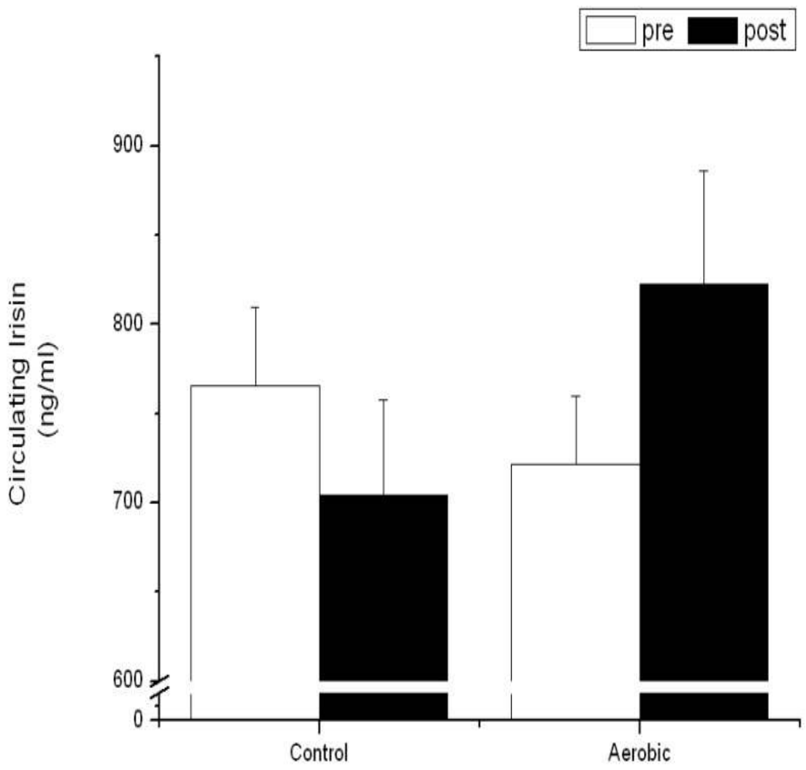
❖ Change of VO_2max showed negative correlation with change of WHR and glucose

