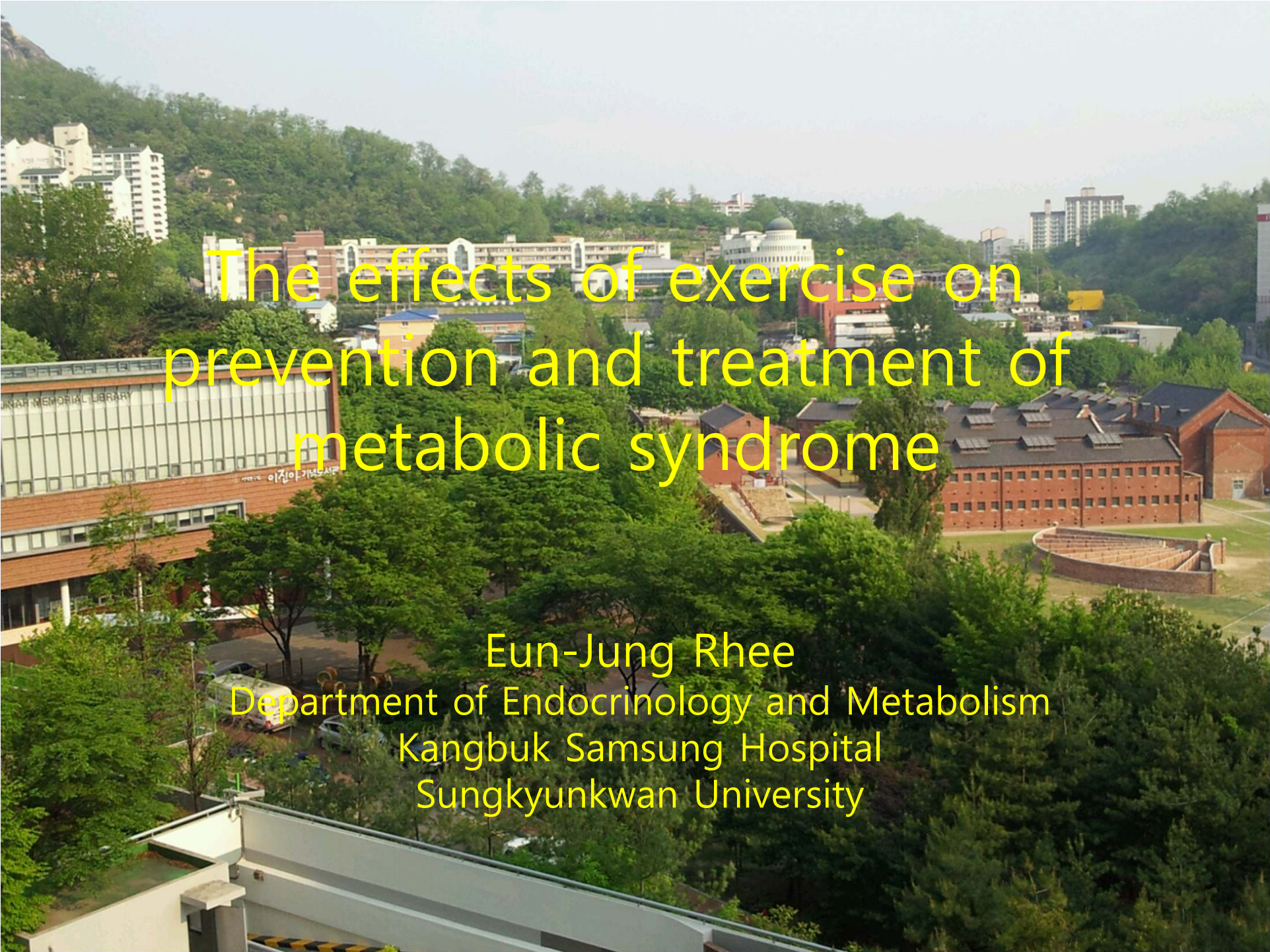


An aerial photograph of the Sungkyunkwan University campus. The image shows a large green hill in the background with several buildings, including a prominent white building with a dome. In the foreground, there are lush green trees and a large brick building with a curved roof. A parking lot with several cars is visible. The text "The effects of exercise on prevention and treatment of metabolic syndrome" is overlaid in yellow. The text "Eun-Jung Rhee" is overlaid in yellow. The text "Department of Endocrinology and Metabolism" is overlaid in yellow. The text "Kangbuk Samsung Hospital" is overlaid in yellow. The text "Sungkyunkwan University" is overlaid in yellow.

The effects of exercise on prevention and treatment of metabolic syndrome

Eun-Jung Rhee
Department of Endocrinology and Metabolism
Kangbuk Samsung Hospital
Sungkyunkwan University

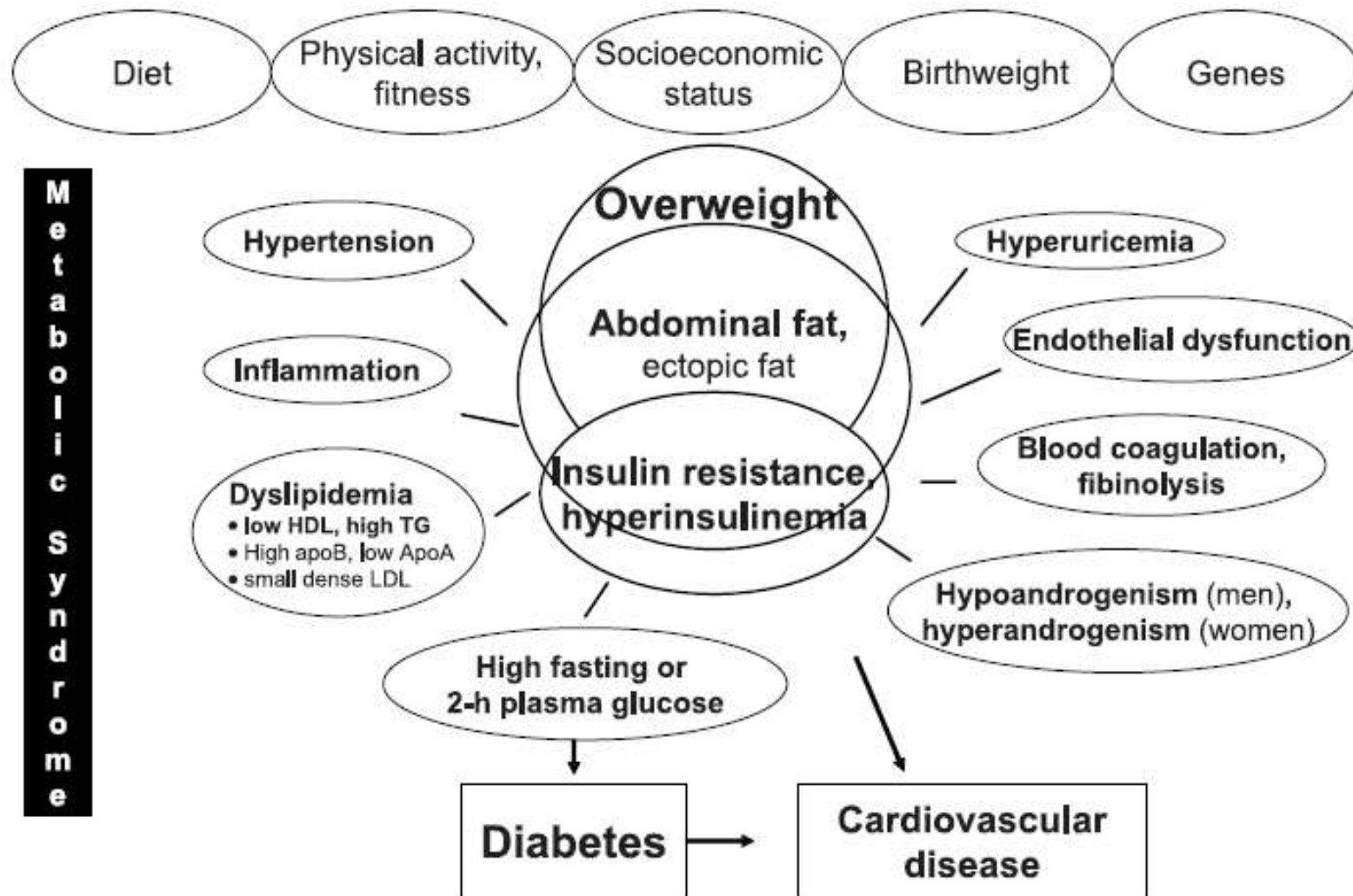
오늘 말씀드릴 내용

- 대사증후군의 전반적 개요
- 운동의 효과: 근육, 지방세포
- 대사증후군과 운동의 관계 – Clinical data
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- 운동의 효과-실제 data를 중심으로
- 운동의 방법

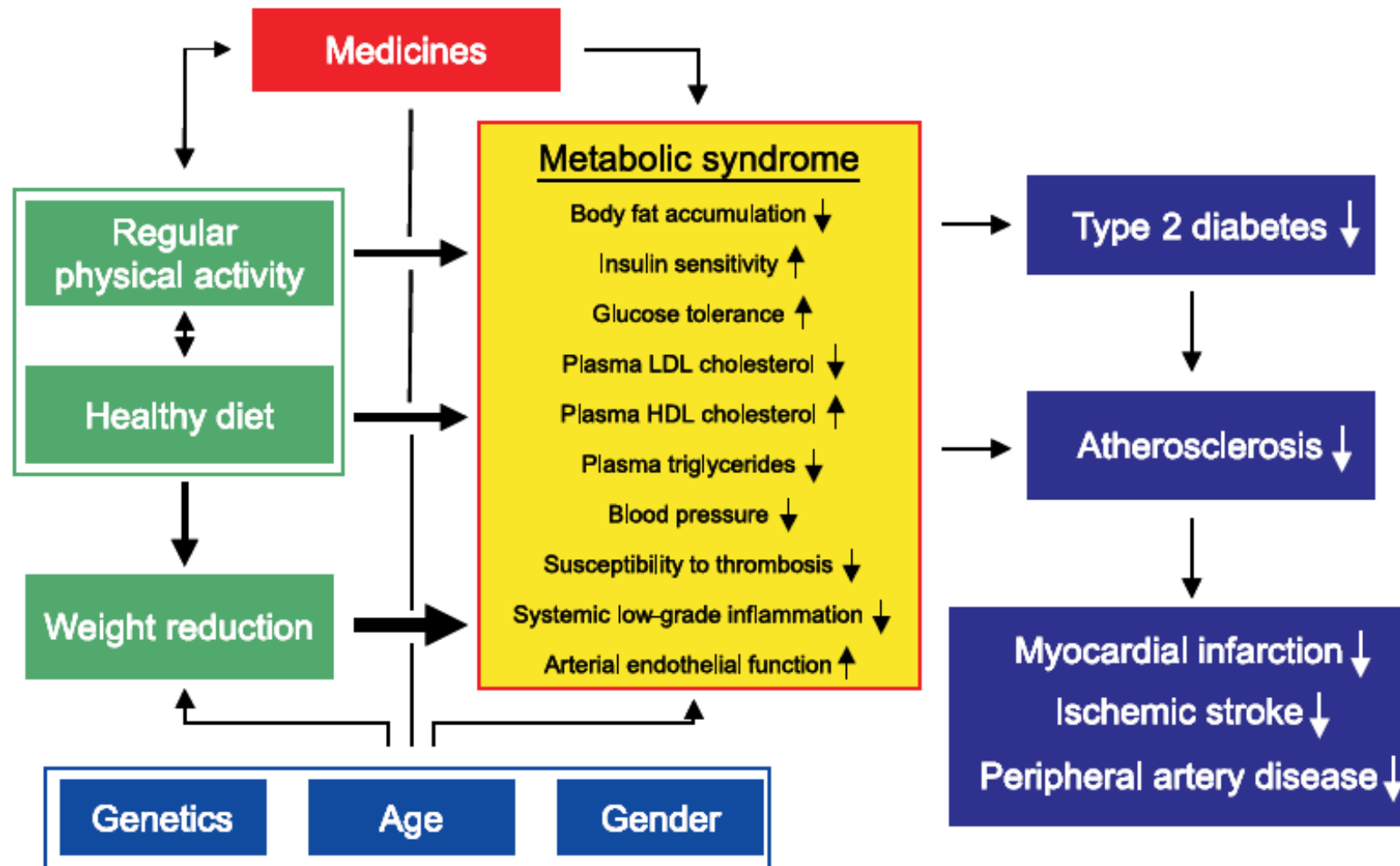
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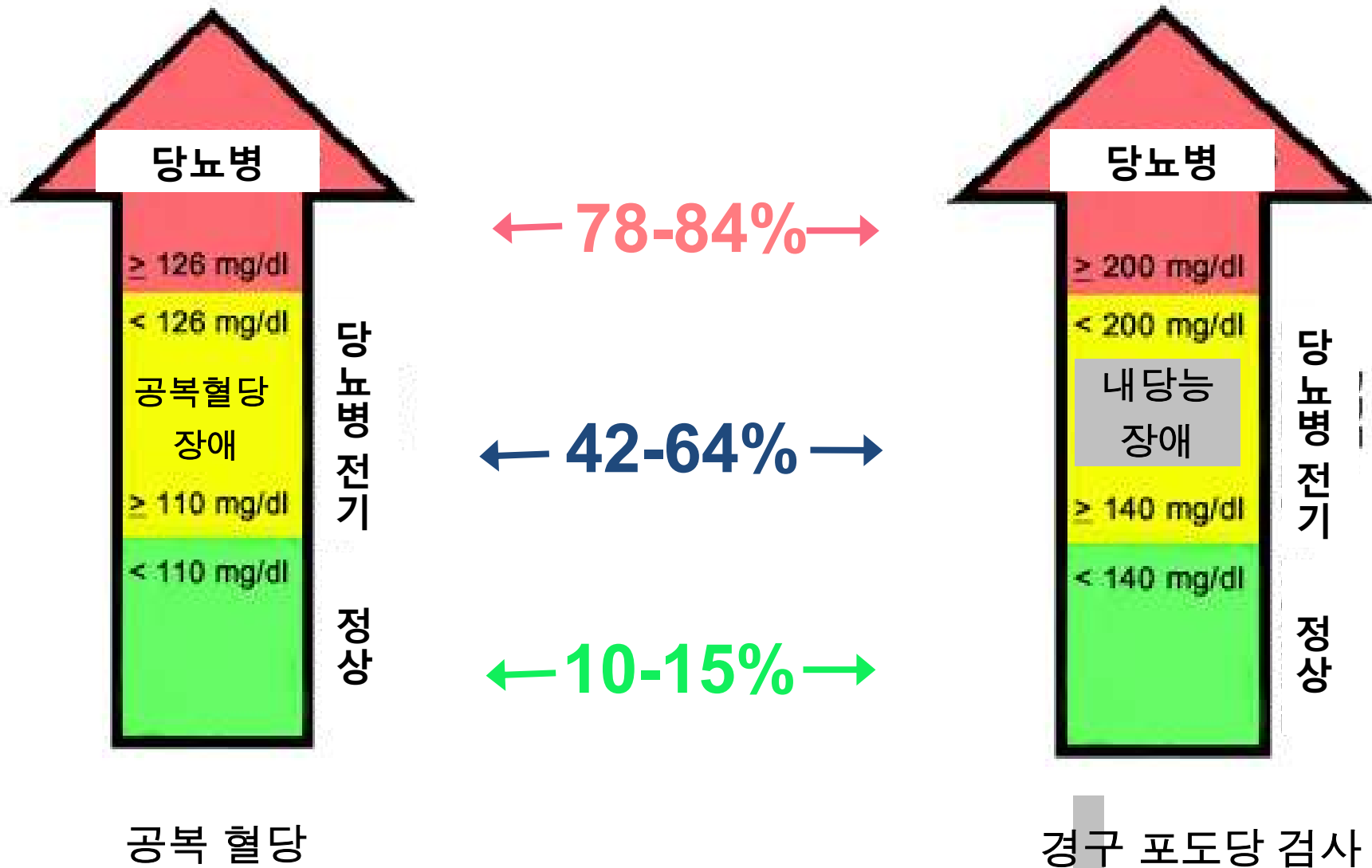
The "Metabolic Syndrome"



