Effects of Resistance Training on Muscle and Fat mass and Muscle Strength in Type 2 Diabetic Women

민경완

을지중앙의료원 당뇨병센터

- 유산소 운동은 내장지방을 감소시키고 인슐린 저항성 개선에 긍정적인 효과가 있으나 근육량에는 변화가 없다

- 미국당뇨병학회: 제2형 당뇨병 환자에서
  유산소 운동과 함께 저항운동을 병합시행 권고
  최대 근력 (one repetition maximum, 1RM)
  의 75~85% 강도
  1일 8-10회, 3 set
  일주일에 3회 실시

제2형 당뇨병환자에서 나이에 따른 최대근력의 변화

권휘련[1], 안희정[1], 석희금[1], 구보경[2], 김현진[2], 박강서[2], 한경아[2], 민경완[2], 김응진[2]
을지병원 당뇨센터[1], 을지대학교 의과대학 내과학교실 [2]

권휘련 외. Korean Diabetes J 33:412~420, 2009

- 연구 대상
  - 40~75세 제 2형 당뇨병 환자 266명
  - HbA1c ≤10%
  - 최대 중량운동에 금기사항에 해당되지 않는 환자

Measurement

1. 신체계측 : 신장, 체중, 혈압, 허리둘레
2. 기초 임상 검사 :

   Insulin (fasting), Glucose (fasting, HbA1c)

   Lipid profile (TC, TG, HDL-C, LDL-C)

Measurement

1RM

(1) 측정 부위 : 상지 (chest press) / 하지 (Leg press)

(2) 측정 방법

① 피검자는 예상되는 최대중량(상체: 체중의1/3, 하체: 체중)의 40~50%를 8~10회 반복하는 가벼운 warm-up 을 실시한다.

② 가벼운 스트레칭을 하고 1분 동안 휴식을 취한 후, 피검자는 예상되는 최대중량의 10% 강도를 3회 반복으로 1set를 실시한다.

③ 다시 1분 후 예상되는 최대중량의 90% 강도로 3회 1set 로 1RM을 실시한다.

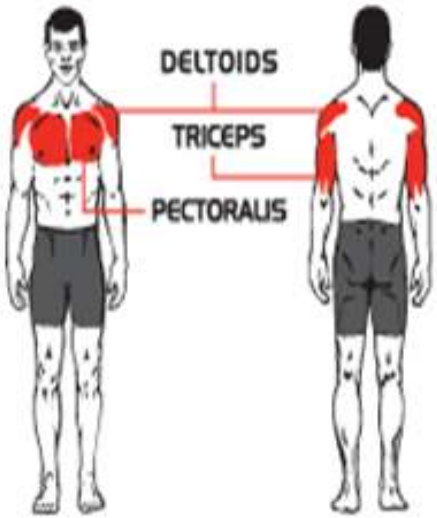
Measurements

Muscle strength

: One repetition maximum, 1RM (KEISER, USA)

Upper extremity	
Air 350 Bi-Axial Chest press	muscle

Lower extremity	
Air 300 Leg press	muscle



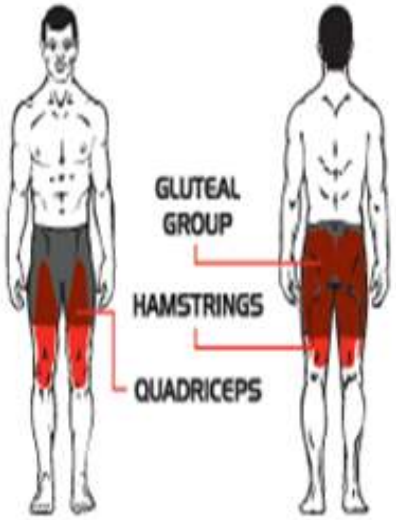


Table 1. The clinical characteristics of the subjects

	Men (N = 95)	Women (N = 171)	Total (N = 266)
Age (years)	58.4 ± 10.2	58.1 ± 8.9	58.3 ± 9.4
Duration of diabetes (years)	8.3 ± 7.8	9.3 ± 8.6	8.7 ± 7.2
BMI (kg/m^2)	24.2 ± 2.9	25.7 ± 3.5	25.1 ± 3.4
Systolic BP (mm Hg)	110.4 ± 15.6	110.6 ± 17.4	110.5 ± 16.7
Diastolic BP (mm Hg)	74.5 ± 11.4	77.8 ± 16.5	76.5 ± 14.8
HbA1c (%)	8.1 ± 1.8	7.7 ± 1.3	7.8 ± 1.5
C-peptide (ng/mL)	1.7 ± 0.8	2.1 ± 2.3	1.9 ± 1.9
Total cholesterol (mg/dL)	177.3 ± 48.6	166.9 ± 36.6	170.6 ± 41.5
Triglyceride (mg/dL)	154.2 ± 128.1	151.0 ± 104.9	152.2 ± 113.4
HDL-C (mg/dL)	46.6 ± 9.1	46.5 ± 11.3	46.6 ± 10.4
LDL-C (mg/dL)	110.9 ± 33.9	98.6 ± 30.9	102.9 ± 32.5

Data are means ± SD. BMI, Body mass index; BP, blood pressure; HbA1c, hemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

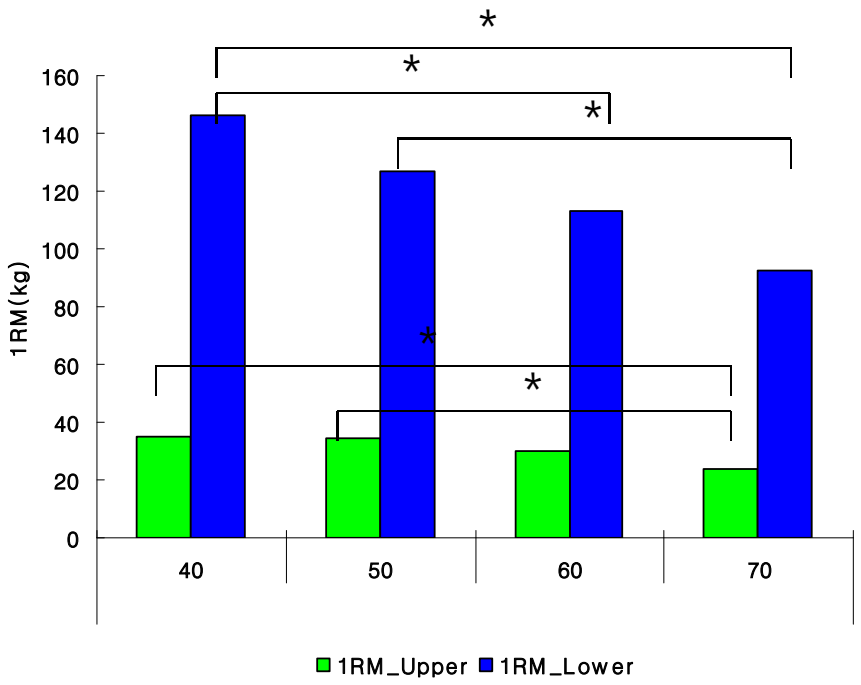
Table 2. One repetition maximum (1RM) according to age quartile

Gender	Limb	Age (years)	N	Weight (kg)	1 RM	*P*-value*
Men	Upper	40~49	21	68.0 ± 9.5	35.2 ± 11.0	< 0.001
		50~59	32	69.5 ± 10.1	34.6 ± 12.0	
		60~69	22	68.9 ± 11.1	29.8 ± 10.2	
		70+	20	66.8 ± 9.1	23.5 ± 5.7‡	
	Lower	40~49	21	68.0 ± 9.5	146.5 ± 27.9	< 0.001
		50~59	32	69.5 ± 10.1	127.0 ± 26.9†	
		60~69	21	68.9 ± 11.1	113.0 ± 36.3	
		70+	20	66.8 ± 9.1	92.5 ± 18.4†‡	
Women	Upper	40~49	36	64.0 ± 10.6	20.2 ± 5.7	< 0.001
		50~59	57	64.0 ± 9.6	17.8 ± 5.2†	
		60~69	56	62.8 ± 8.7	14.7 ± 4.0†	
		70+	22	55.5 ± 8.7	13.3 ± 4.2	
	Lower	40~49	36	64.0 ± 10.6	98.5 ± 29.3	< 0.001
		50~59	57	64.0 ± 9.6	89.8 ± 21.1	
		60~69	56	62.8 ± 8.7	77.8 ± 20.7†	
		70+	21	55.5 ± 8.7	64.1 ± 20.2†	

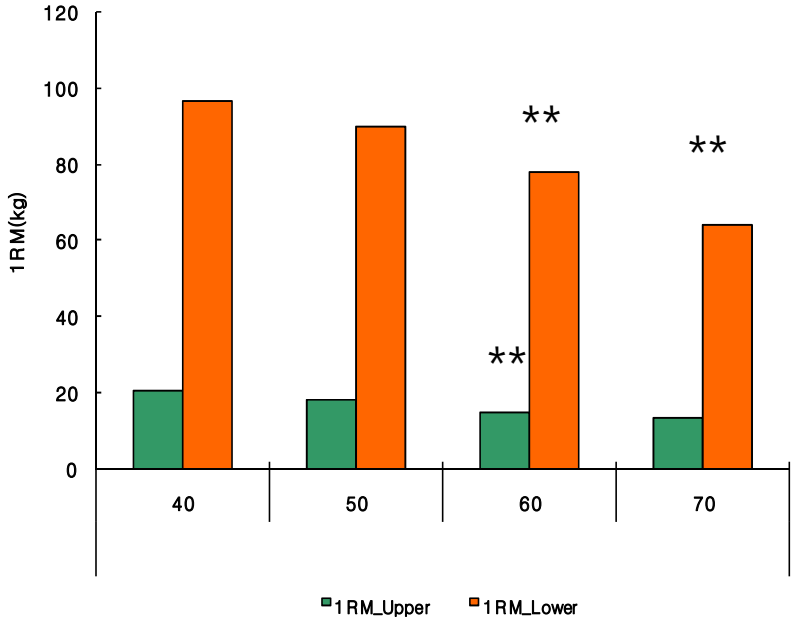
Data are means ± SD. * Difference among age group from ANOVA. † Significantly lower than the antecedent age-group. ‡ Significantly lower than 40s and 50s.