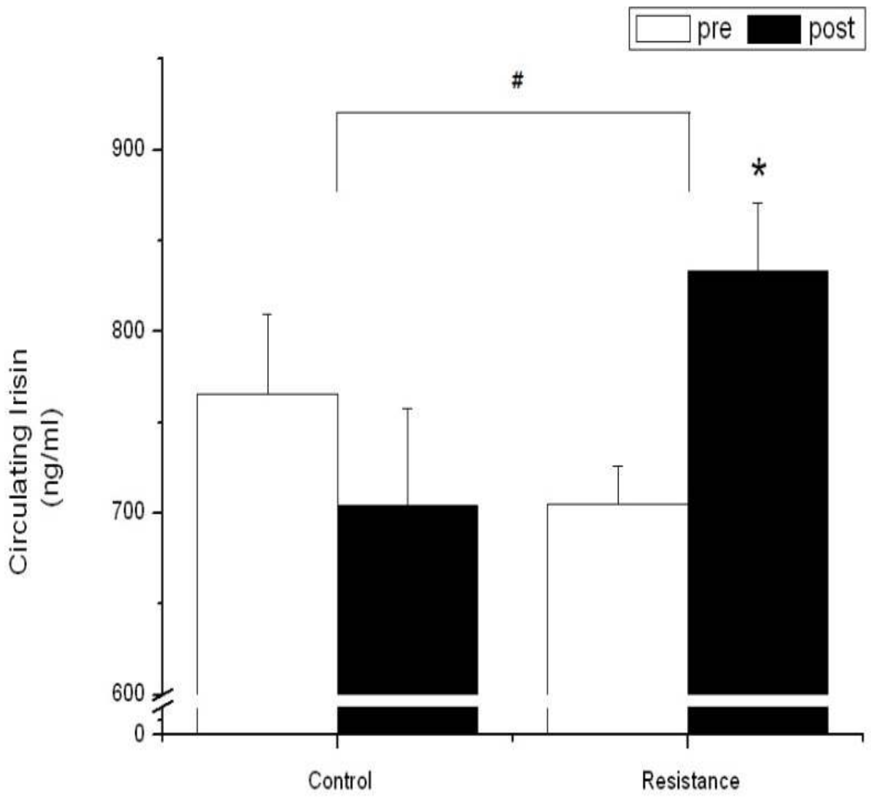




Irisin

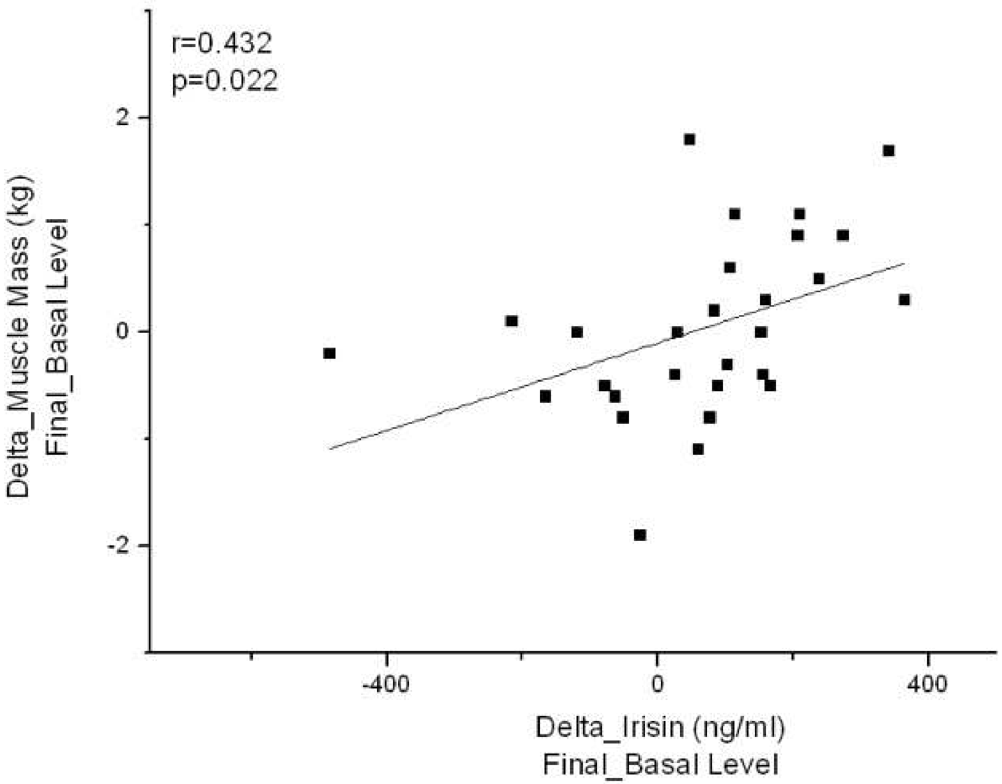
❖ Circulating Irisin level increased in both training group but resistance intervention showed more significant increase.





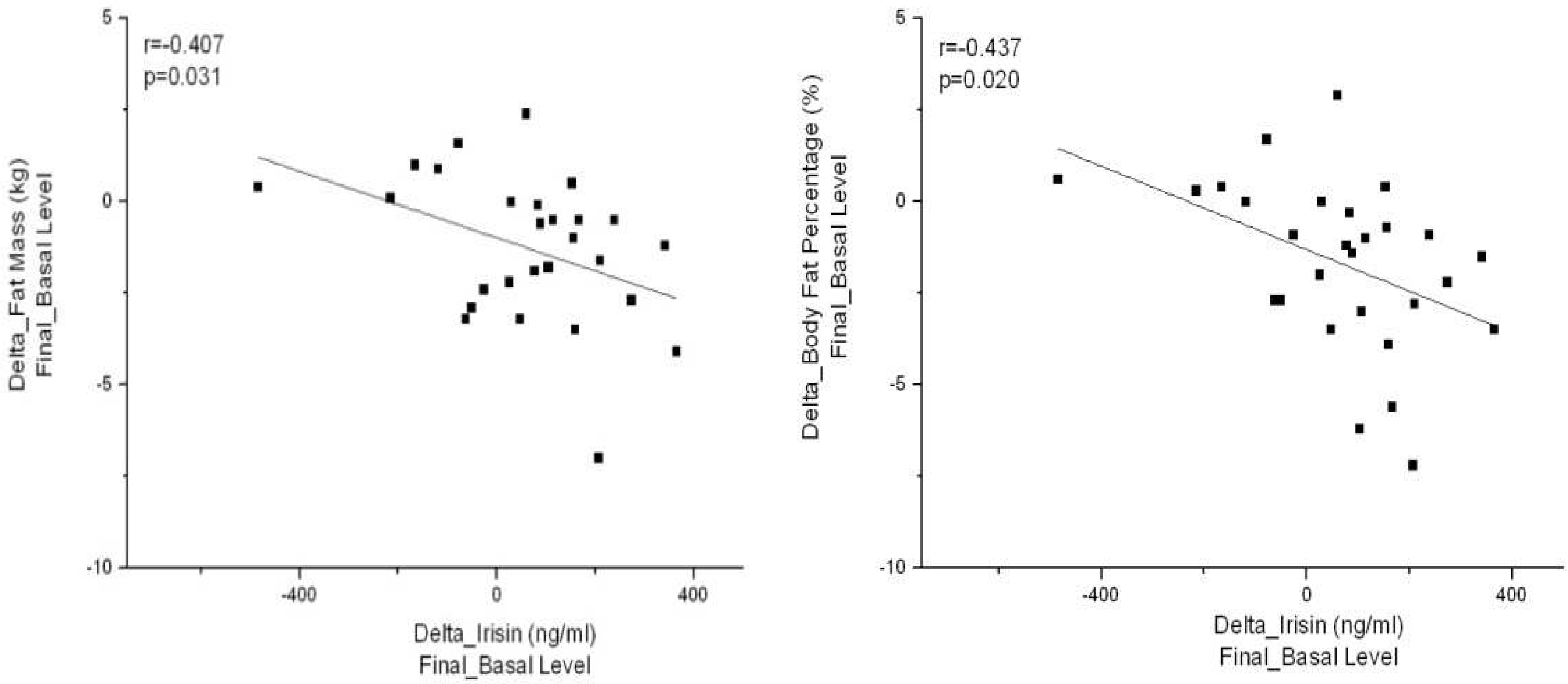
Irisin

❖ 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