Physical activity in the etiology of the metabolic syndrome



고혈당 정도에 따른 대사증후군 유병율

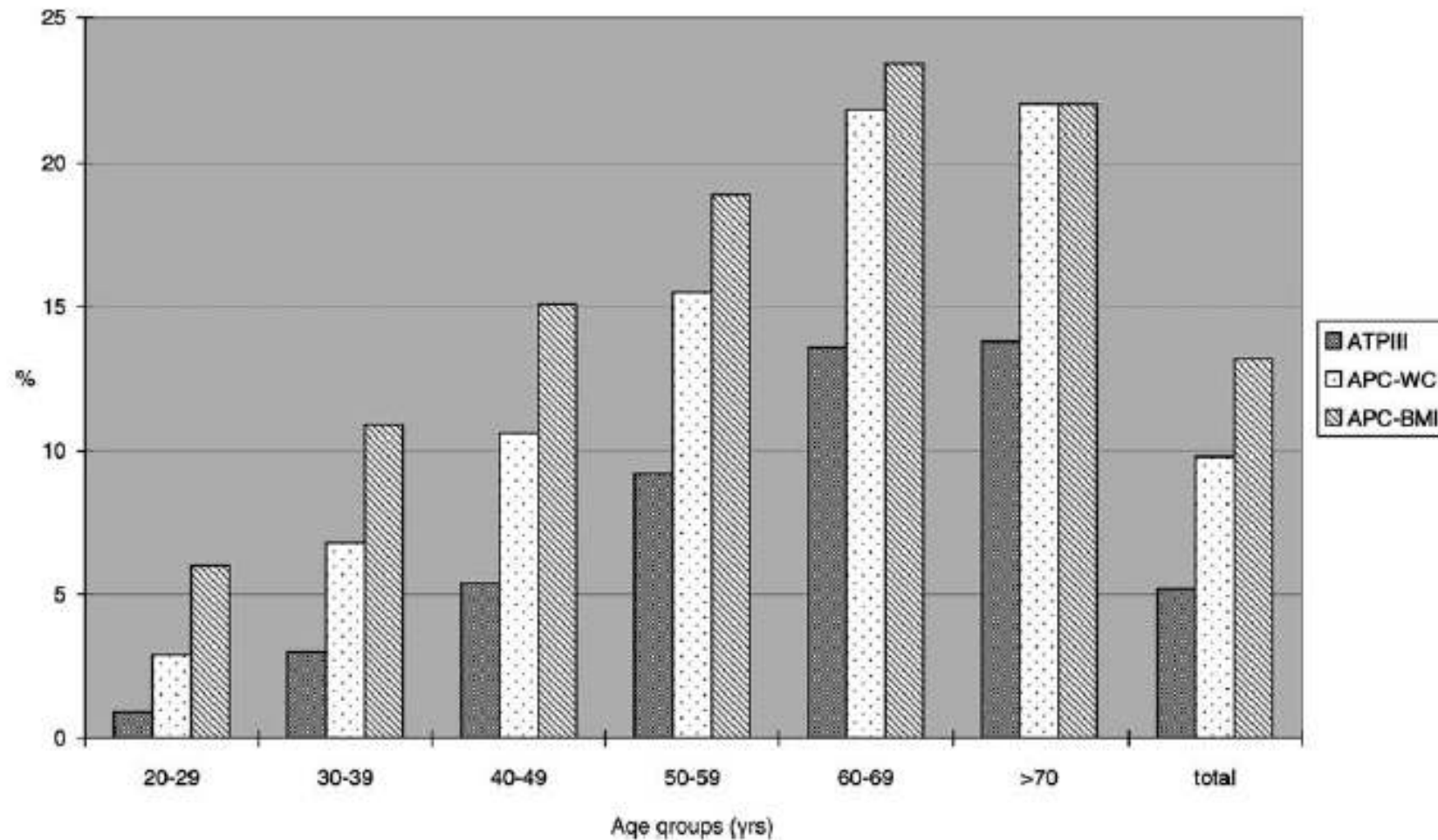


대사증후군의 유병율

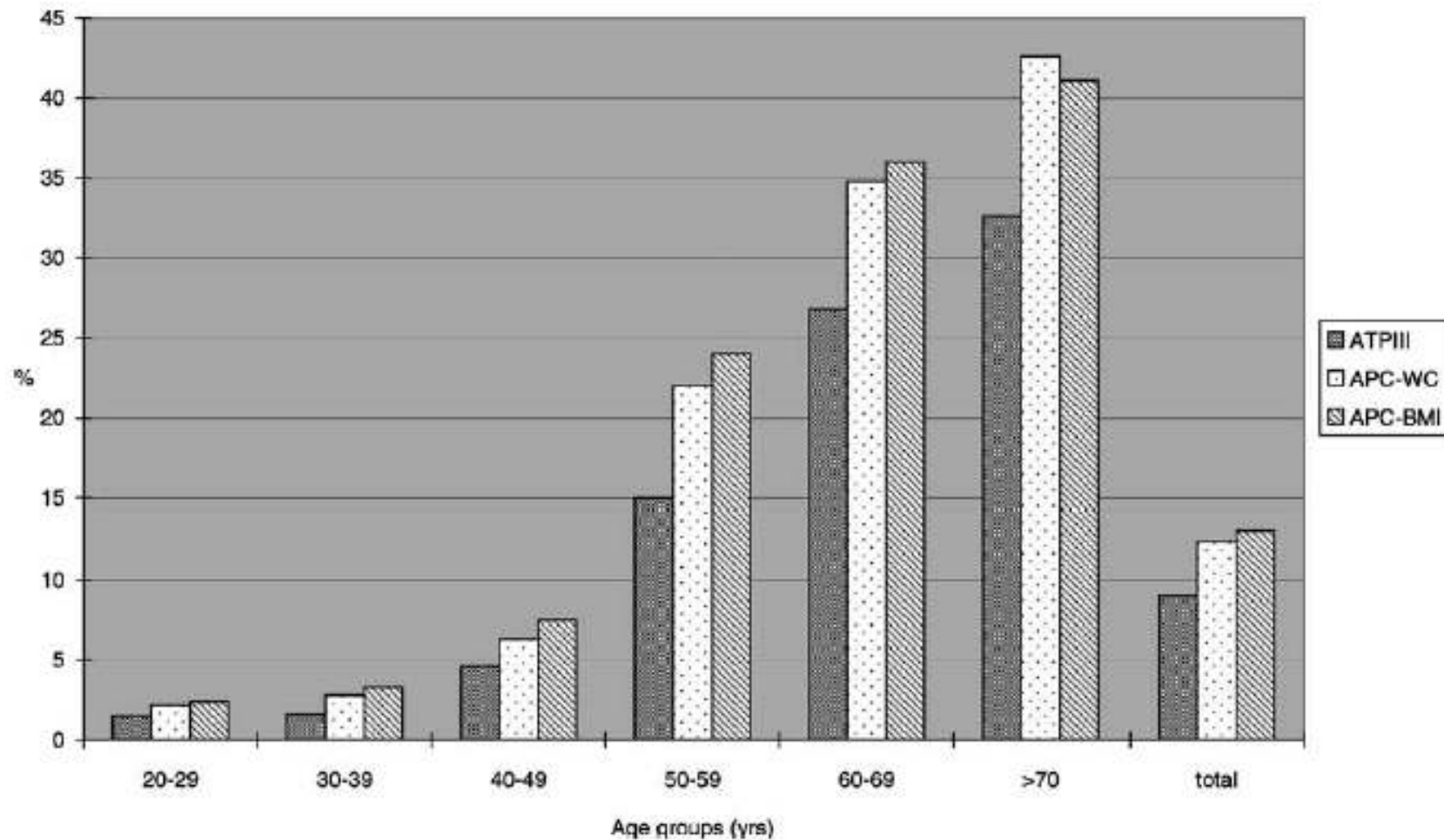
Table 2. Changes in the prevalence of obesity and metabolic syndrome in Korea

		1998 KNHANES	2005 KNHANES	2007-2009 KNHANES
Obesity (BMI ≥ 25 kg/m ²)	Men	25.9	34.8	35.8
	Women	27.5	28.3	26.1
	All	26.7	31.5	30.9
Severe obesity (BMI ≥ 30 kg/m ²)	Men	1.72	3.42	3.88
	Women	3.08	3.60	3.92
	All	2.41	3.52	3.90
Central obesity	Men	20.6	24.0	24.8
	Women	24.1	23.8	23.5
	All	22.4	23.9	24.1
Metabolic syndrome	Men	16.8	33.8	35.0 ^a
	Women	21.9	26.8	30.1 ^a
	All	19.6	30.2	32.4 ^a

Prevalence of the metabolic syndrome among 40,698 Korean metropolitan subjects (male)



Prevalence of the metabolic syndrome among 40,698 Korean metropolitan subjects (female)



Diagnosis of metabolic syndrome

	Categorical cutpoints
Increased waist circumference*	Population-specific and country-specific definitions
Increased triglycerides (drug treatment for elevated TG is alternate indicator†)	≥150 mg/dL (1.7 mmol/L)
Reduced HDL cholesterol (drug treatment for reduced HDL cholesterol is alternate indicator†)	<40 mg/dL (1.0 mmol/L) in men; <50 mg/dL (1.3 mmol/L) in women
Increased blood pressure (antihypertensive drug treatment in patient with history of hypertension is alternate indicator)	Systolic ≥130 and/or diastolic ≥85 mm Hg
Increased fasting glucose‡ (drug treatment of increased glucose is alternate indicator)	> 100 mg/dL (5.5 mmol/L)
*It is recommended that the IDF cutpoints be used for non-Europeans and either the IDF or AHA/NHLBI cutpoints used for people of European origin until more data are available. †Most commonly used drugs for increased triglycerides and reduced HDL cholesterol are fibrates and nicotinic acid. A patient on one of these drugs can be presumed to have high triglycerides and low HDL. Use of high-dose ω-3 fatty acids presumes high triglycerides. ‡Most patients with type 2 diabetes will have the metabolic syndrome by the proposed criteria.	
Table: Criteria for clinical diagnosis of metabolic syndrome	