연령에 따른 1RM의 변화

Men



Women



* p<0.05

** 이전 연령대에 비해 유의한 감소 있음 (p<0.05).

1RM to Body weight ratio according to age

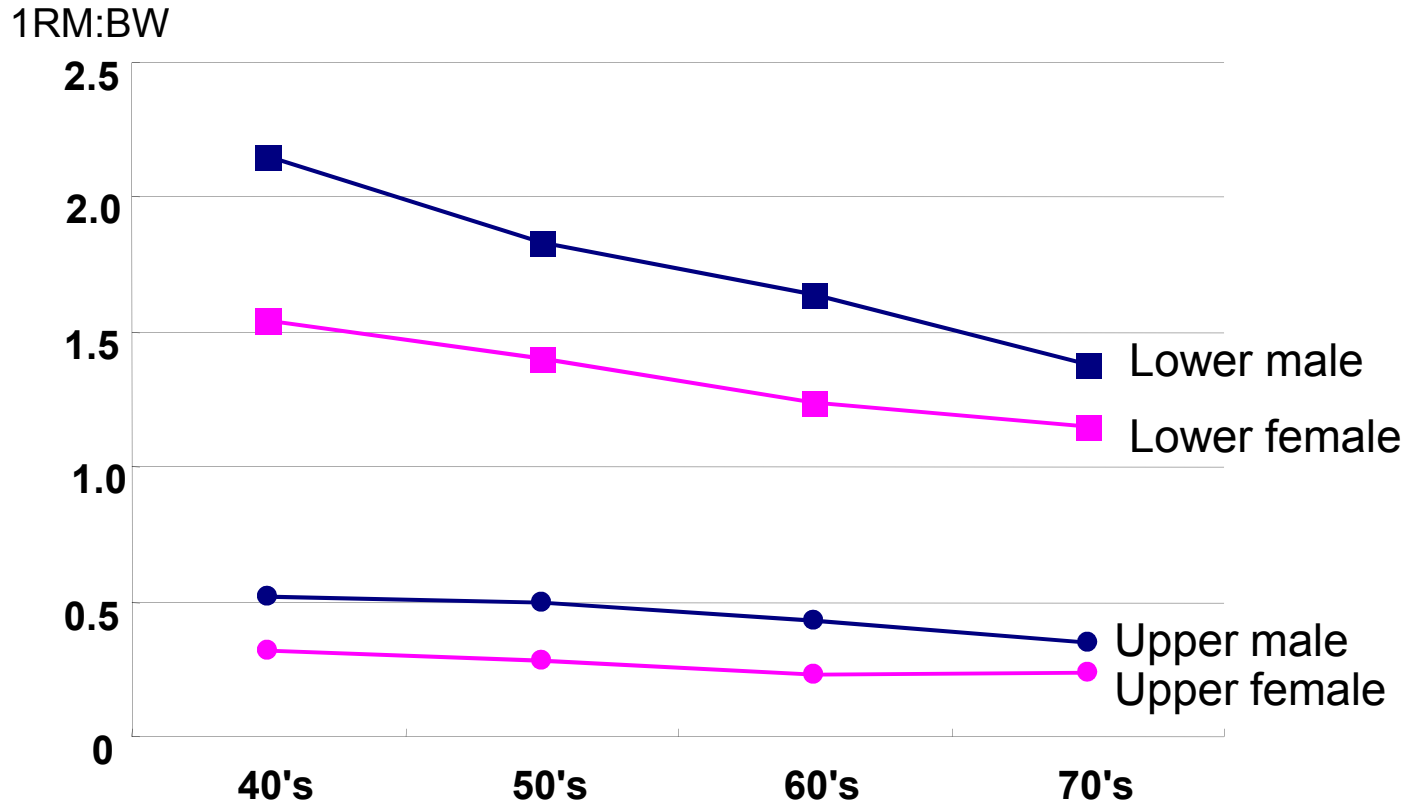


Table 4. Lower one repetition maximum/ Upper one repetition maximum ratio

Gender	Age (years)	N	Ratio	*P*-value
Men	40~49	21	4.4 ± 1.1	0.377
	50~59	32	3.9 ± 1.4	
	60~69	21	3.8 ± 1.3	
	70+	20	4.1 ± 12	
Women	40~49	36	5.1 ± 1.4	0.262
	50~59	57	5.3 ± 1.6†	
	60~69	56	5.6 ± 1.6†	
	70+	21	4.9 ± 1.5	

Ratio was derived from lower one repetition maximum divided by upper one repetition maximum. Data are means ± SD. Difference among age group from ANOVA.

제2형 당뇨병환자에서 최대근력과 유산소 운동능력 및 비만도의 관련성

권휘련[1], 안희정[1], 석희금[1], 구보경[2], 김현진[2], 박강서[2], 한경아[2], 민경완[2], 김응진[2]
을지병원 당뇨센터[1], 을지대학교 의과대학 내과학교실 [2]

권휘련 외. Korean Diabetes J 33:511~517, 2009

연구대상:

Total of 177 (men: 85, women: 92) diabetic subjects

HbA1c ≤ 10%

권휘련 외. Korean Diabetes J 33:511~517, 2009

Measurement

1. 신체계측 : 신장, 체중, 혈압, 허리둘레, 흡연력 조사
2. 기초 임상 검사 : Insulin (fasting)

   Glucose (fasting, HbA1c)

   Lipid profile (TC, TG, HDL-C, LDL-C)
3. 체성분 검사 (Inbody 3.0)
4. 운동 부하 검사 (JAGER, ER900) : 최대 산소 섭취량(VO_{2max}),

   무산소성 역치의 산소섭취량 ($VO2_{AT}$)
5. 1RM

Table 1. The clinical characteristics of the subject

	Men (n = 85)	Women (n = 92)	Total (n = 177)
Age (yr)	55.3 ± 7.9	57.4 ± 7.7	56.4 ± 7.9
Height (cm)	168.3 ± 5.1	156.0 ± 5.9	161.9 ± 8.3
Weight (cm)	69.2 ± 10.1	59.7 ± 7.9	64.3 ± 10.2
Diabetes Duration (yr)	8.0 ± 6.1	9.3 ± 7.2	8.7 ± 6.7
BMI (kg/m^2)	24.4 ± 2.9	24.5 ± 2.8	24.4 ± 2.9
HbA1c (%)	7.6 ± 1.1	7.7 ± 1.2	7.6 ± 1.1
Total cholesterol (mg/dL)	179.0 ± 43.8	173.2 ± 41.4	175.9 ± 42.5
Triglyceride (mg/dL)	162.4 ± 130.3	163.3 ± 126.4	162.9 ± 127.9
HDL-C (mg/dL)	45.8 ± 9.1	47.6 ± 11.2	46.7 ± 10.3
LDL-C (mg/dL)	109.0 ± 33.5	100.6 ± 30.7	104.5 ± 32.2
Muscle mass (kg)	51.8 ± 6.7	38.9 ± 4.6	45.1 ± 8.6
Fat mass (kg)	15.7 ± 5.0	19.2 ± 5.0	17.5 ± 5.3
Body fat (%)	21.9 ± 5.3	31.4 ± 4.8	26.9 ± 6.9
1RM_Upper (kg)	34.2 ± 10.7	16.9 ± 5.5	25.2 ± 12.0
1RM_lower (kg)	130.4 ± 32.1	85.5 ± 22.5	107.0 ± 35.5
VO_2max (mL/min/kg)	18.7 ± 5.3	16.6 ± 4.3	17.6 ± 4.9

Data are means ± SD. BMI, body mass index; HbA1c, hemoglobin A1c; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; 1RM, one repetition maximum.

Table 2. Correlations between 1RM, diabetes duration and HbA1c

Gender	1RM	Diabetes duration		HbA1c	
		r	*P*	*r*	*P*
Men	Upper	-0.072	0.531	0.001	0.995
	Lower	-0.006	0.958	-0.036	0.736
Women	Upper	-0.165	0.122	0.071	0.523
	Lower	-0.082	0.446	-0.105	0.323

1RM, one repetition maximum; HbA1c, hemoglobin A1c.

Table 3. Correlations between 1RM, aerobics capacity and BMI

Gender	1RM	VO_2max		BMI	
		r	*P*	*r*	*P*
Men	Upper	0.151	0.122	0.468	< 0.001
	Lower	0.164	0.138	0.415	< 0.001
Women	Upper	-0.006	0.952	0.279	0.007
	Lower	-0.060	0.570	0.295	0.005

BMI, body mass index; 1RM, one repetition maximum.

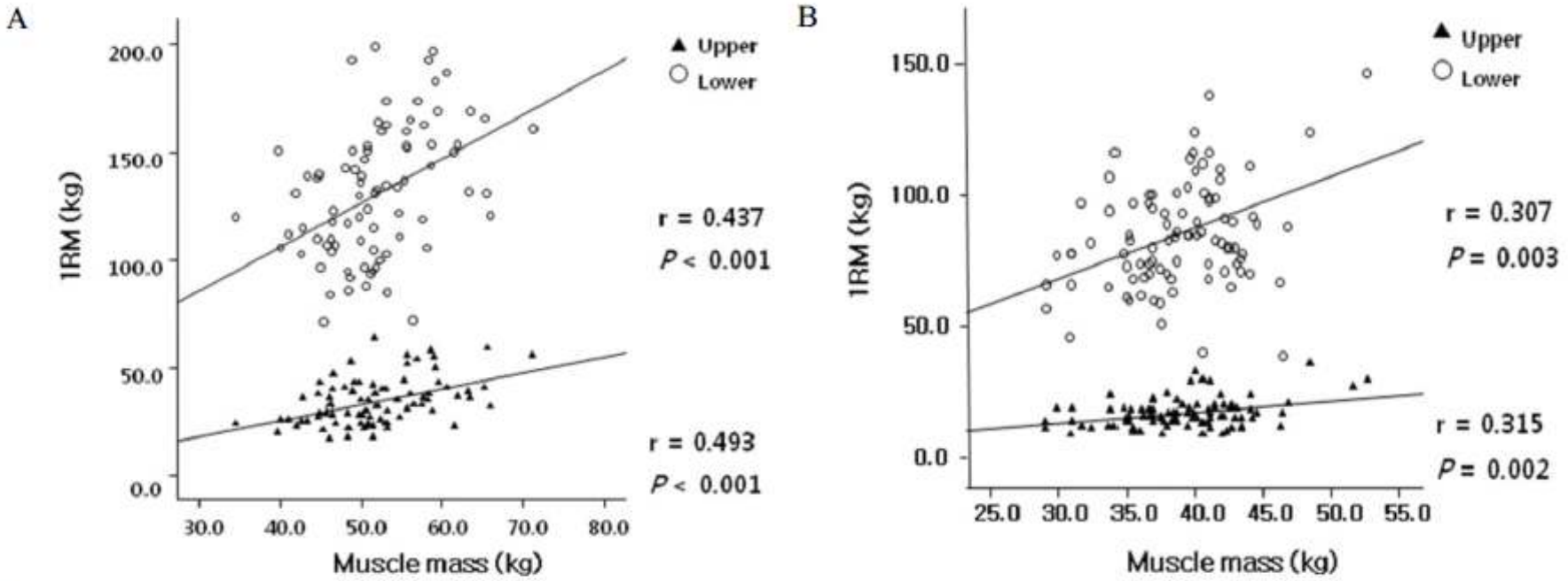


Fig. 1. Correlations between 1RM and muscle mass. A. Men. B. Women. 1RM, one repetition maximum.

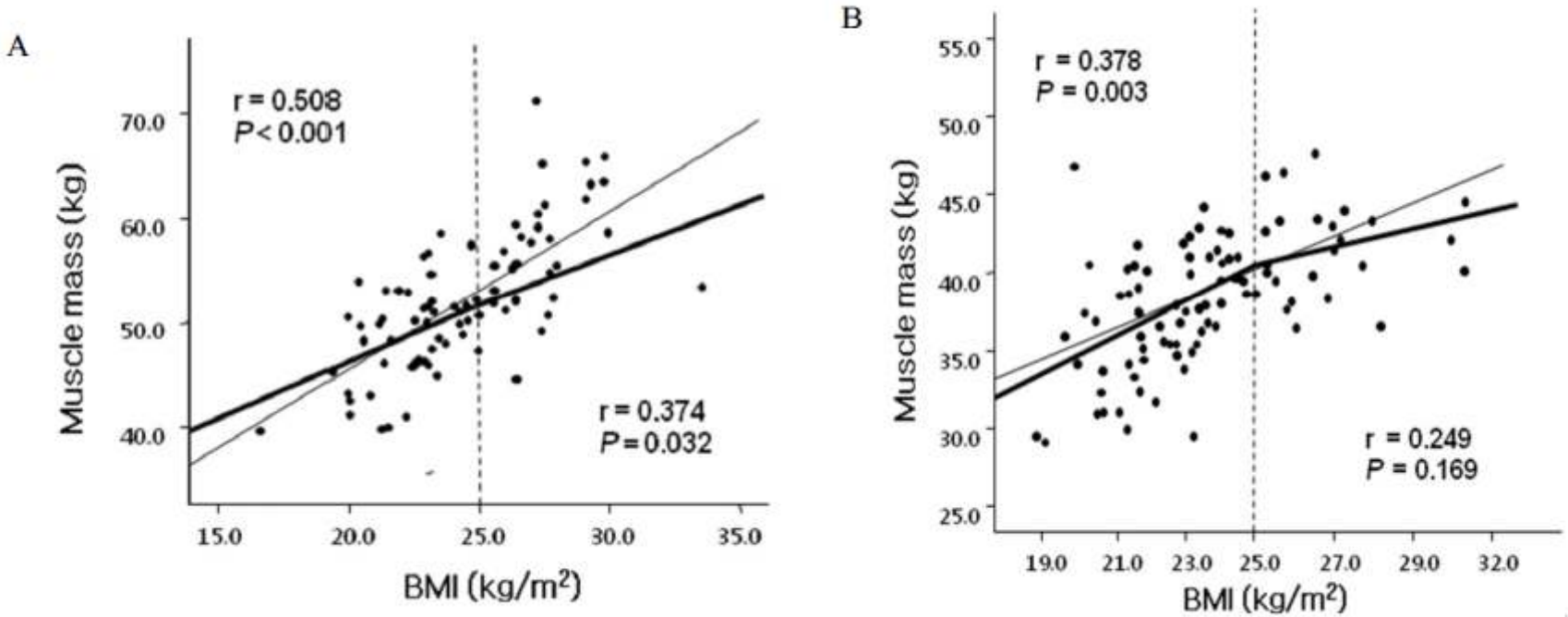


Fig. 2. Correlations between muscle mass and BMI. A. Men. B. Women. BMI, body mass index.

결론

- 당뇨병 환자는 남녀 모두 60대부터 유의한 근력의 감소가 있었다.
- 남녀 모두 근력은 근육량과 유의한 상관 관계가 있었다.
- 남자의 경우 체중이 증가하면 근력도 같이 증가하나 비만한 여자는 체중이 증가하여도 근력이 증가하지 않았다.

Effects of Resistance Exercise Training on Muscular Mass and Strength in Type 2 Diabetic Women

Hwi-Ryun Kwon[1], Yun Hyi Ku[2], Hee-Jung Ahn[1], Hee-Geum Seok[1], Jin-Taek Kim[2], Hyun-Jin Kim[2], Gang-Seo Park[2], Ho Chul Kim[3],
Kyung-Ah Han[2], Kyung-Wan Min[2]

[1]Diabetes Center, Eulji Hospital,
[2]Department of Internal Medicine, Eulji University School of Medicine,
[3]Kim Ho Chul Radiology

Method

- 28 overweight women with type 2 diabetes
- resistance training group (RG, n=13)
  control group (CG, n=15)

- RG completed resistance training using elastic band
  40-50% of one repetition maximum,
  3set, 60min,
  3 days/week under supervision
  12 weeks exercise program

Measurements

- Anthropometrics
  height, weight, BMI, waist circumference

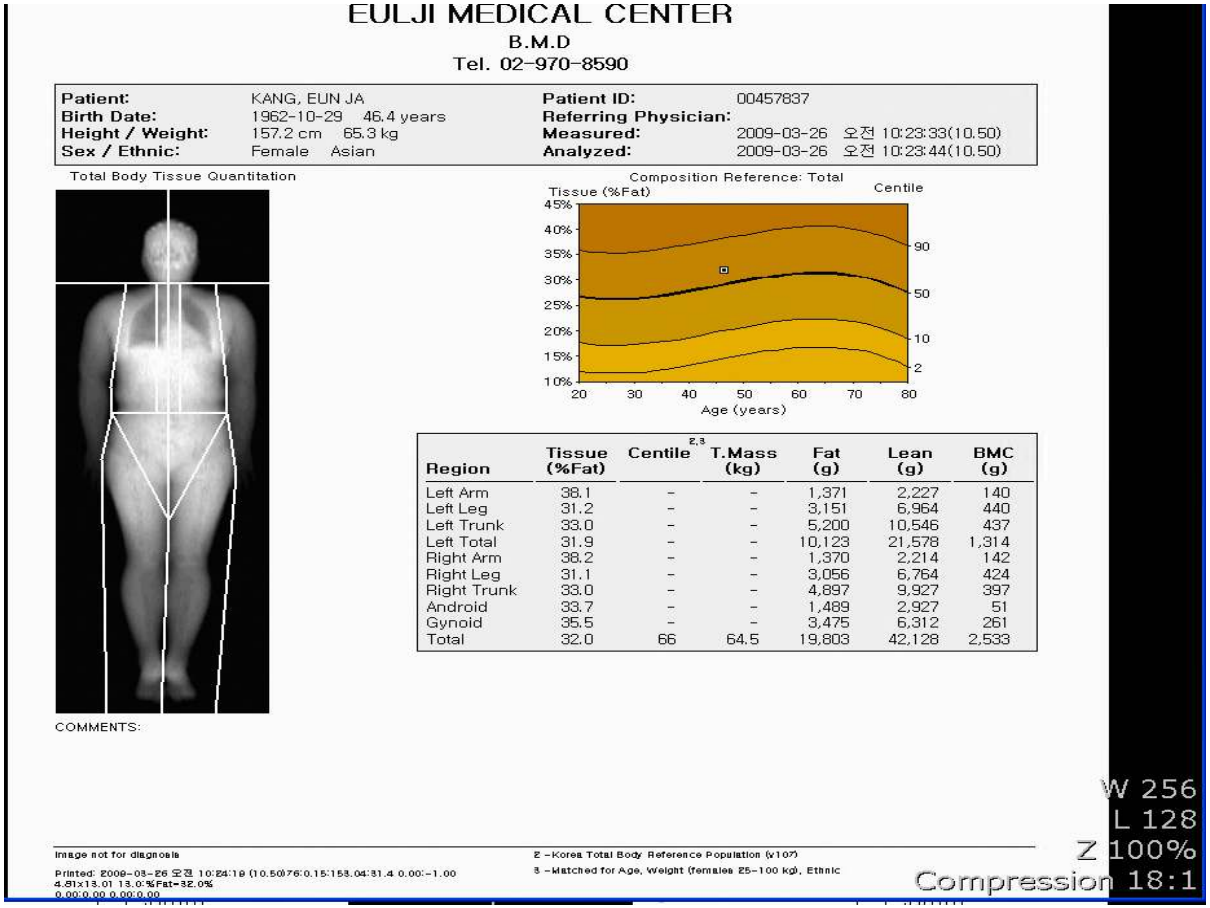
- Biochemical test
  insulin (fasting), glucose (fasting, HbA1c),
  lipid profile (TC, TG, HDL-C, LDL-C)

- Lifecorder
  Total energy expenditure (TEE, kcal/day)
  Activity energy expenditure (AEE, kcal/day)

- Insulin Sensitivity
  : K_{ITT} (from insulin tolerance test)

Measurements

- Muscle and fat mass
  : by DEXA (GE, Lunar, USA)



EULJI MEDICAL CENTER
B.M.D
Tel. 02-970-8590

Patient:	KANG, EUN JA	**Patient ID:**	00457837
Birth Date:	1962-10-29 46.4 years	**Referring Physician:**	
Height / Weight:	157.2 cm 65.3 kg	**Measured:**	2009-03-26 오전 10:23:33(10.50)
Sex / Ethnic:	Female Asian	**Analyzed:**	2009-03-26 오전 10:23:44(10.50)

Total Body Tissue Quantitation

Composition Reference: Total

Region	Tissue (%Fat)	Centile [2,3]	T.Mass (kg)	Fat (g)	Lean (g)	BMC (g)
Left Arm	38.1	-	-	1,371	2,227	140
Left Leg	31.2	-	-	3,151	6,964	440
Left Trunk	33.0	-	-	5,200	10,546	437
Left Total	31.9	-	-	10,123	21,578	1,314
Right Arm	38.2	-	-	1,370	2,214	142
Right Leg	31.1	-	-	3,056	6,764	424
Right Trunk	33.0	-	-	4,897	9,927	397
Android	33.7	-	-	1,489	2,927	51
Gynoid	35.5	-	-	3,475	6,312	261
Total	32.0	66	64.5	19,803	42,128	2,533

COMMENTS:

Image not for diagnosis

Printed: 2009-03-26 오전 10:24:19 (10.50)76:0.15:153.04:31.4 0.00:-1.00
4.81x13.01 13.0:%Fat=32.0%
0.00:0.00 0.00:0.00

2 - Korea Total Body Reference Population (v107)
3 - Matched for Age, Weight (females 25-100 kg), Ethnic

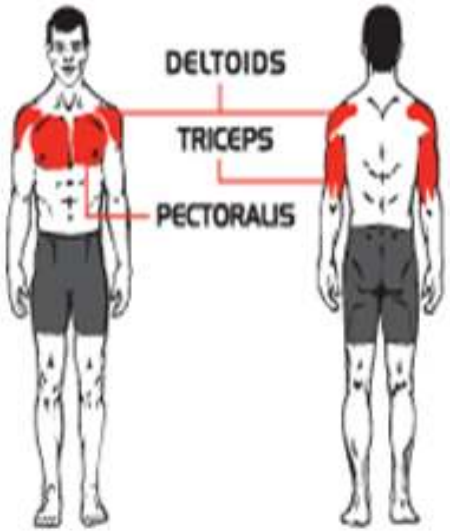
W 256
L 128
Z 100%
Compression 18:1

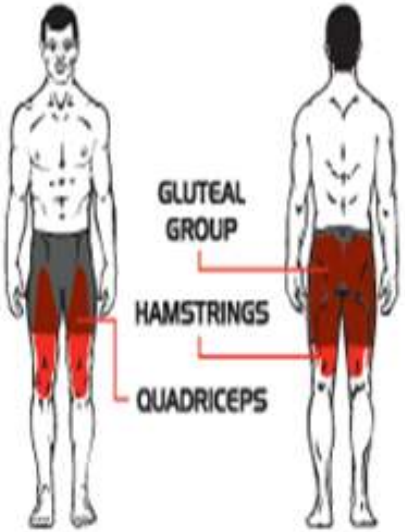
Measurements

- Muscle power (One repetition maximum; KEISER, USA)

Upper extremity	
Air 350 Bi-Axial Chest press	muscle

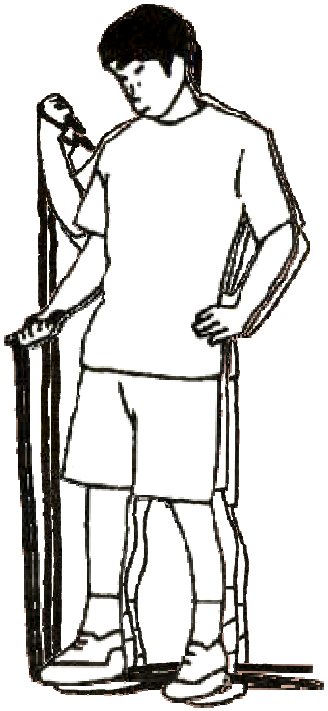
Lower extremity	
Air 300 Leg press	muscle