Alberti KGMM et al. Circulation
120:1640-45, 2009

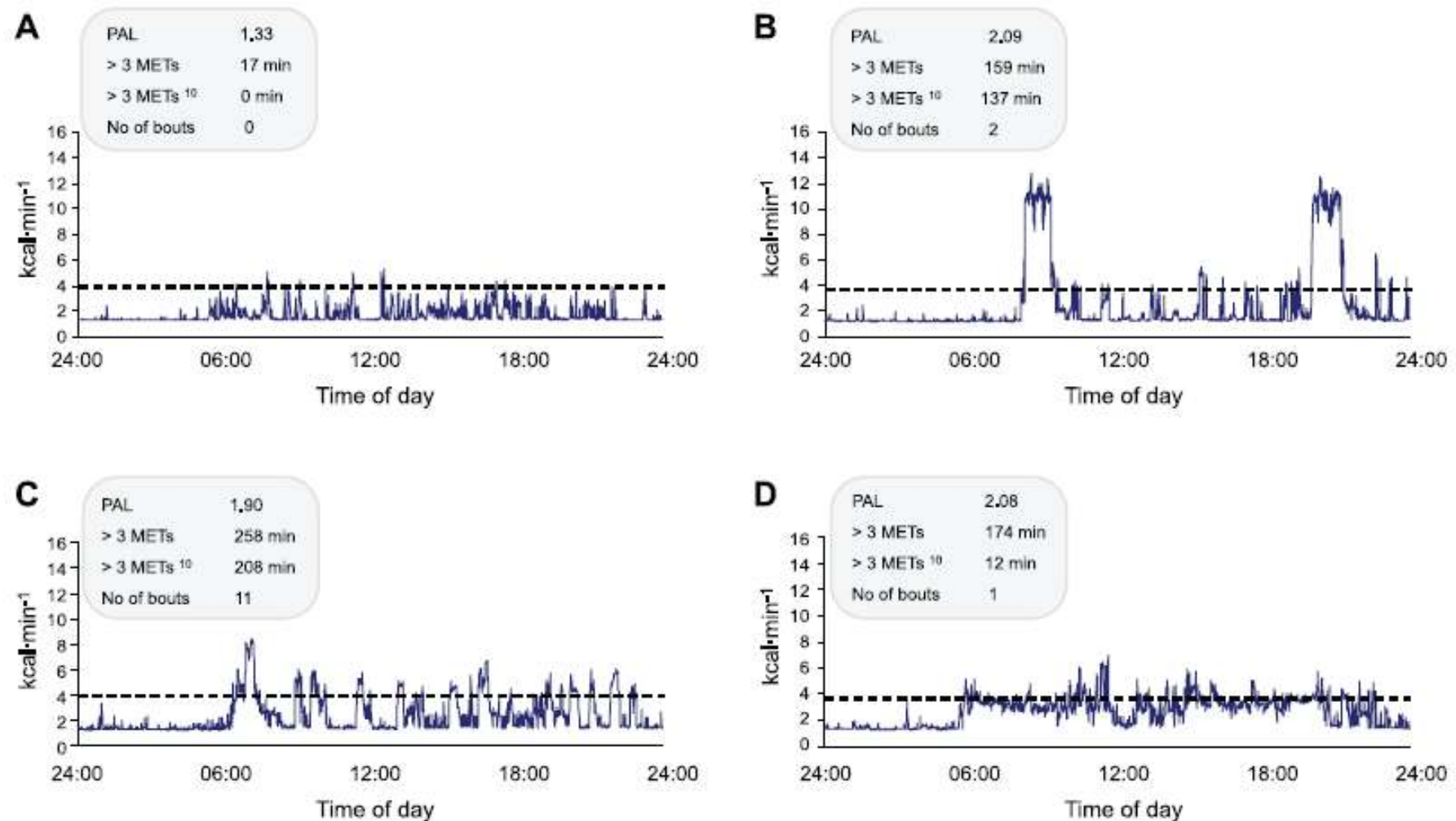
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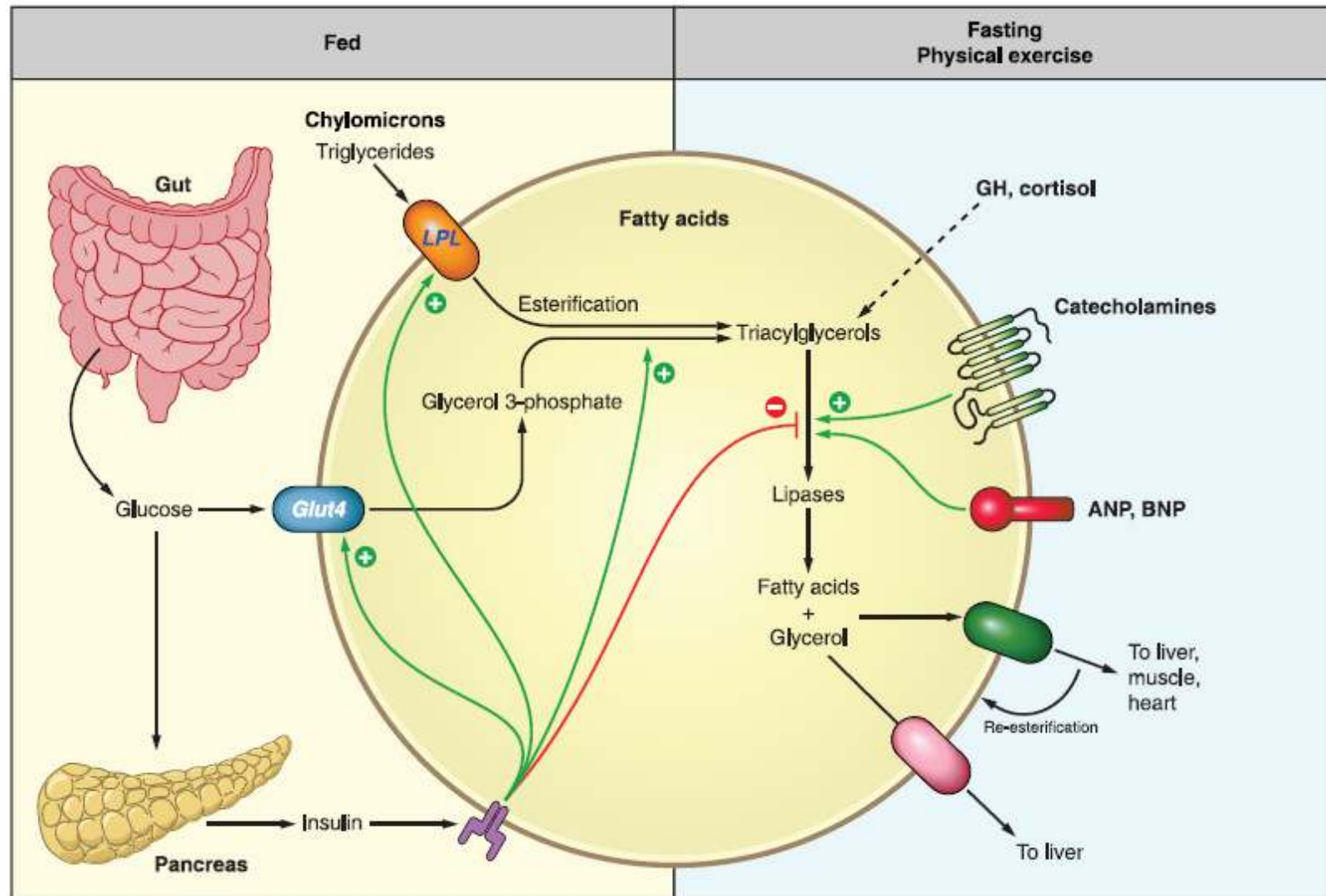
Physical activity의 정의

- **Physical activity:** any movement (or force) exerted skeletal muscle that leads to an increase in energy expenditure above rest
- **Exercise:** subcomponent of physical activity that is planned or structured
- Physical activity level (PAL): TEE/BMR (TEE: total energy expenditure, BMR: basal metabolic rate)

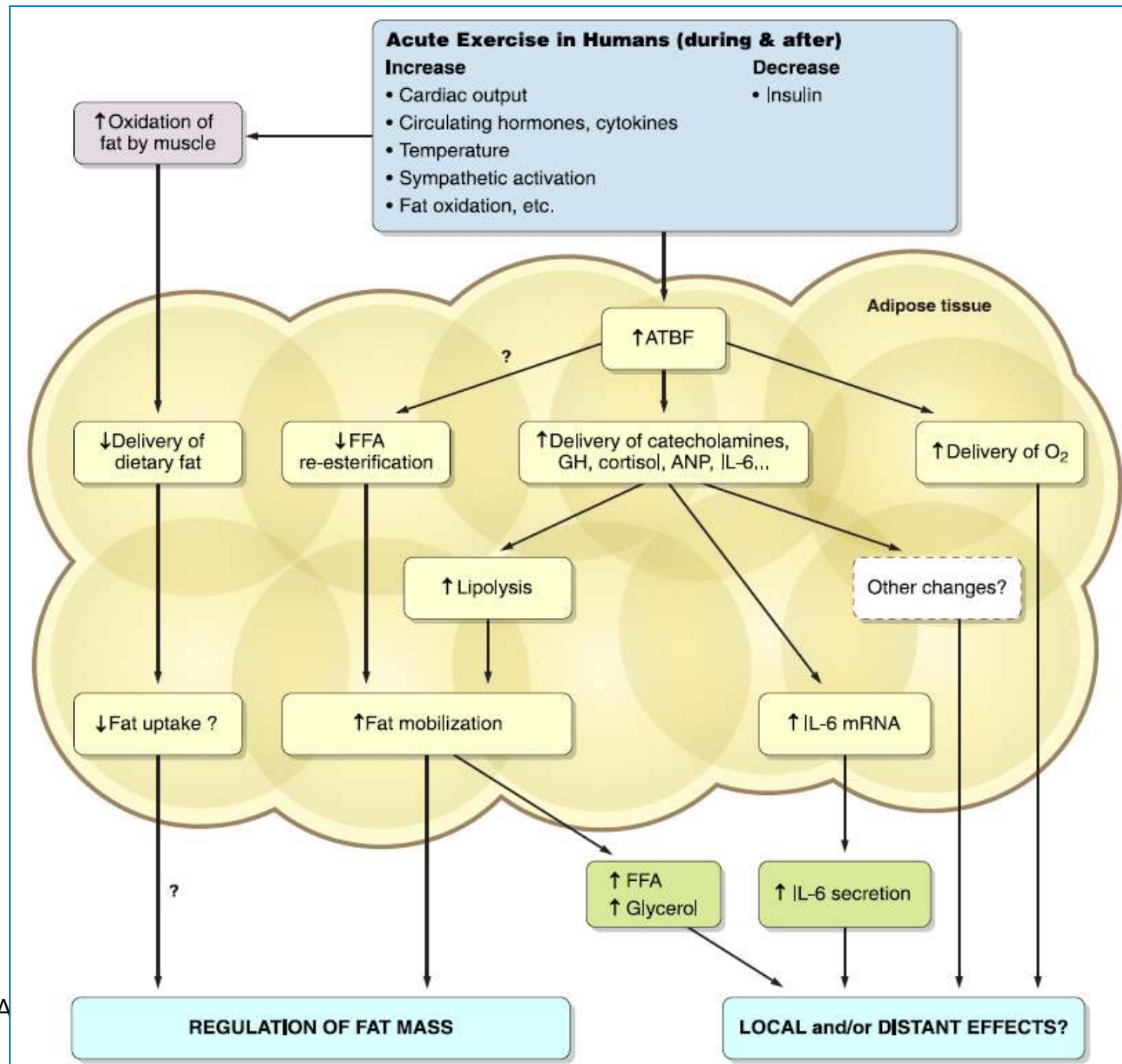
Physical activity energy expenditure (kcal/min) over 24-h period in 4 different middle-aged men assessed by accelerometry