Resistance Exercise Training

Bicep curl
Triceps extension
Upright row
Shoulder chest press
Trunk side bend
Seated row
Leg press
Hip flexion
Leg flexion
Leg extension



(Topp et al. Arch phys Med rehab, 2002
Ishii et al. Diabetes Care,1998)

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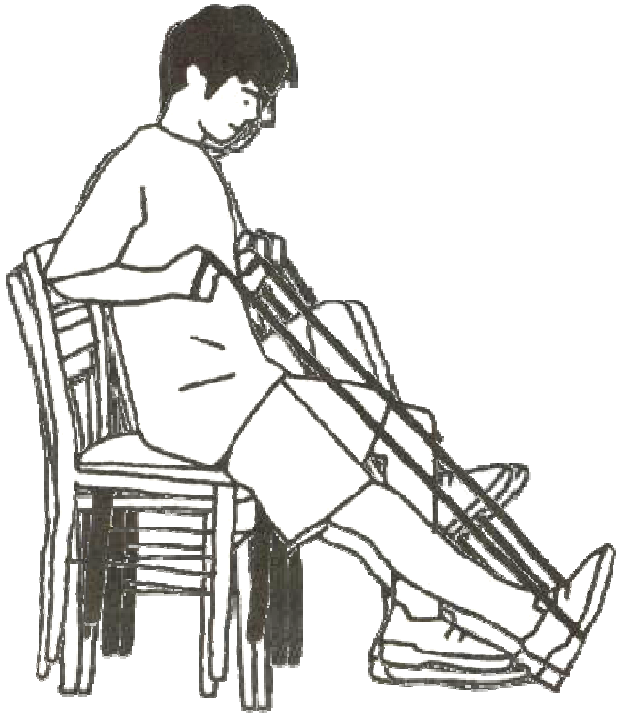

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(Topp et al. Arch phys Med rehab, 2002
Ishii et al. Diabetes Care,1998)

Table 1. Baseline characteristics

Characteristics	Resistance training Group (n = 13)	Control Group (n = 15)	*P*-value
Age (years)	55.7 ± 6.2	57.0 ± 8.0	0.635
DM duration (years)	5.7 ± 4.8	6.1 ± 6.3	0.862
Height (cm)	156.2 ± 4.8	157.3 ± 5.6	0.579
Weight (kg)	66.1 ± 4.4	68.2 ± 7.5	0.385
Body mass index (kg/m^2)	27.1 ± 2.3	27.6 ± 2.8	0.666
HbA1c (%)	7.3 ± 0.9	7.4 ± 0.7	0.943
Fasting c-peptide (ng/mL)	1.9 ± 0.8	1.7 ± 0.6	0.304
Total Cholesterol (mg/dL)	155.7 ± 25.4	159.4 ± 41.2	0.785
Triglyceride (mg/dL)	185.2 ± 113.0	181.9 ± 155.5	0.950
HDL-C (mg/dL)	42.5 ± 8.3	40.1 ± 13.2	0.565
LDL-C (mg/dL)	89.2 ± 25.6	97.7 ± 34.2	0.473
KITT(%/min)	1.8 ± 1.0	2.0 ± 0.8	0.499
Dietary energy intake (kcal/day)	1848.2 ± 170.4	1915.0 ± 199.7	0.354
Total energy expenditure (kcal/day)	1833.5 ± 197.4	1809.2 ± 184.5	0.739
Activity energy expenditure (kcal/day)	279.4 ± 109.2	230.0 ± 70.6	0.161

The values were presented as mean ± standard deviation. HbA1c, glycosylated hemoglobin; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; KITT, insulin tolerance test. *P*-values for comparison between resistance training grnd control group.

Table 2. Changes in Anthropometric and Biochemical Parameters

	Resistance training Group (n = 13)			Control Group (n = 15)			†*P*-values
	Baseline	12 weeks	*P*-values	Baseline	12 weeks	*P*-values	
Weight (kg)	66. 1± 4.4	65.0 ± 4.7	0.009	68.2 ± 7.5	67.5 ± 7.3	0.084	0.415
BMI (kg/m^2)	27.1 ± 2.2	26.7 ± 2.2	0.008	27.6 ± 2.8	27.3 ± 2.8	0.089	0.515
Waist (cm)	90.2 ± 5.0	87.9 ± 5.6	0.009	89.8 ± 12.5	89.3 ± 5.7	0.901	0.485
A1c (%)	7.3 ± 0.9	7.0 ± 0.9	0.187	7.4 ± 0.7	7.3 ± 0.9	0.538	0.569
K_{itt} (%/min)	1.8 ± 1.0	2.1 ± 0.8	0.456	2.0 ± 0.8	2.1 ± 0.6	0.427	0.692
Dietary energy intake (kcal/day)	1848.2 ± 170.4	1618.9 ± 217.6	< 0.001	1915.4 ± 199.7	1763.5 ± 199.6	0.002	0.150
Total energy expenditure (kcal/day)	1833.5 ± 197.4	1835.9 ± 138.8	0.954	1809.7 ± 184.5	1767.7 ± 172.3	0.152	0.283
Activity energy expenditure (kcal/day)	279.4 ± 109.2	281.2 ± 84.2	0.928	230.0 ± 70.6	197.0 ± 83.2	0.175	0.128

The values were presented as mean ± standard deviation. †*P*-values for comparisons between resistance training group and control group.

Table 3. Changes in muscle, fat mass, regional fat, muscle strength and aerobic capacity

	Resistance training Group (n = 13)			Control Group (n = 15)			†P-values
	baseline	12 weeks	P-values	baseline	12 weeks	P-values	
Muscle mass_Arm (g)	4006.7 ± 449.4	4218.6 ± 481.7	0.001	4124.5 ± 801.5	4081.9 ± 725.5	0.539	0.005
_Leg (g)	12000.1 ± 1441.4	12155.4 ± 1491.6	0.241	12319.5 ± 1735.1	12304.4 ± 1641.1	0.919	0.390
_Trunk (g)	20893.1 ± 1667.3	21753.3 ± 2482.9	0.015	21361.6 ± 2482.7	21374.3 ± 2554.3	0.969	0.036
_Total (g)	40296.4 ± 3426.5	41519.5 ± 4107.0	0.003	41185.7 ± 5042.0	41121.1 ± 4771.9	0.859	0.007
Fat mass_Arm (g)	2312.0 ± 395.1	2178.0 ± 455.8	0.019	2650.8 ± 698.3	2584.5 ± 795.0	0.431	0.606
_Leg (g)	5874.6 ± 2026.1	5431.3 ± 2043.3	0.002	5738.5 ± 1393.4	5716.2 ± 1387.9	0.856	0.044
_Trunk (g)	14066.2 ± 2541.2	12947.9 ± 2590.3	< 0.001	15420.2 ± 3485.9	14865.9 ± 3490.6	0.004	0.155
_Total (g)	23076.2 ± 4479.1	21327.2 ± 4616.1	< 0.001	24655.1 ± 5118.8	23999.8 ± 51847.5	0.016	0.039
Regional fat_TAT (mm^2)	40060.2 ± 8420.3	37409.6 ± 8158.4	0.008	41626.3 ± 7782.2	41466.7 ± 7606.9	0.718	0.017
_VAT (mm^2)	15657.8 ± 4753.6	14677.8 ± 3455.9	0.159	17268.7 ± 5060.9	17745.1 ± 4715.3	0.401	0.087
_SAT (mm^2)	24402.4 ± 7903.2	22731.9 ± 7264.2	0.005	24357.5 ± 5437.8	23721.7 ± 5131.6	0.017	0.119
1RM_Upper extremities (kg)	16.5 ± 4.3	18.5 ± 4.4	0.004	18.1 ± 6.6	17.0 ± 6.7	0.021	< 0.001
_Lower extremities (kg)	86.8 ± 24.8	96.9 ± 15.1	0.040	85.7 ± 33.1	75.1 ± 24.1	0.043	0.006
AT-VO_2 (ml/min/kg)	10.3 ± 3.5	12.0 ± 4.8	0.400	9.0 ± 2.8	11.7 ± 3.9	0.282	0.809

The values were presented as mean ± standard deviation. SAT, subcutaneous adipose tissue; TAT, total adipose tissue; VAT, visceral adipose tissue; AT-VO_2, uptake Oxygen at anaerobic threshold. †P-values for comparisons between resistance training group and control group.

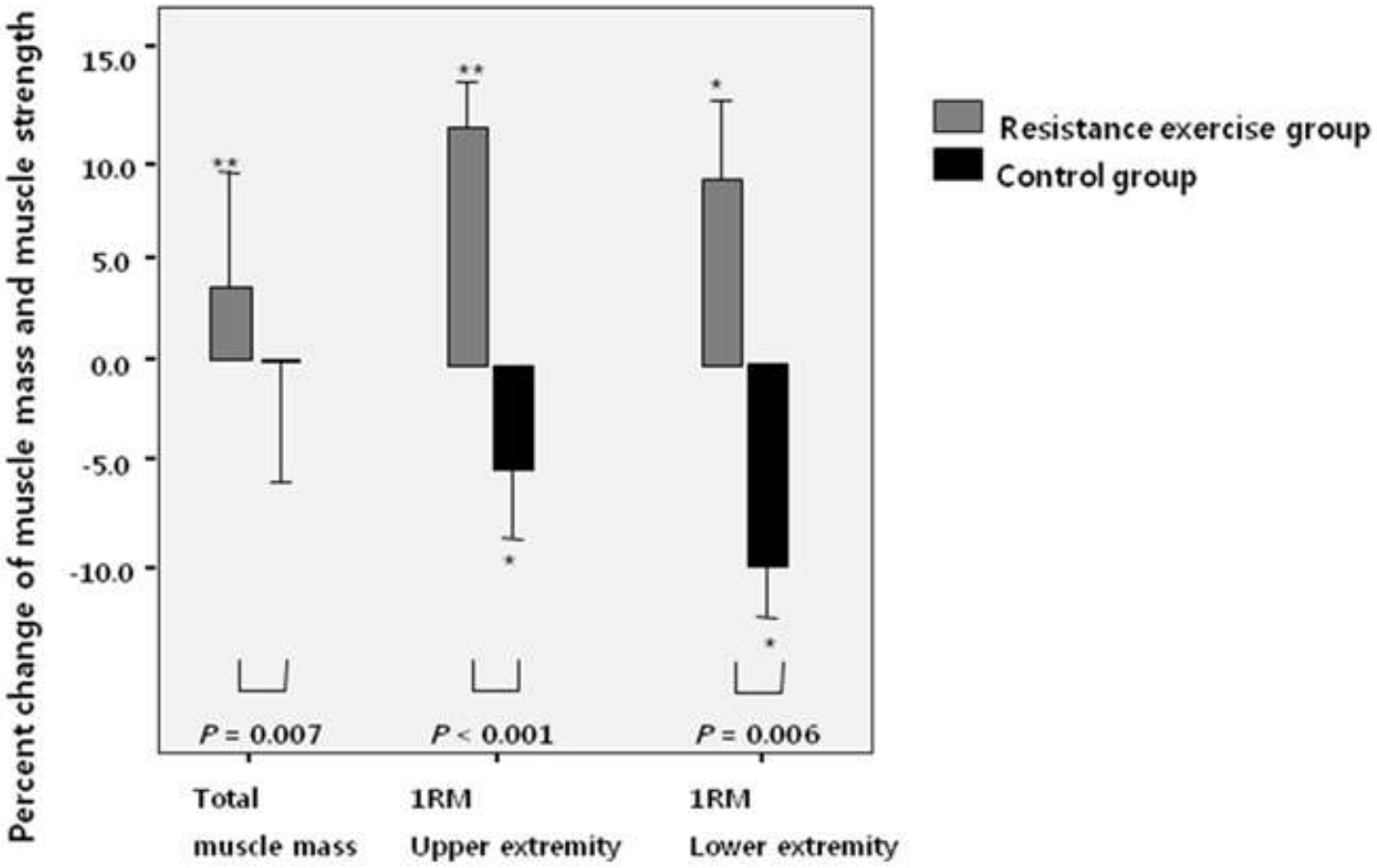

Fig. 1 Percent changes of total muscle mass and muscle strength.

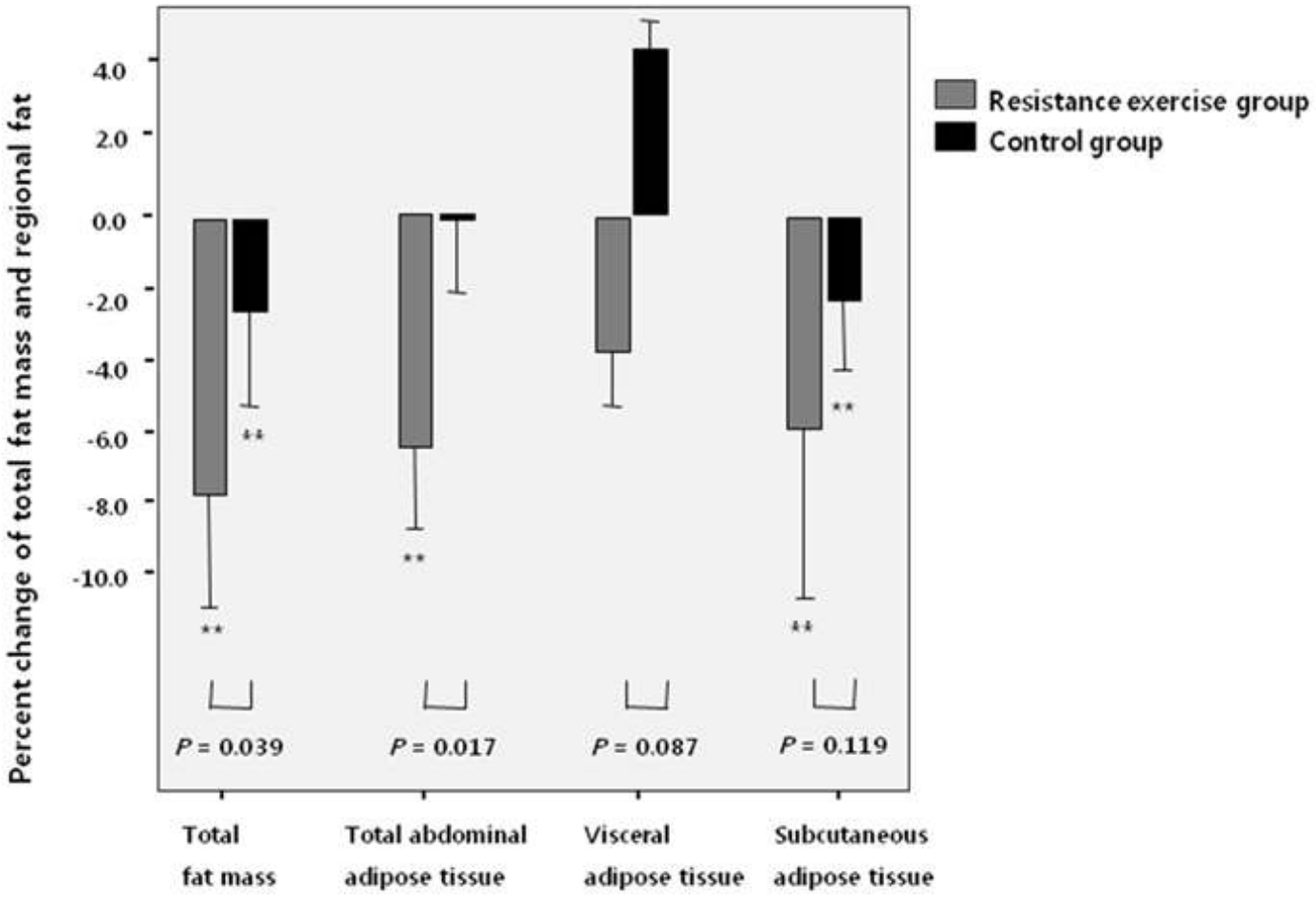

Fig. 2 Percent changes of total fat mass and regional fat

결론

- 비만한 제2형 여자 당뇨병 환자에서 1RM의 40-50% 의 낮은 강도의 밴드 저항 운동은

- 인슐린 저항성의 개선을 보이지는 않았지만
  근육량 및 최대근력의 증가와 총 지방량 감소에 긍정적인 효과가 있었다.

Effect of Supervised Progressive Resistance-Exercise Training Protocol on Insulin Sensitivity, Glycemia, Lipids, and Body Composition in Asian Indians With Type 2 Diabetes

- Method
  30 patients with type 2 diabetes
  12 weeks of PRT
  six muscle groups ,two sets, 10 repetitions each
  75~85% of one repetition maximum, 1RM

- Measurements
  Insulin sensitivity by Insulin tolerance test (KITT)
  total body fat, regional fat, and lean body mass
  by dual-energy X-ray absorptiometry
  cross-sectional skeletal muscle area of upper arm and thigh
  by computed tomography scan

Misra A et al. Diabetes Care. 2008 Jul;31(7):1282-7.

Table 1. Changes in metabolic parameters with PRT protocol

Variables	PRT (0 months)	PRT (1 month)	PRT (2 months)	PRT (3 months)	Mean difference	*P**
n	30	30	30	30	—	—
FBG (mmol/l)	10.07 ± 2.0	8.7 ± 1.3	8.2 ± 1.1	7.4 ± 1.2	2.7 ± 2.2	<0.001
Total cholesterol (mmol/l)	4.58 ± 0.7	4.35 ± 0.5	4.29 ± 0.6	4.19 ± 0.5	0.39 ± 0.7	0.003
TG (mmol/l)	1.99 ± 0.6	1.81 ± 0.5	1.63 ± 0.5	1.59 ± 0.4	0.39 ± 0.5	<0.001
HDL cholesterol (mmol/l)	1.19 ± 0.08	1.19 ± 0.06	1.19 ± 0.09	1.21 ± 0.09	−0.02 ± 0.1	0.331
LDL cholesterol (mmol/l)	1.46 ± 0.6	1.35 ± 0.4	1.34 ± 0.4	1.35 ± 0.4	0.09 ± 0.4	0.210
VLDL cholesterol (mmol/l)	1.06 ± 0.6	0.82 ± 0.3	0.75 ± 0.2	0.71 ± 0.2	0.34 ± 0.6	0.003
A1C (%)	7.7 ± 0.5	7.5 ± 0.5	7.3 ± 0.5	7.2 ± 0.3	0.54 ± 0.4	<0.001

Data are means ± SD. *$P < 0.05$ considered significant. TG, triglyceride.

Table 2. Changes in anthropometric variables with PRT protocol

Variables	PRT (0 months)	PRT (3 months)	Mean difference	*P**
n	30	30	—	—
BMI (kg/m^2)	24.1 ± 3.9	24.1 ± 3.7	0.1 ± 1.1	0.614
Circumferences (cm)				
Waist	87.9 ± 13.1	86.3 ± 12.7	−1.6 ± 1.9	<0.001
Hip	94.3 ± 10.5	92.5 ± 10.5	1.8 ± 1.2	<0.001
Mid-thigh	46.5 ± 5.9	44.9 ± 5.6	1.7 ± 1.1	<0.001
Mid-arm	29.3 ± 5.2	28.1 ± 4.6	−1.2 ± 1.0	<0.001
Waist-to-hip ratio	1.0 ± 0.2	1.0 ± 0.1	−0.0 ± 0.1	0.091
Skinfolds (mm)				
Biceps	7.2 ± 2.1	6.3 ± 1.9	−0.9 ± 0.6	<0.001
Triceps	15.4 ± 8.6	14.1 ± 8.1	−1.3 ± 1.3	<0.001
Subscapular	25.9 ± 10.3	24.3 ± 9.8	−1.6 ± 1.3	<0.001
Anterior axillary	18.4 ± 11.8	17.4 ± 11.2	−0.9 ± 1.2	<0.001
Suprailiac	27.2 ± 13.4	25.8 ± 13.1	−1.4 ± 1.3	<0.001
Thigh	23.8 ± 11.6	22.4 ± 11.3	−1.5 ± 1.1	<0.001
Calf	7.9 ± 3.9	7.1 ± 3.4	−0.9 ± 0.9	<0.001
Lateral thoracic	26.6 ± 11.0	25.6 ± 10.7	−1.3 ± 0.9	<0.001
Subscapular-to-triceps skinfold ratio	1.8 ± 0.7	1.90 ± 0.8	0.08 ± 0.2	0.075
Central skinfolds	98.1 ± 40.5	92.9 ± 38.7	5.2 ± 3.5	<0.001
Peripheral skinfolds	54.4 ± 21.6	49.8 ± 20.4	4.5 ± 3.1	0.001

Data are means ± SD. Central skinfolds: sum of values of subscapular and suprailiac skinfolds. Peripheral skinfolds: sum of values of biceps and triceps skinfolds.
*$P < 0.05$ considered significant.