Metabolic pathways of adipose tissue fat, storage and mobilization



Thompson et al. *Physiol Rev* 92:157-191, 2012



Mechanisms evolved in acute exercise-induced glucose transport

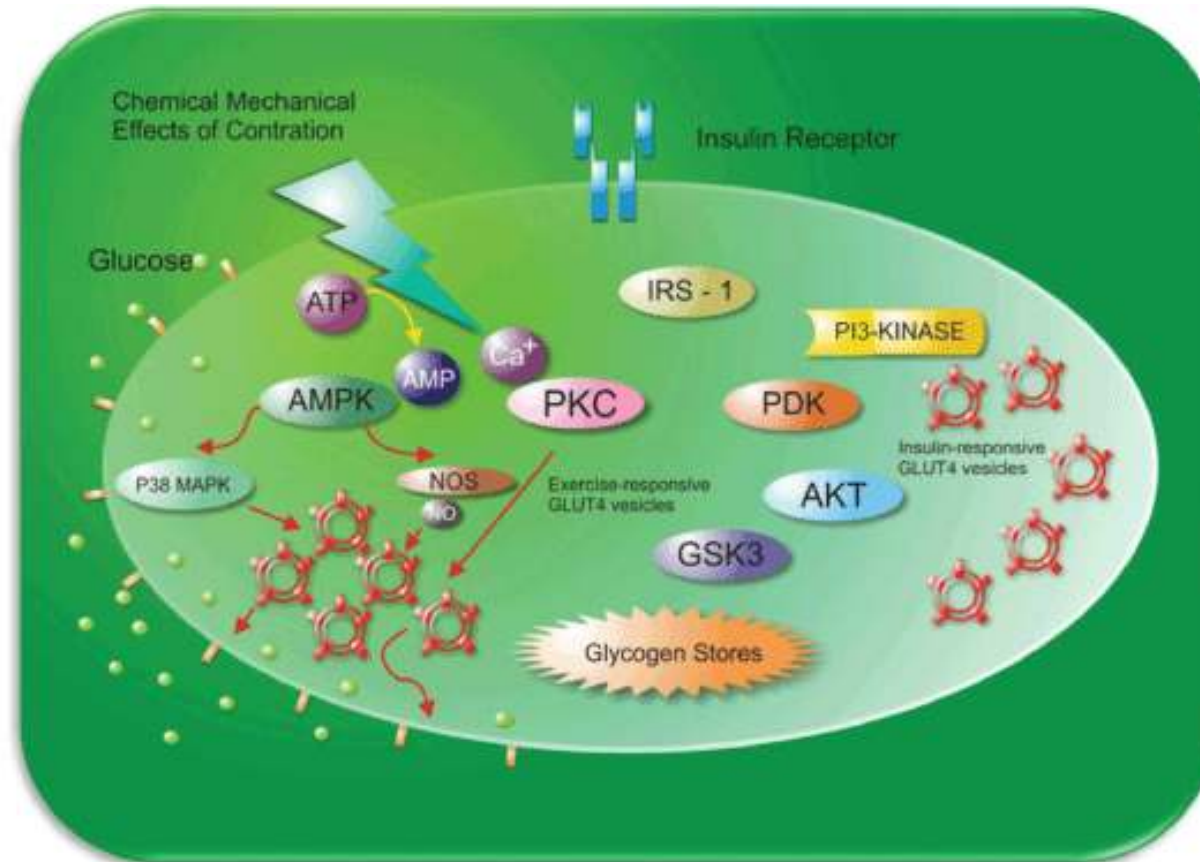
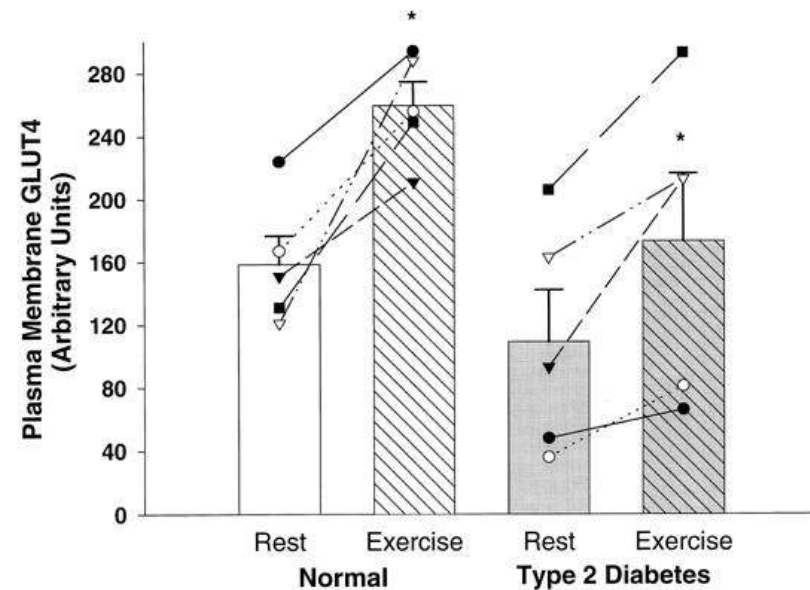
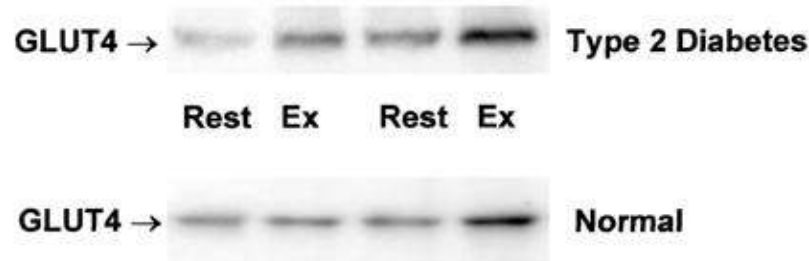


FIGURE 1 - Mechanisms evolved in the acute exercise-induced glucose transport. (Hayashi, Wojtaszewski, Goodyear, 1997; Zierath, 2002).

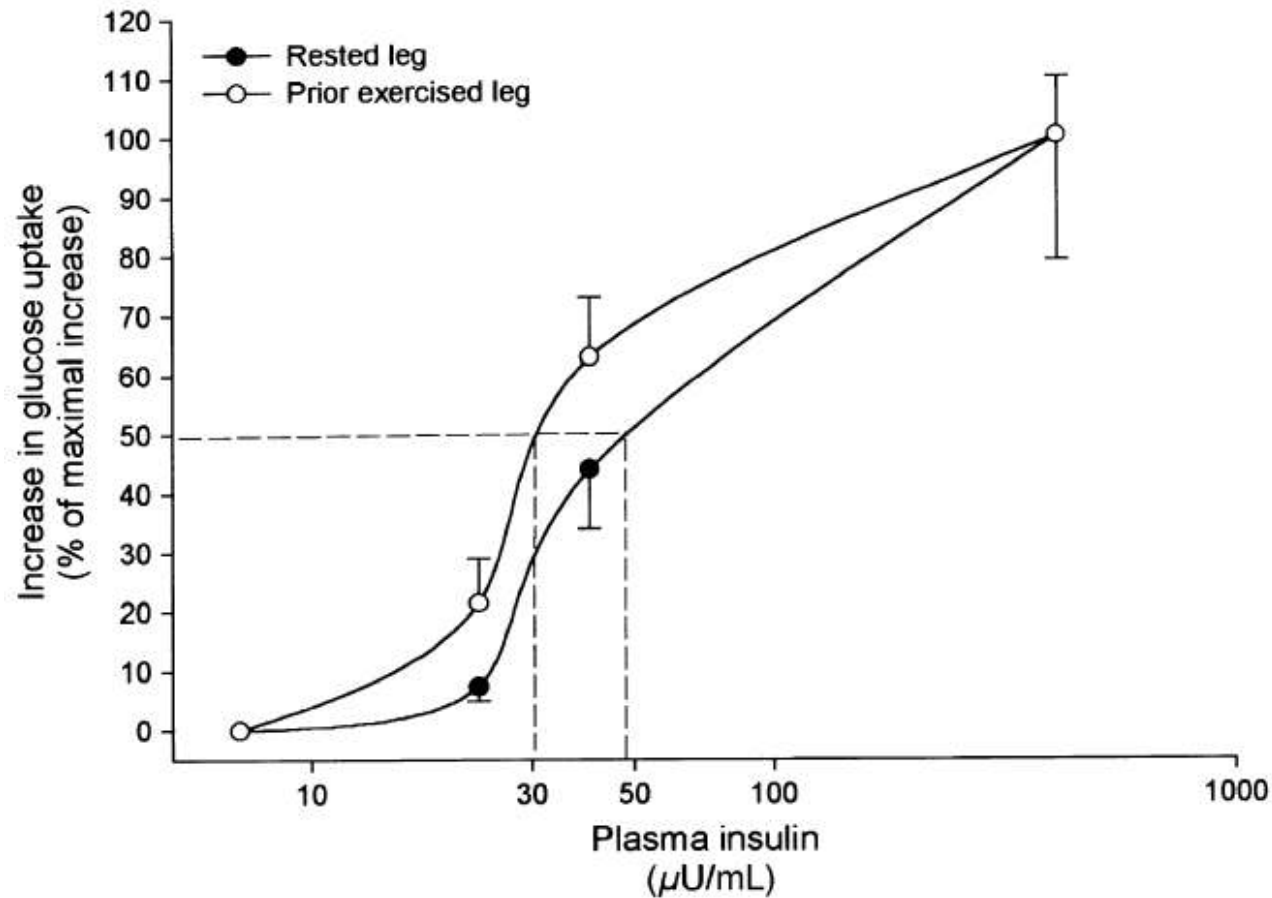
Acute exercise induces GLUT4 translocation in skeletal muscle in normal and T2DM patients

In 5 normal subjects and 5 T2DM patients, translocation of GLUT4 to the plasma membrane of skeletal muscle (vastus lateralis) assessed



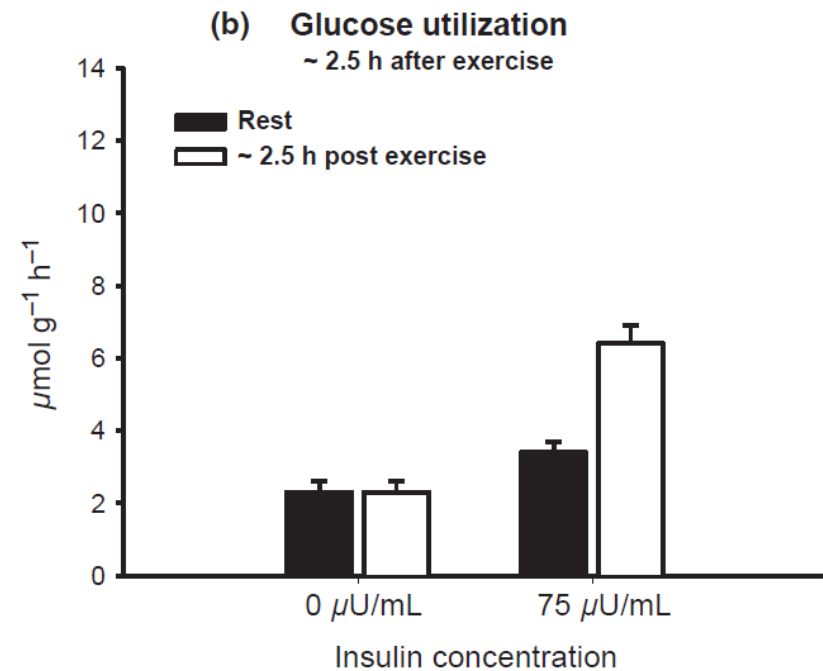
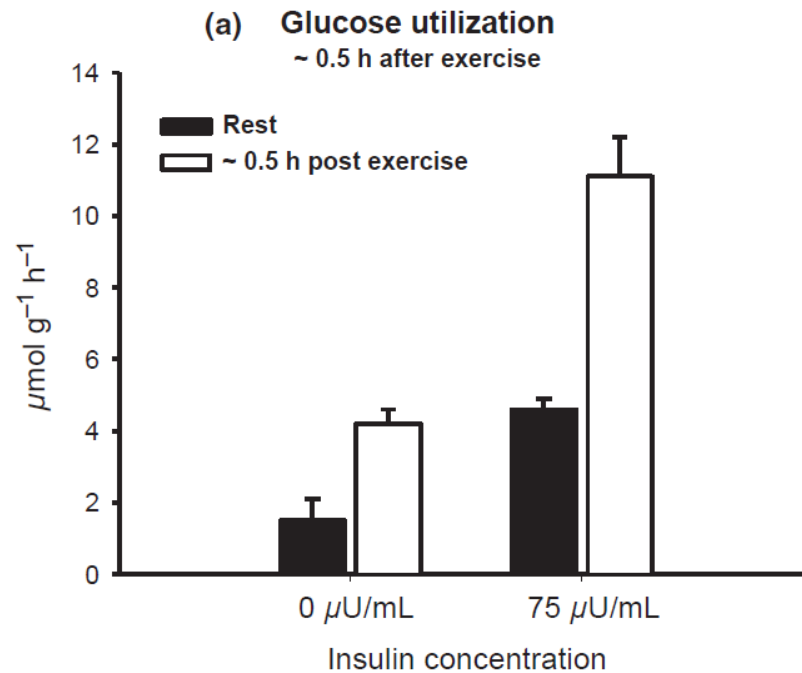
Kennedy JW et al. Diabetes, 1999

Exercise increases sensitivity of glucose uptake to insulin in human muscle



Wojtaszewski et al. J Appl
Physiol 93:384-392, 2002

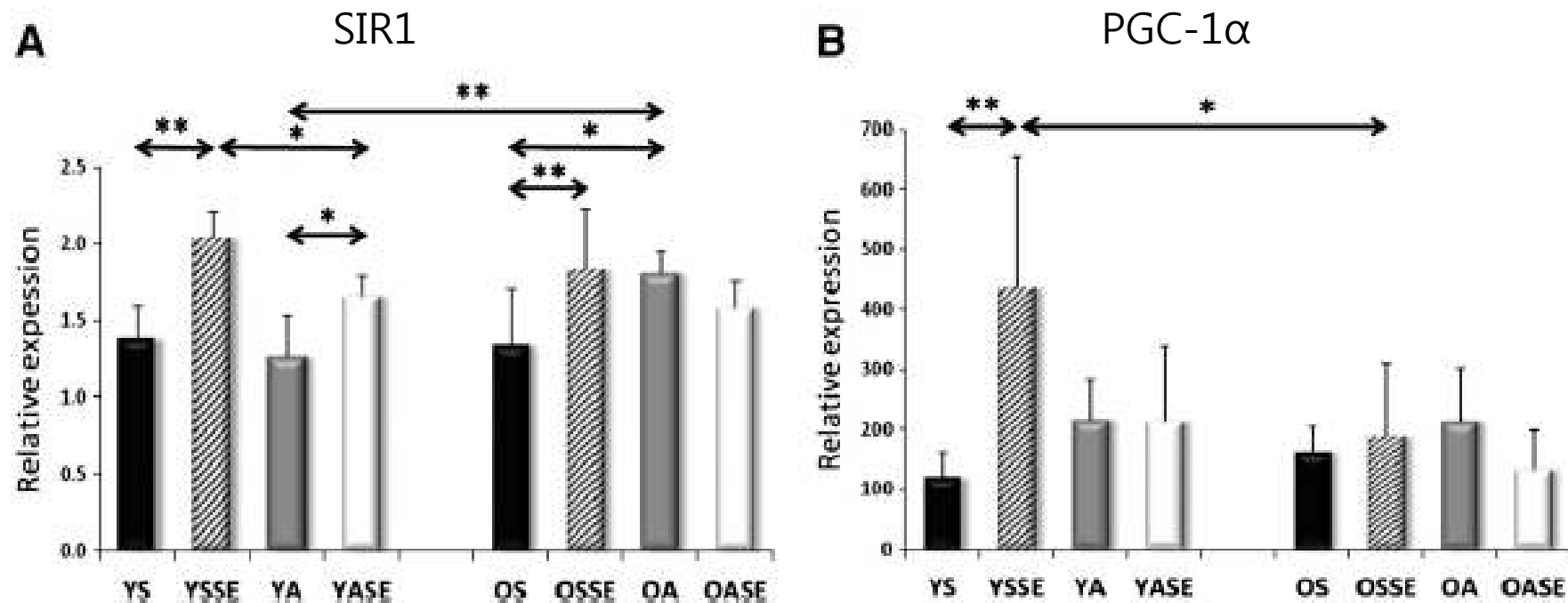
Glucose utilization and insulin-stimulated glucose utilization after cessation of exercise in rats



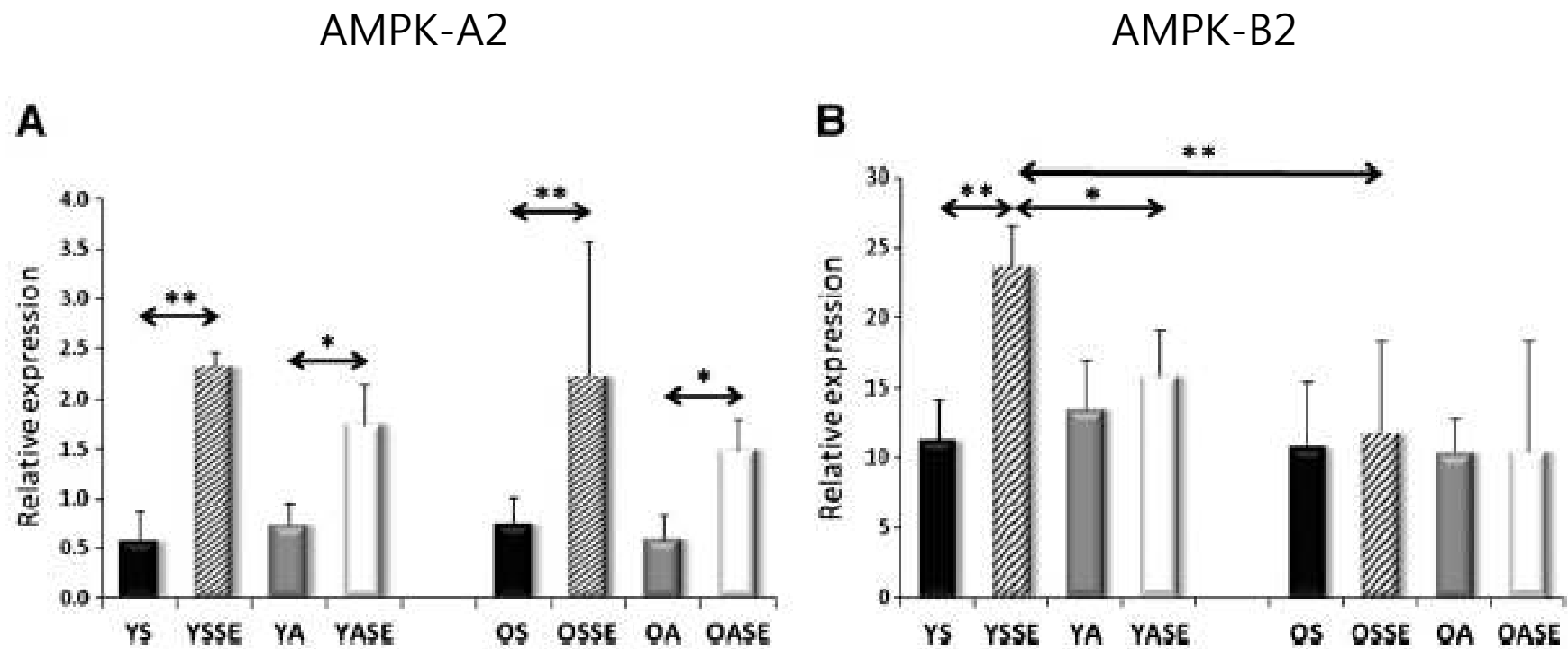
Garetto et al. Am J Physiol
246:E471-475, 1984

Effects of exercise on mitochondrial protein expression in human skeletal muscle

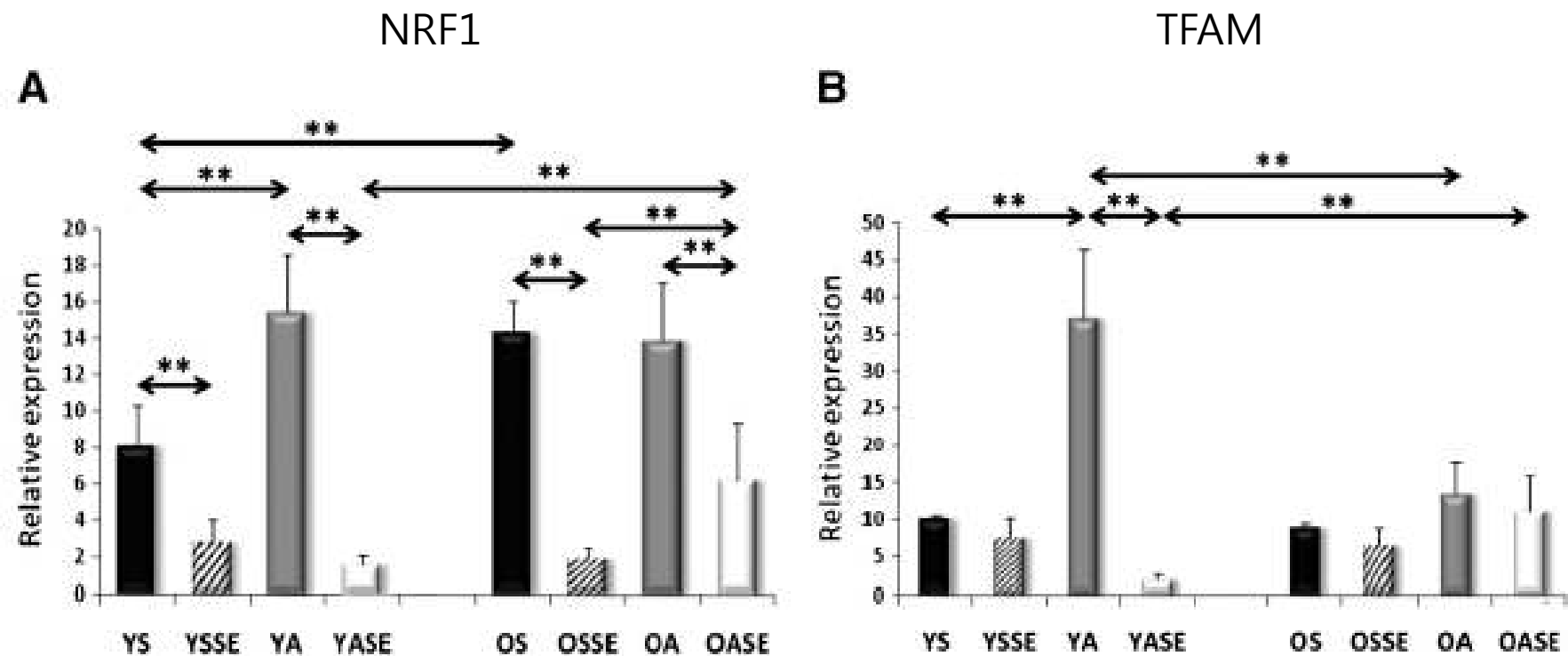
In 24 subjects : young sedentary (YS), young active (YA), old sedentary (OS), old active



Effects of exercise on mitochondrial protein expression in human skeletal muscle



Effects of exercise on mitochondrial protein expression in human skeletal muscle



Physical activity and dyslipidemia

- Single bouts of exercise: TG 감소, HDL-C 증가
- Endurance training: HDL-C 증가
- Aerobic exercise training: LDL-C, apoB 감소, LDL particle size 증가, apoA 증가, TG감소

Physical activity and blood pressure

- 운동 중에는 혈압이 증가하나 20분 이상의 운동 후 2-4시간 후에는 다시 떨어짐
- 고혈압이 없는 사람에서는 수축기 혈압이 single bout의 운동 후에는 8-10 mmHg, 이완기 혈압은 3-5mmHg 감소하고, 고혈압이 있는 사람에서는 2배 정도 더 효과가 있다.
- 기전: 체성분의 향상, 인슐린저항성의 개선, 내피 세포 기능의 향상, 자율신경계 이상의 향상

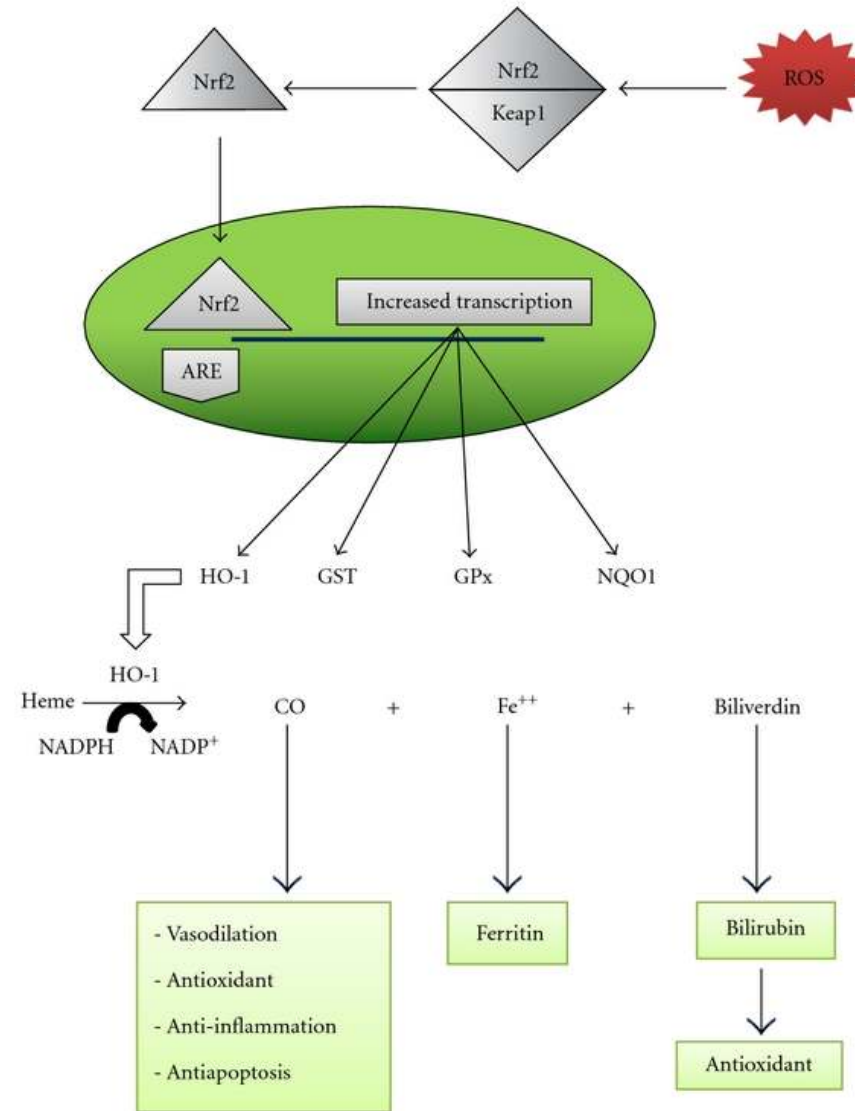
Effect of aerobic exercise on blood pressure : meta-analysis of 54 RCTs

Table 1. Mean Net Changes in Systolic and Diastolic Blood Pressure according to Different Exclusion Criteria