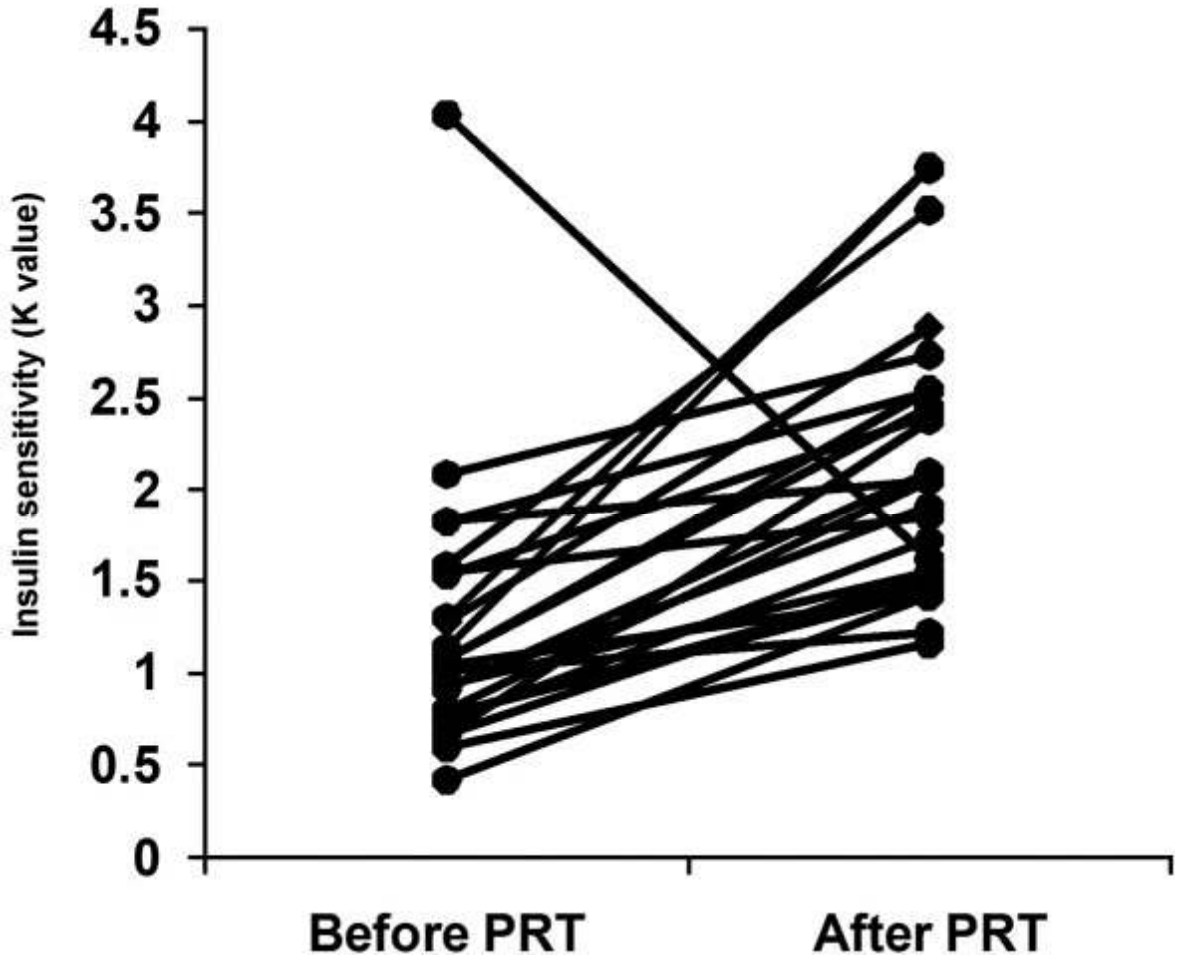

Figure 1—*Insulin sensitivity as assessed by SITT and depicted as K value (see text for details) before and after intervention. Increasing value denotes improved insulin sensitivity.*

Table 3. Changes in percent total body fat, regional fat, lean body mass, and cross-sectional skeletal muscle area of upper and lower extremities with PRT protocol

Variable	PRT (0 month)	PRT (3 months)	Mean difference	*P**
n	30	30	—	—
Body fat (%)	27.7 ± 10.6	27.3 ± 10.3	0.3 ± 1.5	0.239
Truncal—to–total body fat ratio	0.6 ± 0.1	0.6 ± 0.1	0.0 ± 0.0	0.96
Lean body mass (kg)	42.3 ± 6.0	42.6 ± 6.2	0.2 ± 1.5	0.384
Right arm fat (%)	25.1 ± 12.5	23.9 ± 12.6	1.2 ± 6.2	0.311
Right arm regional fat (%)	23.9 ± 12.1	22.8 ± 12.5	1.2 ± 6.3	0.328
Right arm lean mass (kg)	2.8 ± 0.8	2.9 ± 0.6	0.1 ± 0.5	0.166
Right midarm muscle area (cm^2)	34.1 ± 6.7	33.6 ± 8.3	−0.5 ± 3.8	0.487
Right leg fat (%)	25.0 ± 11.8	24.7 ± 11.3	0.3 ± 1.5	0.218
Right leg regional fat (%)	23.9 ± 11.4	23.7 ± 10.9	0.2 ± 1.4	0.386
Right leg lean mass (kg)	6.8 ± 1.2	6.9 ± 1.2	0.1 ± 0.4	0.294
Right mid-thigh muscle area (cm^2)	111.4 ± 17.8	111.6 ± 19.0	−0.1 ± 6.7	0.092

Data are means ± SD. Measurements of percent total body fat, regional fat, lean body mass done by dual-energy X-ray absorptiometry. Measurements of cross-sectional skeletal muscle area of upper and lower extremities done by CT scan. *$P < 0.05$ considered significant.

Resistance training improves metabolic health in type 2 diabetes: A systematic review

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Diabetes Res Clin Pract 83:157-75, 2009

Table 3 – Metabolic outcomes.

Author (year) country	Group	Time of follow-up	Type of change	HbA1c (%)	Glucose (mmol/L)	Insulin (pmol/L)	Insulin sensitivity method	Insulin sensitivity
Winnick et al. (2008) USA [28]	Whites RT AT African RT AT	NR	Pre:Post Δ Time effect Group × time	7.9 ± 2.0:NR 7.8 ± 1.2:NR 6.5 ± 1.0:NR 7.6 ± 1.5:NR NR NR			HOMA IR	6.8 ± 4.8:NR +13.2% 10.6 ± 8.5:NR −3.68% 5.8 ± 2.4:NR −19.15% 8.6 ± 7.4:NR +3.79% NR P < 0.05 RT African v Whites P > 0.05 AT African v Whites
Baum et al. (2007) Germany [21]	RT Vib Flex	72–96 h	Pre:Post Δ Time effect Group × time	6.8% ± 0.17:NR +0.2 ± 0.15 Δ 7.3% ± 0.66:NR −0.3 ± 0.22 Δ 6.7% ± 0.26:NR +0.34 ± 0.26 Δ NR NR	6.99 ± 1.28: 6.66 ± 1.22 7.38 ± 3.16: 6.77 ± 1.94 6.66 ± 1.39: 6.38 ± 1.22 NR NR		OGTT – ear lobe Glucose only	NR:NR −5.6% Δ NR:NR −6.3% Δ NR:NR 0.00% Δ P < 0.05 RT and Vib NR
Brooks et al. (2007) USA [22]	RT Con	72 h	Pre:Post Δ Time effect Group × time	8.7 ± 10.0: 7.6 ± 8.4 −1.0 ± 1.1 Δ 7.8 ± 8.9: 8.3 ± 7.2 +0.4 ± 1.7 Δ NR P < 0.001	8.8 ± 2.8:7.9 ± 2.2 −0.9 ± 2.8 Δ 9.9 ± 3.9:9.5 ± 3.3 −0.3 ± 4.5 Δ NR P – 0.92	116 (124):105 (70)* −16 (69)* Δ 115 (131):133 (126)* +6 (86)* Δ NR P – 0.27	HOMA-IR	7.1 (5.7):5.3 (5.5)* −0.7 (3.6)* Δ 6.7 (9.0):6.4 (6.8)* +0.8 (3.8)* Δ NR P – 0.05
Sigal et al. (2007) Canada [27]	RT AT CT Con	Minimum 48 h	Pre:Post Time effect Group × time	7.5 ± 1.5: 7.2 ± 1.5 7.4 ± 1.5: 7.0 ± 1.5 7.5 ± 1.5: 6.6 ± 1.6 7.4 ± 1.4: 7.5 ± 1.5 P – 0.018 RT P – 0.002 AT P < 0.001 CT P – 0.57 Con P – 0.038 RT v Con P – 0.007 AT v Con P – 0.001 CT v RT P – 0.014 CT v AT				

Dunstan et al. (2006) Australia [25]	Centre Home	48 h	Pre:Post Δ Time effect Group × time	7.8 ± 0.9:NR +0.1 ± 1.0 Δ 7.5 ± 0.5:NR +0.2 ± 1.2 Δ P < 0.05 both grps NS	9.0 ± 2.0:NR −0.3 ± 1.8 Δ 8.4 ± 1.9:NR −0.2 ± 2.2 Δ NS NS	143.7 ± 66.1:NR −21 ± 47.6 Δ 126.6 ± 55.1:NR −8.5 ± 32.8 Δ P < 0.05 centre NS	HOMA	46.9 ± 26.1:NR +9.4 ± 16.4 Δ 50.7 ± 24.6:NR +2.4 ± 12.4 Δ P < 0.05 centre NS
Gordon et al. (2006) USA [26]	RT Con	72 h	Pre:Post Time effect Group × time	8.7 ± 1.9:7.7 ± 1.6 8.0 ± 1.6:8.3 ± 1.6 NR P < 0.01		173 ± 108:132 ± 54 157 ± 101:168 ± 139 NR P < 0.05	HOMA-IR	8.5 (7.2):5.3 (6.3)* 6.7 (7.8):7.1 (7.4)* NR P = 0.08
Cauza et al. (2005) Austria [24]	RT AT		Pre:Post Δ Time effect Group × time	8.3 ± 8.0:7.1 ± 1.7 −1.2 Δ 7.7 ± 1.2:7.4 ± 1.2 −0.3Δ P = 0.001 RT, NS AT P = 0.009	11.32 ± 7.62:8.16 ± 3.77 −3.2 Δ 8.88 ± 2.06:8.83 ± 2.31 −0.05 Δ P < 0.001 RT, NS AT P = 0.002	130.9 ± 84.0:118.4 ± 85.4 −12.5 Δ 105.1 ± 77.5:125.6 ± 96.1 +20.46 Δ NS both grps P = 0.04	HOMA-IR	9.1 ± 7.0:7.2 ± 5.6 −2.0 Δ 6.8 ± 5.8:8.4 ± 7.8 +1.5 Δ P = 0.04 RT, NS AT P = 0.009
Cauza et al. (2005) Austria [23]	RT AT		Pre:Post Time effect Group × time	7.5 ± 1.4:7.0 ± 2.1 8.0 ± 3.8:7.6 ± 4.8 NS both groups NR				
Dunstan et al. (2005) Australia [20]	RT Con	48 h	Pre:post Δ Time effect Group × time	Returned towards baseline Returned towards baseline P < 0.05 NR	NR:NR +0.3 ± 2.2 Δ NR:NR −0.5 ± 2.1 Δ NS both grps NS	NR:NR −0.1 ± 46.8 Δ NR:NR −19.3 ± 50.1 Δ P < 0.05 Con, NS RT NS	HOMA-IR	NR:NR +0.04 ± 5.5 Δ NR:NR +5.4 ± 6.5 Δ P < 0.05 Con, NS RT NS
Baldi and Snowling (2003) New Zealand [12]	RT Con	36–48 h	Pre:Post Time effect Group × time	8.9 ± 3.6:8.4 ± 1.8 8.5 ± 2.4:8.4 ± 1.8 P = 0.057 RT, 0.64 Con NR	12.0 ± 2.7:11.4 ± 2.4 11.1 ± 3.3:11.0 ± 3.0 P < 0.05 RT NR	268.1 ± 35.4:146.5 ± 28.5 191.7 ± 63.9:214.6 ± 52.1 P < 0.05 RT NR	Insulin sensitivity index 0.120	20.3 ± 3.9:22.6 ± 3.9 22.2 ± 11.4:19.9 ± 5.1 NS NR
Castaneda et al. (2002) USA [13]	PRT Con	48 h	Pre:Post Δ Time effect Group × time	8.7 ± 1.7:7.6 ± 1.1 −12.6 ± 11.1% Δ 8.4 ± 1.7:8.3 ± 2.8 +1.2 ± 5.6% Δ NR P = 0.01	8.8 ± 2.8:7.9 ± 2.2 9.7 ± 3.9:8.9 ± 3.9 NR P = 0.34			
Dunstan et al. (1998) Australia [15]	CRT Con	48 h	Pre:Post Δ Time effect Group × time	8.2 ± 1.9:8.0 ± 1.9 8.1 ± 2.1:8.3 ± 2.4 NS both grps NS	9.6 ± 3.5:9.4 ± 3.1 9.9 ± 4.2:9.8 ± 4.5 NS both grps NS	64.3 ± 49.1:63.1 ± 48.8 82.6 ± 36.4:93.8 ± 43.7 NS both grps NS	OGTT - Glucose AUC - Insulin AUC	−22 ± 240Δ −2183 ± 6053Δ +191 ± 291Δ +3947 ± 5352Δ NR P < 0.05 glucose and insulin

RT, resistance training; Flex, flexibility training; Vib, vibration training; Con, control; NR, not reported; AT, aerobic training; NS, not significant; PRT, progressive resistance training; CRT, circuit resistance training; CT, combined aerobic and resistance training; *, values are median (interquartile range). Castaneda [29] did not report any metabolic variables.