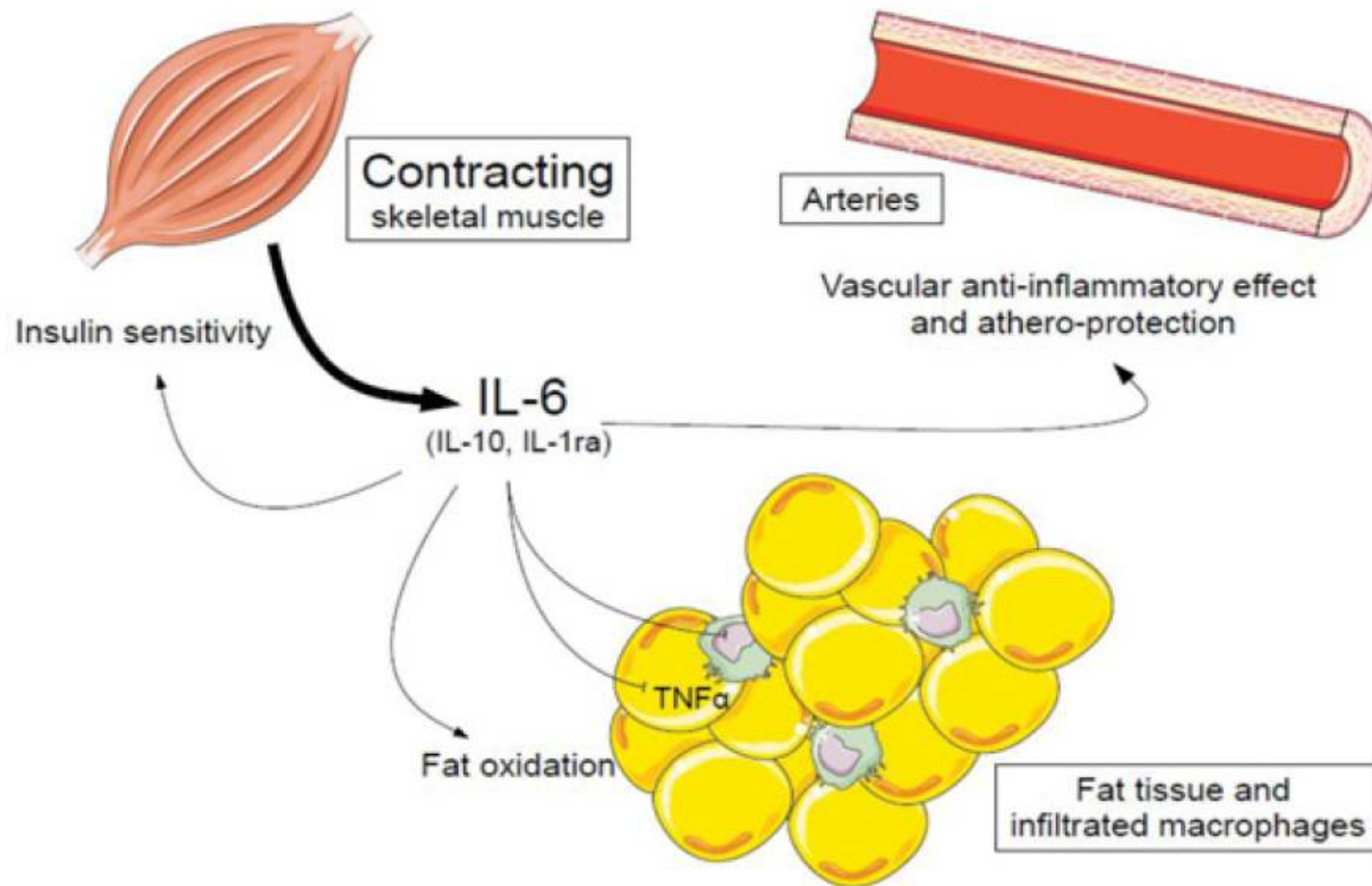
Variable	Systolic Blood Pressure			Diastolic Blood Pressure		
	Trials Examined	Net Change (95% CI)	P Value	Trials Examined	Net Change (95% CI)	P Value
	<i>n</i>	<i>mm Hg</i>		<i>n</i>	<i>mm Hg</i>	
All trials	53	-3.84 (-4.97 to -2.72)	<0.001	50	-2.58 (-3.35 to -1.81)	<0.001
Exercise supervised*	45	-4.13 (-5.21 to -3.05)	<0.001	42	-2.68 (-3.55 to -1.81)	<0.001
Antihypertensive medication not administered†	49	-4.23 (-5.42 to -3.05)	<0.001	46	-2.91 (-3.69 to -2.13)	<0.001
Single intervention between groups‡	47	-4.39 (-5.68 to -3.10)	<0.001	44	-2.97 (-3.82 to -2.12)	<0.001
Blood pressure as primary outcome§	37	-4.39 (-5.93 to -2.86)	<0.001	36	-2.87 (-3.91 to -1.84)	<0.001

Aerobic exercise reduces blood pressure in both hypertensive and normotensive persons.

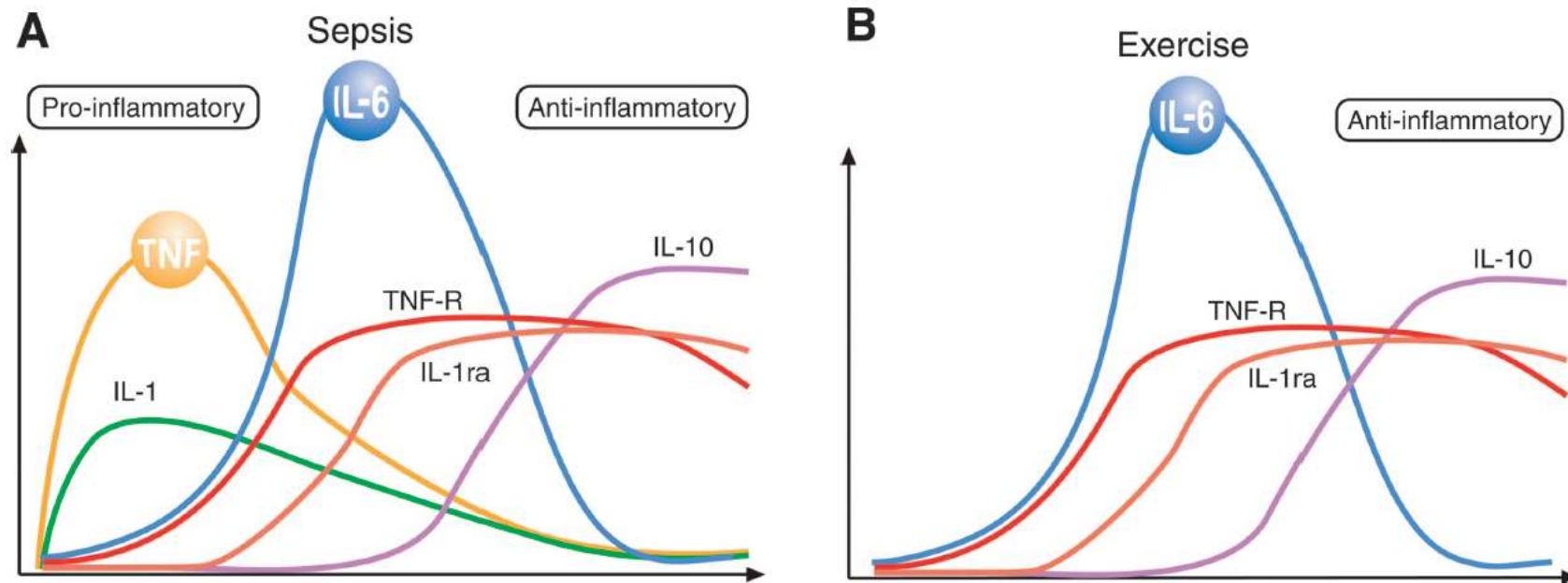
Exercise and antioxidants



The contracting muscle signal

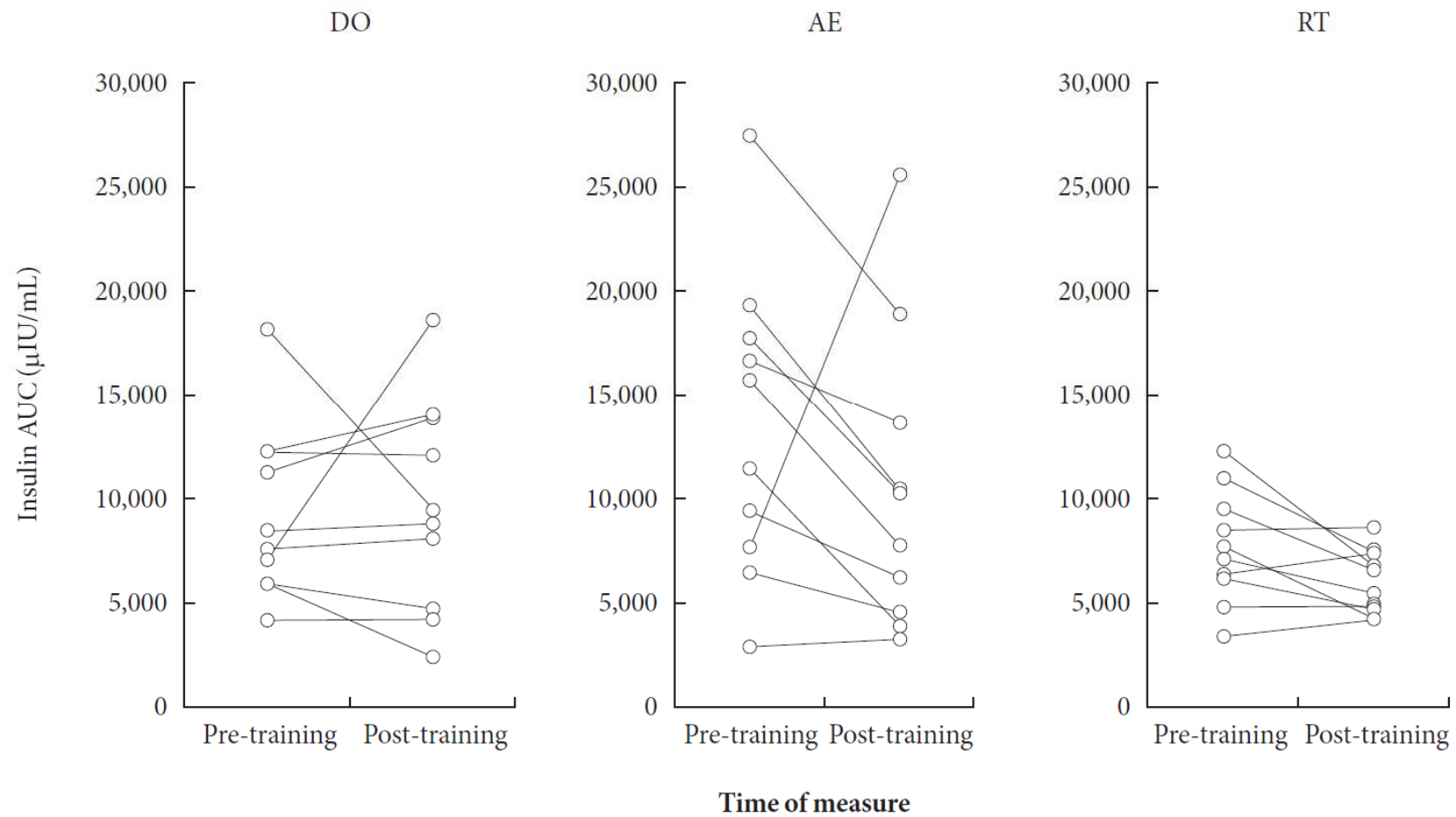


Anti-inflammatory effects of exercise – effects of IL-6



Petersen AMW et al. J Appl Physiol 98:154-1162, 2005

The effects of RT and AT on insulin sensitivity in overweight Korean adolescents

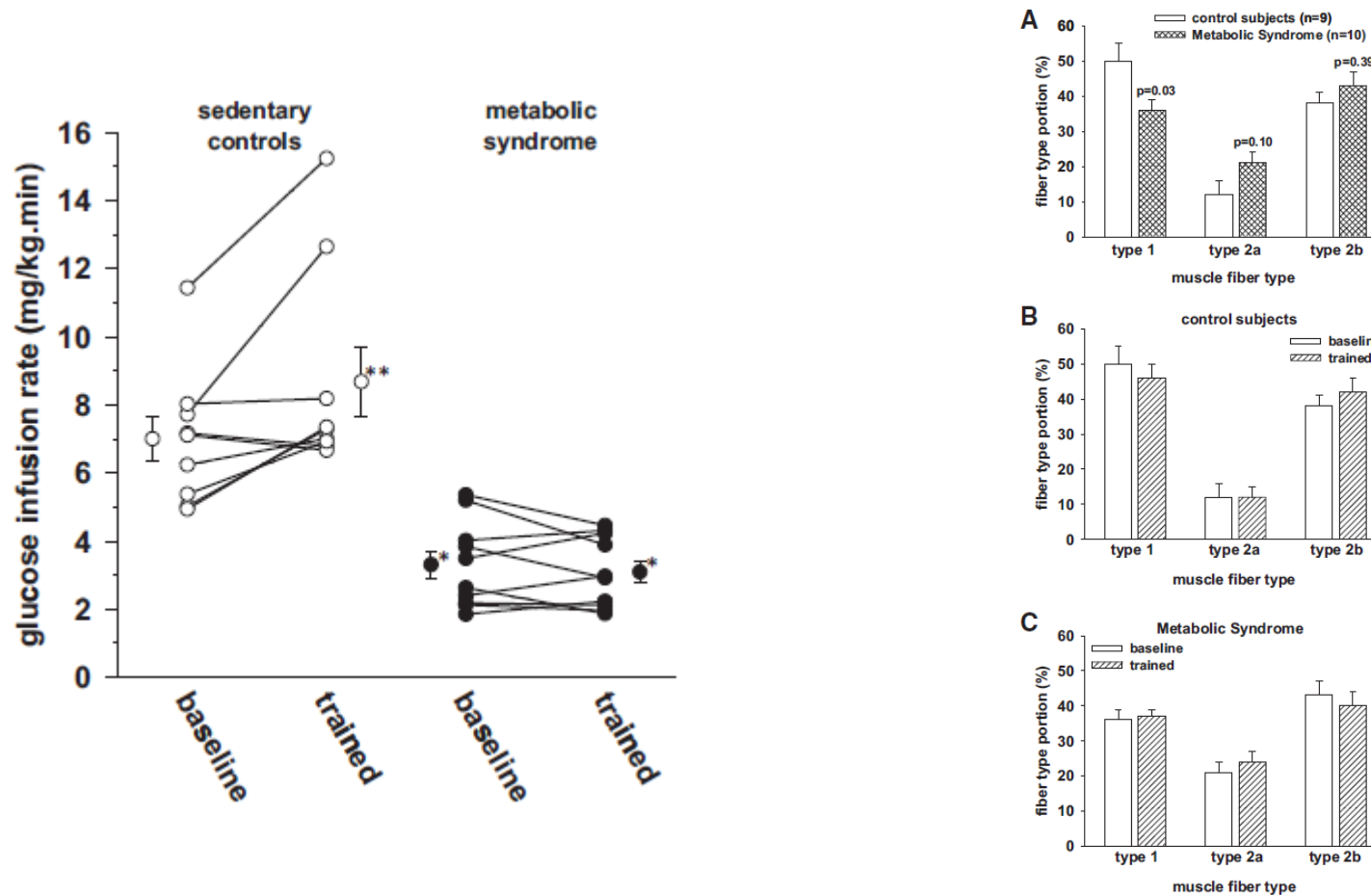


Suh SH et al. DMJ 35:418-426, 2011

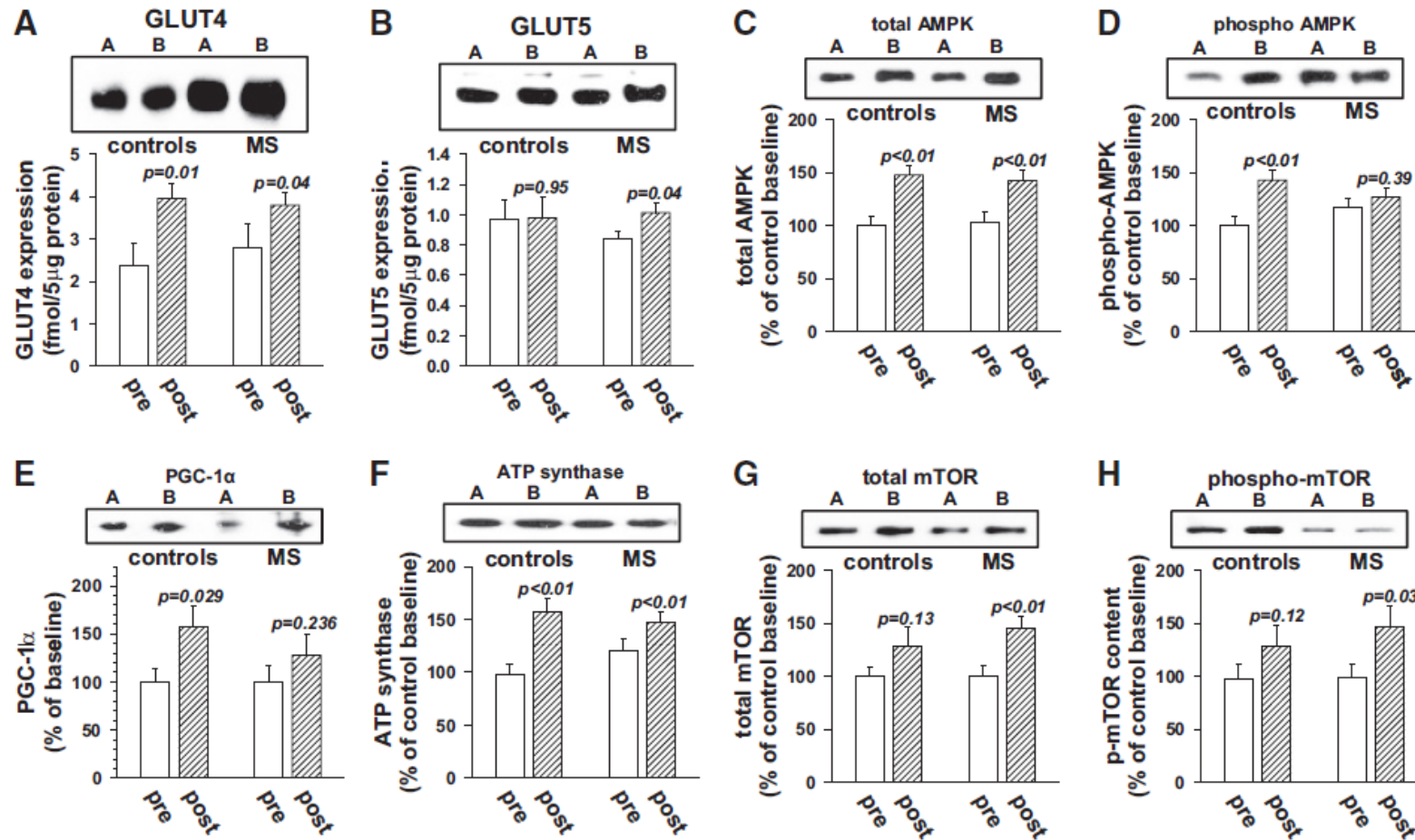
The effects of exercise training on plasma markers of inflammation – conflicting results

- In a 6-month RCT, diet and exercise together reduced plasma CRP, IL-6
- However, the opposite reported
- Mechanisms: decreased body fat, body composition 향상, proinflammatory cytokine의 감소, anti-inflammatory cytokine의 증가, antioxidant의 증가

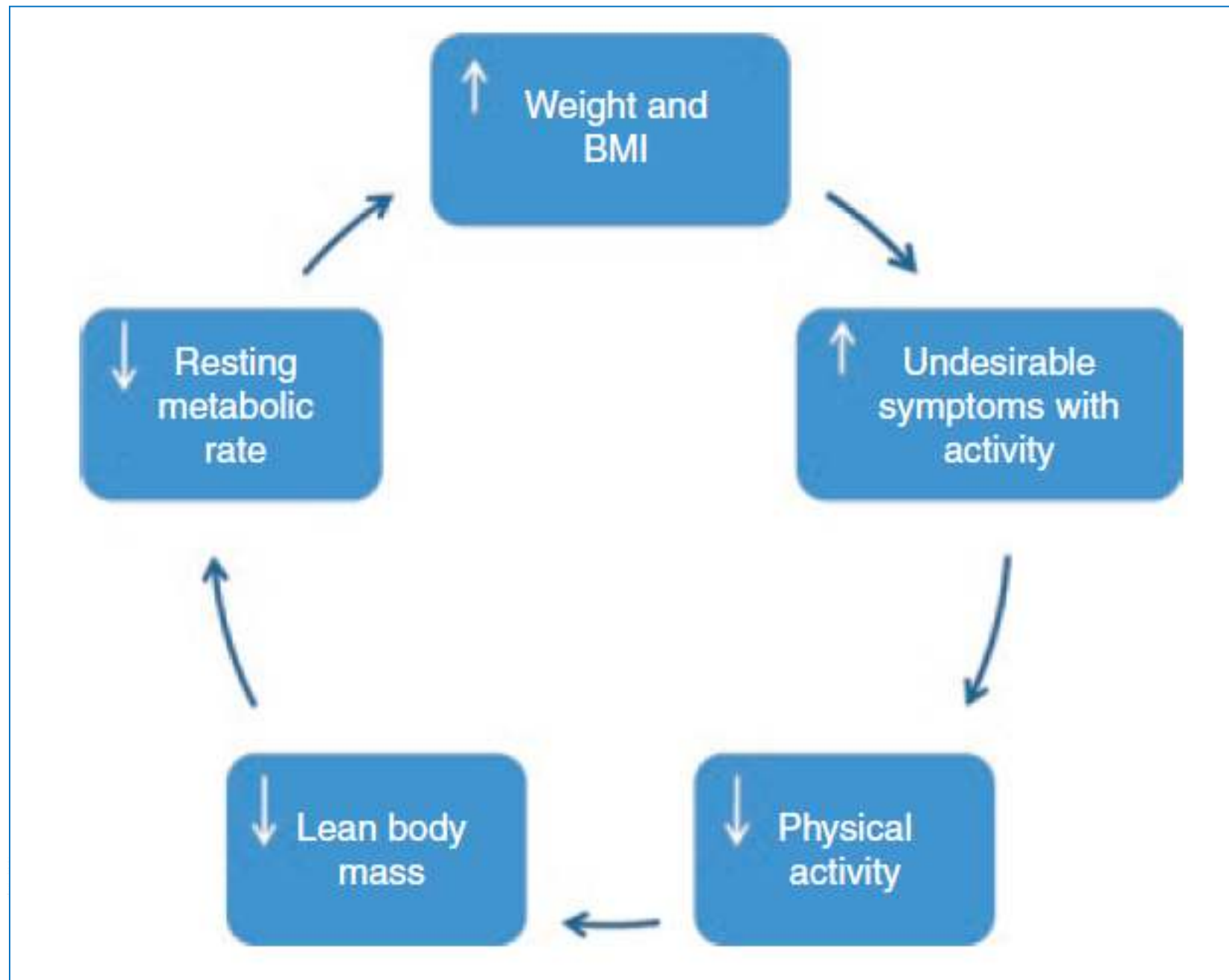
Impaired muscle AMPK activation in the metabolic syndrome may attenuate improved insulin action after exercise training



Impaired muscle AMPK activation in the metabolic syndrome may attenuate improved insulin action after exercise training



Cardiorespiratory fitness and metabolic syndrome



RMR
RMR

RMR
er

Cardiorespiratory fitness and metabolic risk

In 59,820 men and 22,192 women in Cooper Center Longitudinal Study (CCLS) who performed CRF assessment with maximal exercise testing from 1970 to 2009

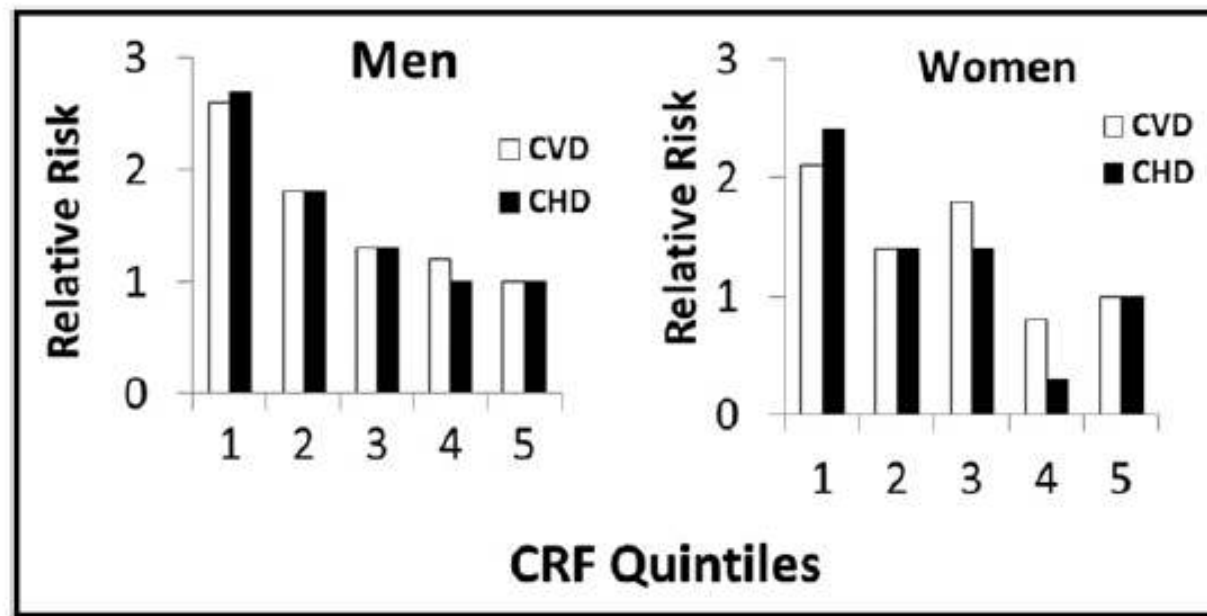
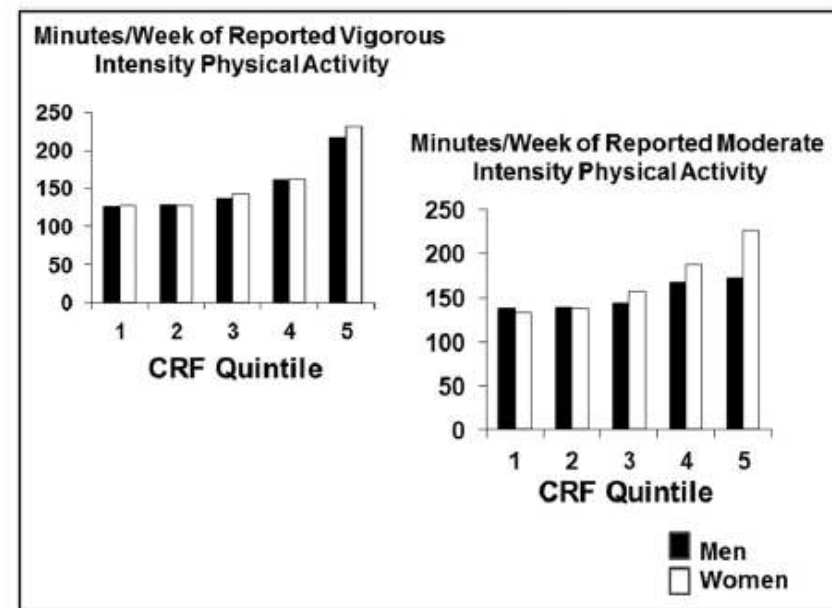
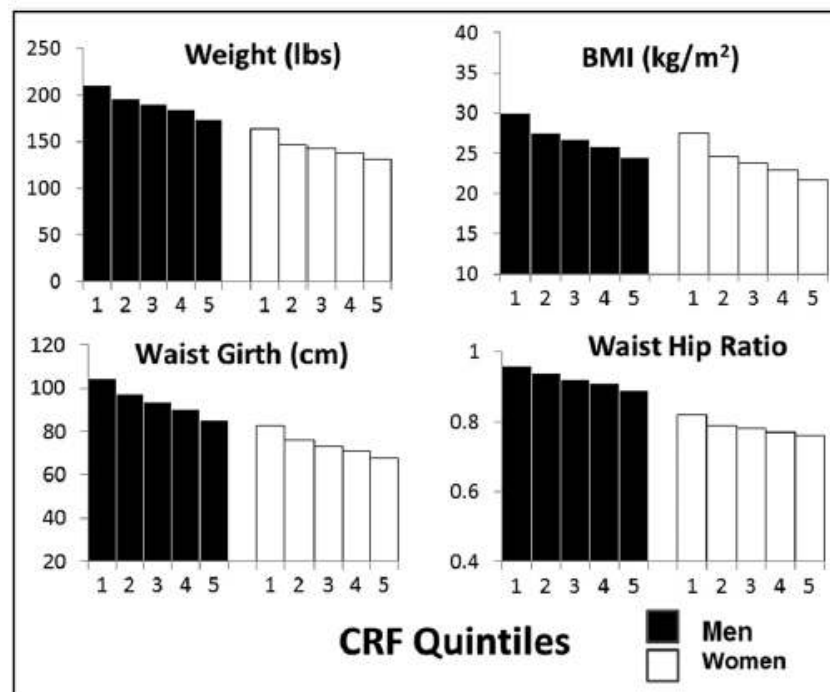
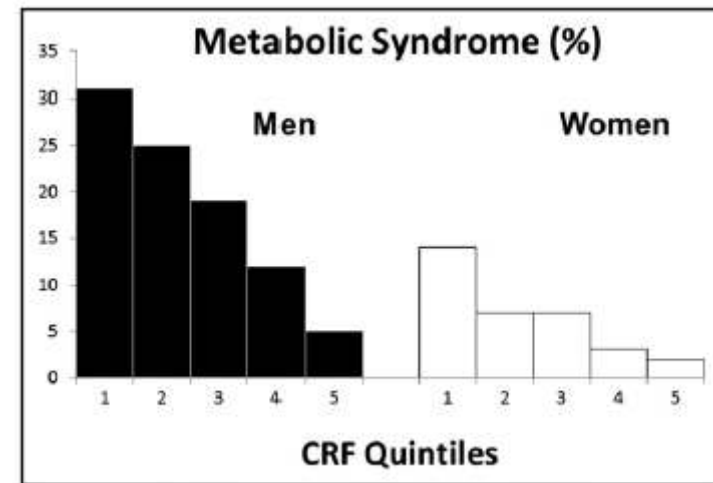
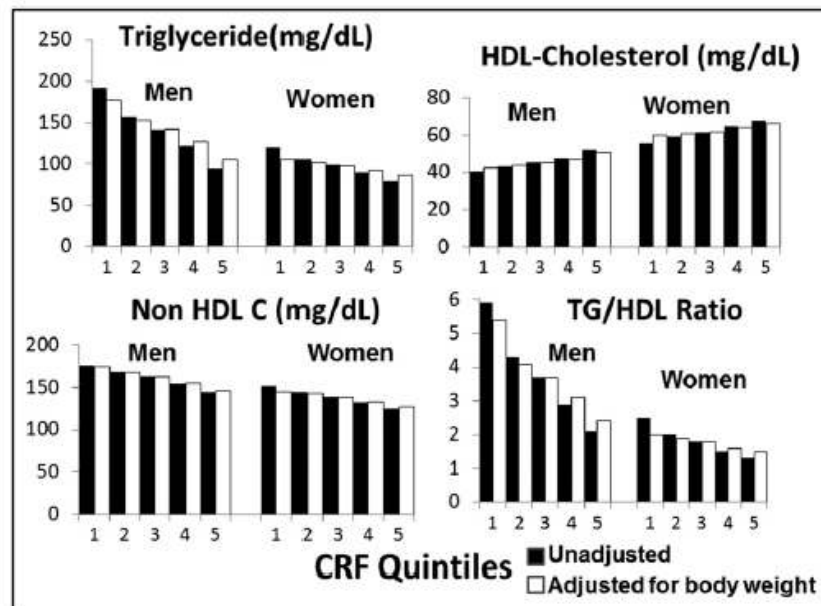