결론

- 당뇨병 환자에서 저항운동에 의한 인슐린저항성 개선의 효과는 강도, 빈도와 기간 등에 따라 다르게 나타난다

- 그러나 인슐린저항성을 개선시킬 목적으로 최소 어느 정도의 강도와 빈도 및 기간이 필요한지는 통일 된 결과가 없으며 앞으로 풀어야 할 과제이다

Anti-inflammatory effect of exercise training in subjects with type 2 diabetes and the metabolic syndrome is dependent on exercise modalities and independent of weight loss

Methods: 82 patients were randomized into

4 groups for 12 months :

sedentary control (A)

low-intensity physical activity (B)

supervised high-intensity aerobic (C)

aerobic þ resistance (D) exercise (with the same caloric expenditure)

Evaluation of leisure-time physical activity and assessment of physical fitness, cardiovascular risk factors and inflammatory biomarkers was performed

S. Balducci et al. . Nutrition, Metabolism & Cardiovascular Diseases (2009)

Table 1 Baseline clinical characteristics of patients.

Characteristics	Group A	Group B	Group C	Group D	*p*-Value
Gender, F/M	9/11	9/11	8/12	8/14	
Age, years (mean ± SD)	61.1 ± 7.1	62.5 ± 7.1	64.3 ± 8.1	60.6 ± 9.3	ns
Duration of diabetes, years (mean ± SD)	7.8 ± 5.2	10.1 ± 7.3	9.4 ± 6.0	8.5 ± 5.7	ns
Smoking, *n* (%)					
Never	14 (70)	14 (70)	15 (75)	17 (77)	ns
Former	3 (15)	4 (20)	3 (15)	2 (9)	ns
Current	3 (15)	2 (10)	2 (10)	3 (14)	ns
Medications, *n* (%)					
Oral hypoglycemic agents	14 (70)	18 (90)	15 (75)	19 (86)	ns
Sulfonylurea	3 (15)	8 (40)	5 (25)	5 (23)	ns
Glinide	6 (30)	6 (30)	7 (35)	4 (18)	ns
Metformin	9 (45)	13 (65)	11 (55)	18 (82)	ns
Thiazolidinedione	4 (20)	4 (20)	4(20)	5 (23)	ns
Insulin use	4 (20)	2(10)	3 (15)	3 (14)	ns
Antihypertensive agents	13 (65)	15 (75)	13 (65)	13 (59)	ns
Angiotensin-converting enzyme inhibitor	5 (25)	5 (25)	3 (15)	6 (27)	ns
Angiotensin-receptor blocker	12 (60)	9 (45)	8 (40)	8 (36)	ns
Diuretic	6 (30)	13 (65)	7 (35)	5 (23)	ns
Calcium-channel blocker	2 (10)	2 (10)	2 (10)	2 (9.1)	ns
Beta-blocker	2 (10)	0 (0)	1 (5)	3 (14)	ns
Alpha1-adrenergic blocker	0 (0)	0 (0)	1 (5)	2 (9.1)	ns
Lipid-lowering agents	9 (45)	9 (45)	10 (50)	11 (50)	ns
Statin	8 (40)	8 (40)	10 (50)	9 (41)	ns
Fibrate	0 (0)	0 (0)	0 (0)	1 (4.5)	ns
ω-3	2 (10)	2 (10)	0 (0)	0 (0)	ns
Antiplatelet agents	10 (50)	9 (45)	7 (35)	6 (27)	ns

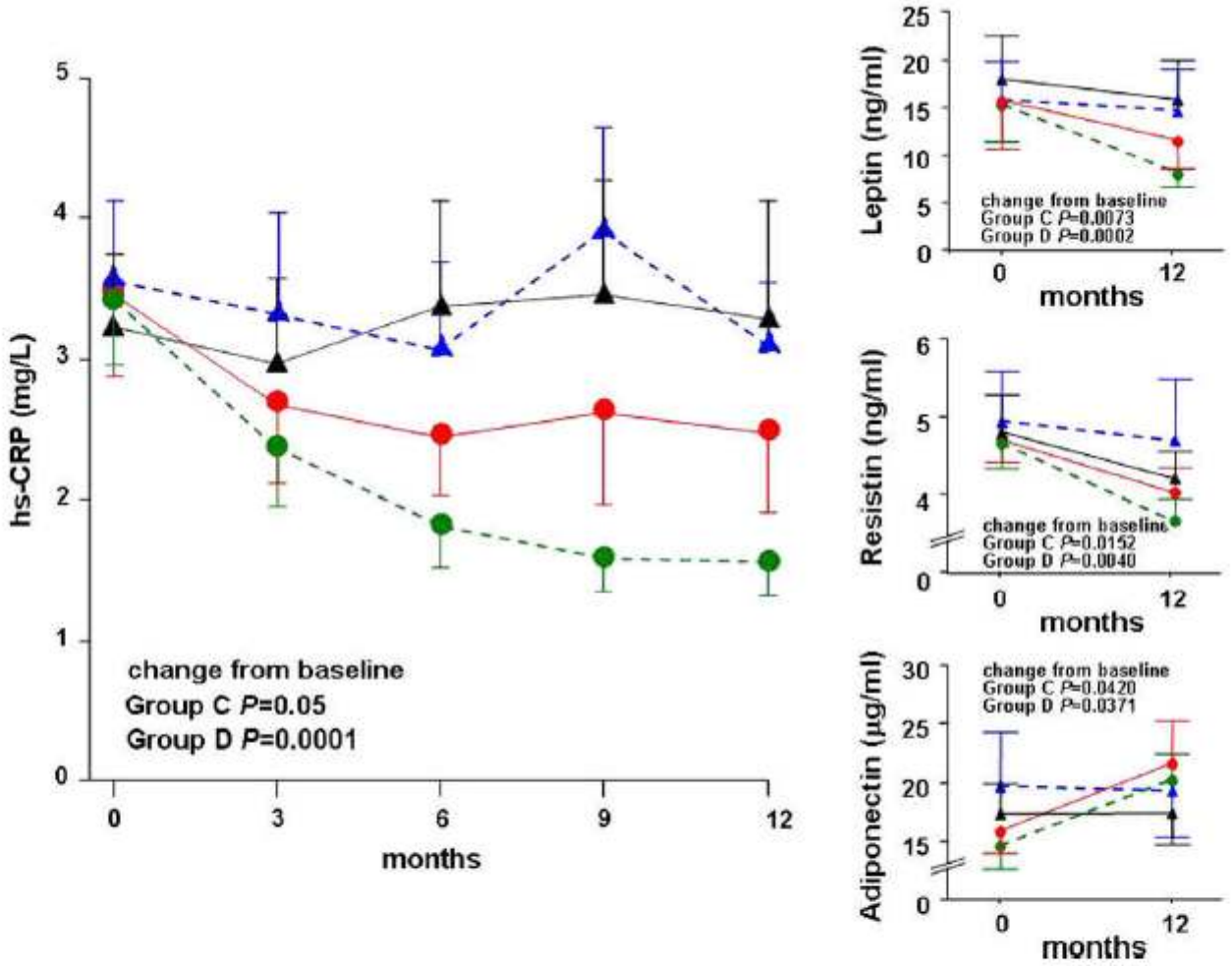

Figure 1 hs-CRP, leptin, resistin and adiponectin levels in Group A (black closed line and triangles), B (blue dashed line and triangles), C (red closed line and circles) and D (green dashed line and circles) patients at time 0 and after 3, 6, 9 (only for hs-CRP) and 12 months of sedentary or active (leasure-time ± prescribed and supervised physical activity) lifestyle (mean ± SEM, *p*-values for Friedman test for hs-CRP, Wilcoxon matched-pairs signed-ranks test for leptin, and paired *t* test for resistin and adiponectin). hs-CRP = high sensitivity-C reactive protein. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

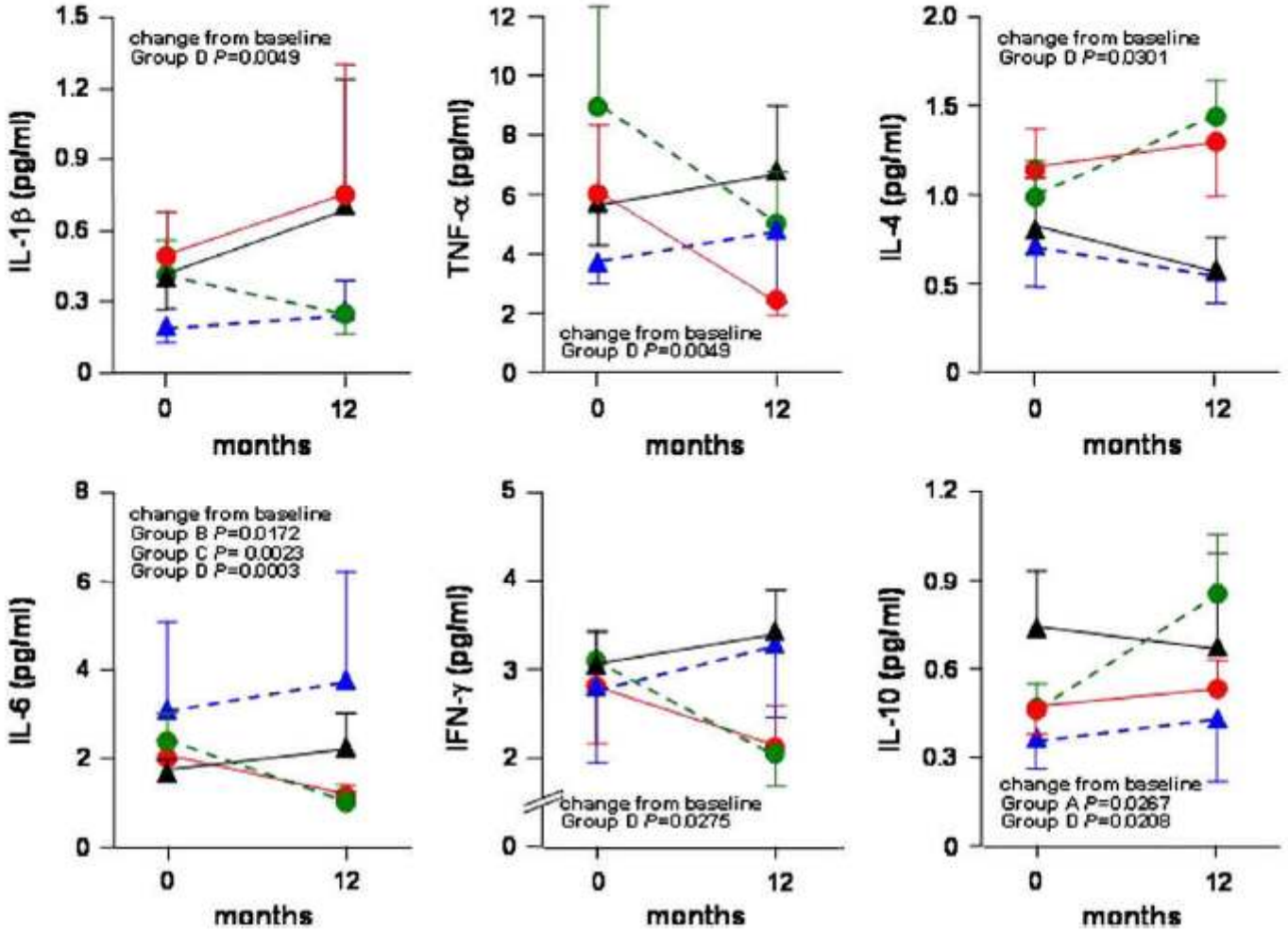

Figure 2 IL-1β, IL-γ, TNF-α, IFN-γ, IL-4 and IL-10 levels in Group A (black closed line and triangles), B (blue dashed line and triangles), C (red closed line and circles) and D (green dashed line and circles) patients at time 0 and after 12 months of sedentary or active (leasure-time ± prescribed and supervised physical activity) lifestyle (mean ± SEM, *p*-values for Wilcoxon matched-pairs signed-ranks test, for IL-1b;, IL-6, TNF-α and IFN-γ, or paired *t* test, for IL-10). IL = interleukin; TNF-α = tumor necrosis factor-α; and IFN-γ = interferon-γ. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

제2형 당뇨병 여자 환자에서 유산소 운동과 저항 운동이 혈관 내피세포 기능에 미치는 영향

- **Methods:** 제2형 당뇨병 여자 총 40명을 대상으로 12주 동안
  유산소 운동군(AG, n=13)
  저항 운동군(RG, n=12)
  대조군(CG, n=15)
- AG는 1주 3회, 1회에 60분씩 중강도의 걷기 운동을 실시
  RG는 1주 3회, 1회에 60분씩, 최대 근력의 40-50% 강도로 탄력밴드를 이용한 저항운동을 실시
- 혈관 내피세포 기능은 내피세포 의존성 확장반응(Endothelium dependent vasodilation: flow-mediated dilation, FMD)과 내피세포 비의존성 확장반응(Endothelium independent vasodilation, EID)으로 측정
- 심폐능력은 운동부하 검사를 실시하여 무산소성 역치의 산소 섭취량 (AT_VO_2)으로 평가

Table 1. Baseline characteristics

Characteristics	AEG (n = 13)	REG (n = 12)	CG (n = 15)	†*P*-value
Age (years)	55.5 ± 8.6	56.3 ± 6.1	58.9 ± 5.7	0.931
DM duration (years)	6.6 ± 6.7	4.6 ± 2.7	4.9 ± 4.7	0.720
Weight (kg)	66.2 ± 7.3	66.3 ± 4.6	65.2 ± 5.6	0.889
Body mass index (kg/m²)	26.7 ± 2.6	27.4 ± 2.1	27.0 ± 2.3	0.639
Waist (cm)	88.4 ± 6.0	90.8 ± 4.8	90.4 ± 5.5	0.407
HbA1c (%)	7.6 ± 0.8	7.4 ± 0.9	7.1 ± 0.7	0.480
Insulin (μIU/mL)	3.3 ± 2.5	5.8 ± 5.9	4.9 ± 3.8	0.770
Fasting c-peptide (ng/mL)	1.7 ± 0.5	1.9 ± 0.8	1.6 ± 0.5	0.249
Total Cholesterol (mg/dL)	171.8 ± 45.3	157.8 ± 25.4	173.1 ± 51.0	0.731
Triglyceride (mg/dL)	145.2 ± 65.9	193.0 ± 114.3	168.0 ± 161.0	0.357
HDL-C (mg/dL)	42.6 ± 9.8	42.8 ± 8.5	44.4 ± 18.6	0.745
LDL-C (mg/dL)	114.8 ± 41.1	89.7 ± 26.8	102.1 ± 40.2	0.337
FMD (%)	4.0 ± 1.9	4.9 ± 2.5	4.8 ± 1.6	0.248
EID (%)	17.0 ± 5.6	18.4 ± 7.3	18.6 ± 4.3	0.964
AT_VO2 (ml/min/kg)	8.8 ± 2.7	10.2 ± 3.6	9.7 ± 4.1	0.272
AEE (kcal/day)	289.2 ± 30.2	291.1 ± 105.2	246.8 ± 54.3	0.210
TEE (kcal/day)	1898.1 ± 165.0	1842.9 ± 203.1	1813.1 ± 180.2	0.638
DEI (kcal/day)	1917.9 ± 151.9	1863.0 ± 169.0	1872.2 ± 114.0	0.591

The values were presented as mean ± standard deviation. AEE, Activity energy expenditure; AEG, aerobic exercise group; AT_VO_2, uptake Oxygen at anaerobic threshold; CG, control group; DEI, Dietary energy intake; FMD, flow-mediated vasodilation; HbA1c, glycosylated hemoglobin; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; REG, resistance exercise group; TEE, Total energy expenditure. †*P*-values was calculated from ANOVA test between 3 group.

Table 3. Changes in energy expenditure, dietary energy intake Endothelial function

	Group	Baseline	Post-intervention	‡*P*- value
Activity energy expenditure (kcal/day)	AEG	287.1 ± 33.0	385.0 ± 88.0*†	0.001
	REG	291.1 ± 105.2	291.1 ± 79.7	
	CG	248.5 ± 54.4	244.7 ± 99.0	
Dietary energy intake (kcal/day)	AEG	1917.9 ± 151.9	1780.5 ± 154.3*	0.164
	REG	1863.0 ± 169.0	1738.2 ± 215.3*	
	CG	1872.2 ± 114.0	1740.6 ± 123.9*	
AT_VO_2(ml/min/kg)	AEG	8.4 ± 3.4	15.6 ± 4.5*†	0.005
	REG	10.2 ± 3.6	11.9 ± 5.0	
	CG	10.0 ± 3.6	9.8 ± 4.1	
FMD (%)	AEG	4.3 ± 1.6	6.4 ± 1.9*†	0.032
	REG	4.9 ± 2.5	5.6 ± 2.8	
	CG	4.7 ± 1.9	4.0 ± 1.9	
EID (%)	AEG	17.7 ± 5.6	20.5 ± 5.7*	0.153
	REG	18.4 ± 7.3	19.3 ± 6.2	
	CG	18.0 ± 4.5	15.4 ± 5.2	

The values were presented as mean ± standard deviation. AEG, aerobic exercise group; CG, control group; FMD, flow-mediated vasodilation; REG, resistance exercise group. **P*-values compared to baseline and intervention within group. †*P*- value <0.05 vs. control group, ‡*P*-values was calculated from ANOVA test between 3 group at the time of 12 week.

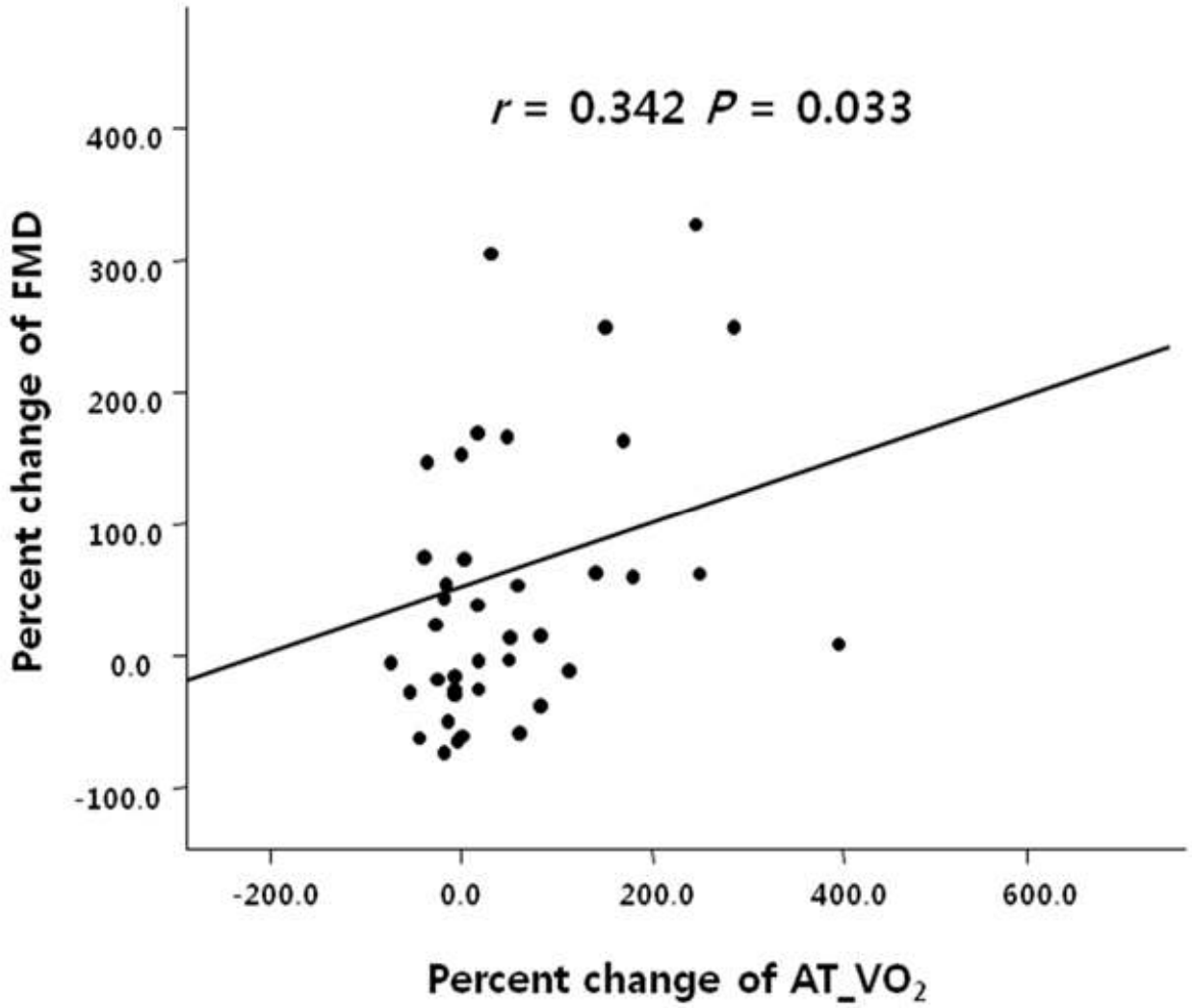

Fig. 1 Correlations between Percent change of uptake Oxygen at anaerobic threshold (AT_VO_2) and percent change of flow-mediated dilation (FMD).

결론

- 유산소운동은 혈관 내피세포 기능을 호전시키지만 저항운동은 효과가 없었다

- 제2형 당뇨병 환자의 혈관 내피세포 기능을 향상시키기 위해서는 심폐 능력의 향상이 필요할 것으로 생각된다