Figure 1. CVD and CHD mortality in men and women plotted against quintiles of CRF.

Cardiorespiratory fitness and metabolic risk

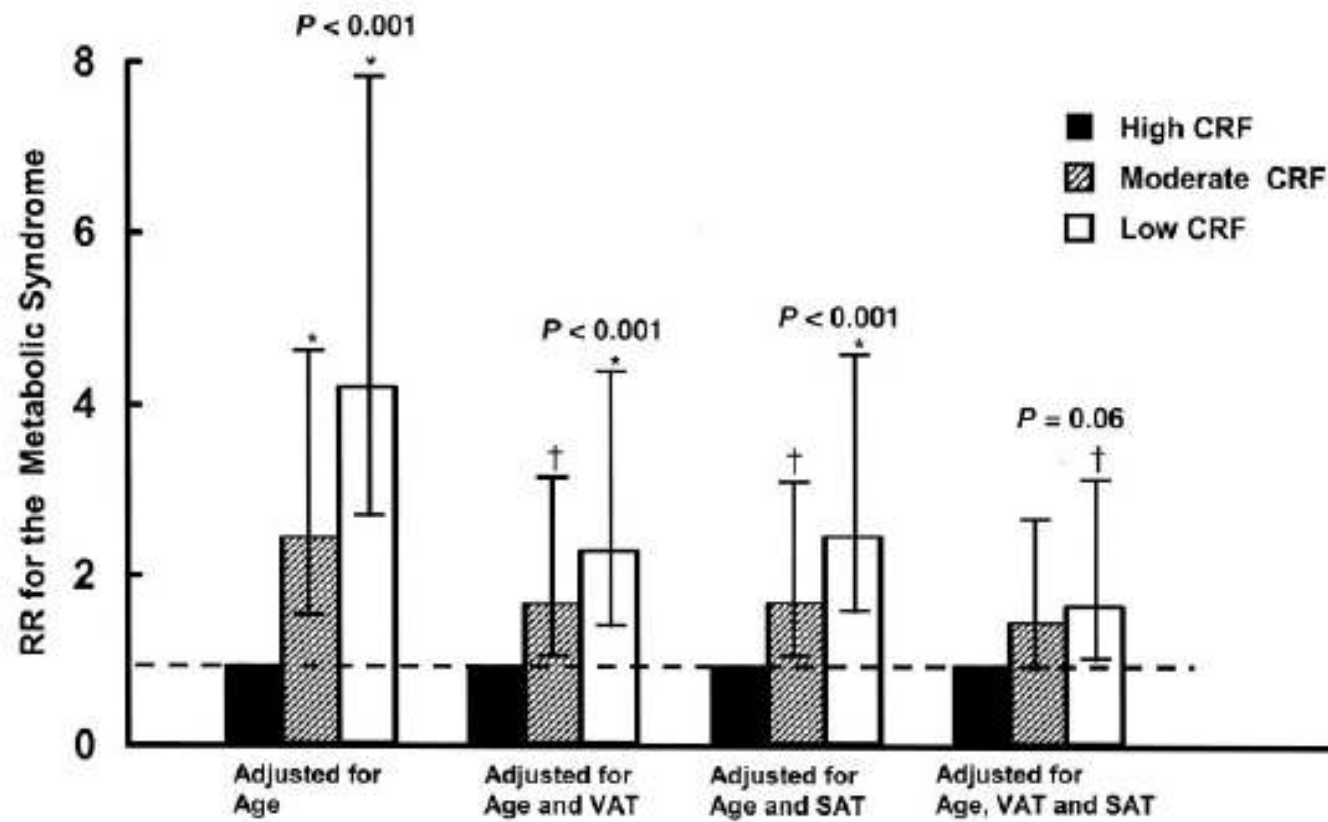


Cardiorespiratory fitness and metabolic risk



CRF attenuates metabolic risk independent of abdominal subcutaneous and visceral fat in men

In 297 healthy men with CT or MRI imaging



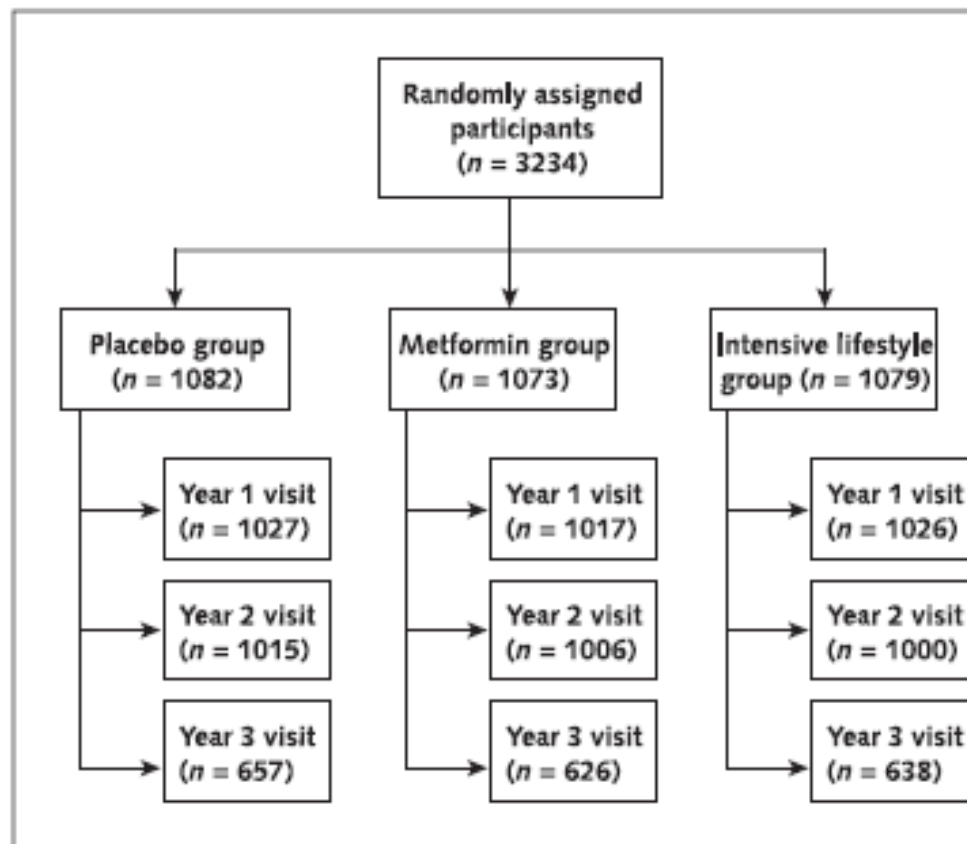
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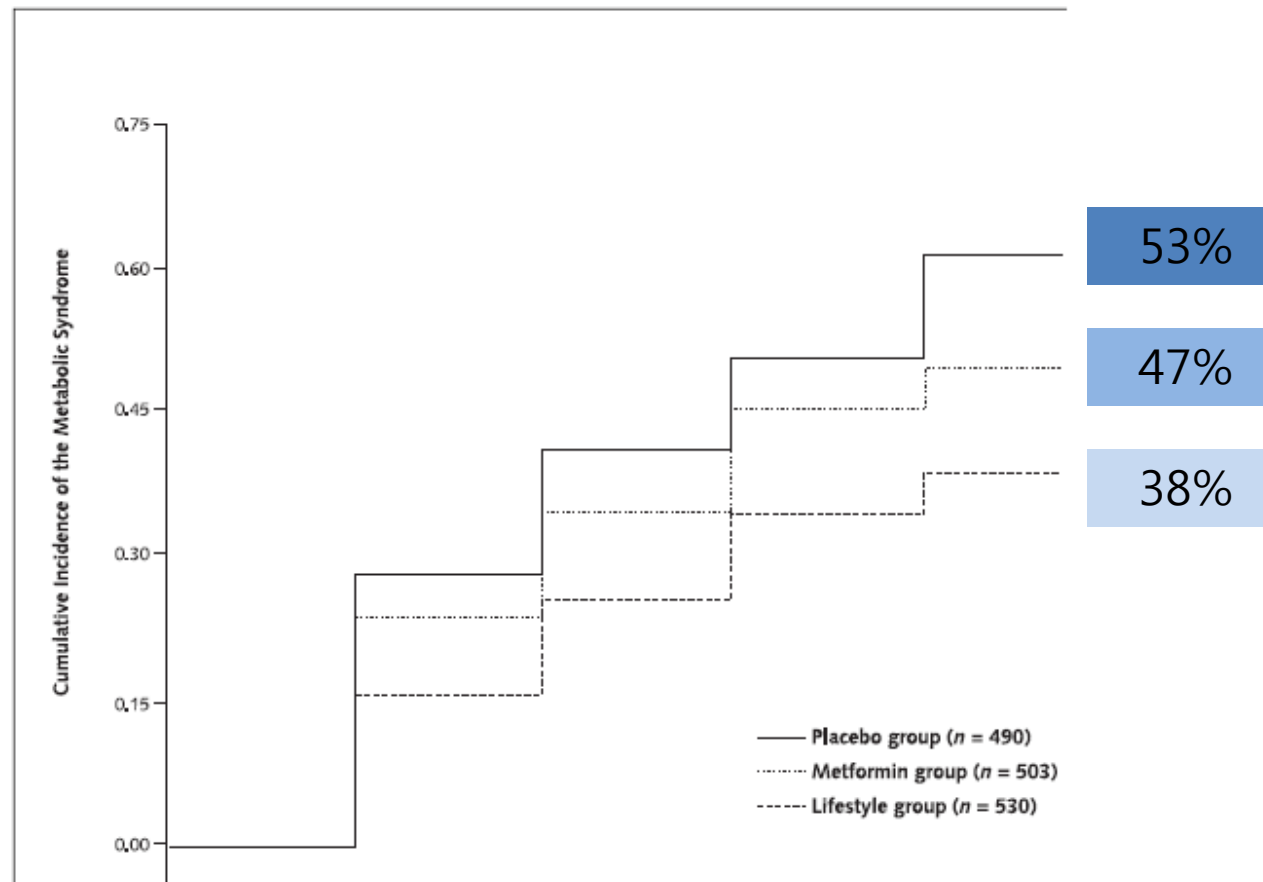
대사증후군에 대한 운동의 효과

- Diabetes Prevention Program -

- DPP: IFG 3000여명을 3.2년간 생활습관군, metformin, 위약으로 나누어 당뇨병 발생여부를 추적관찰함
- Metformin 850 mg bid, 7% weight loss, 주당 150분 운동

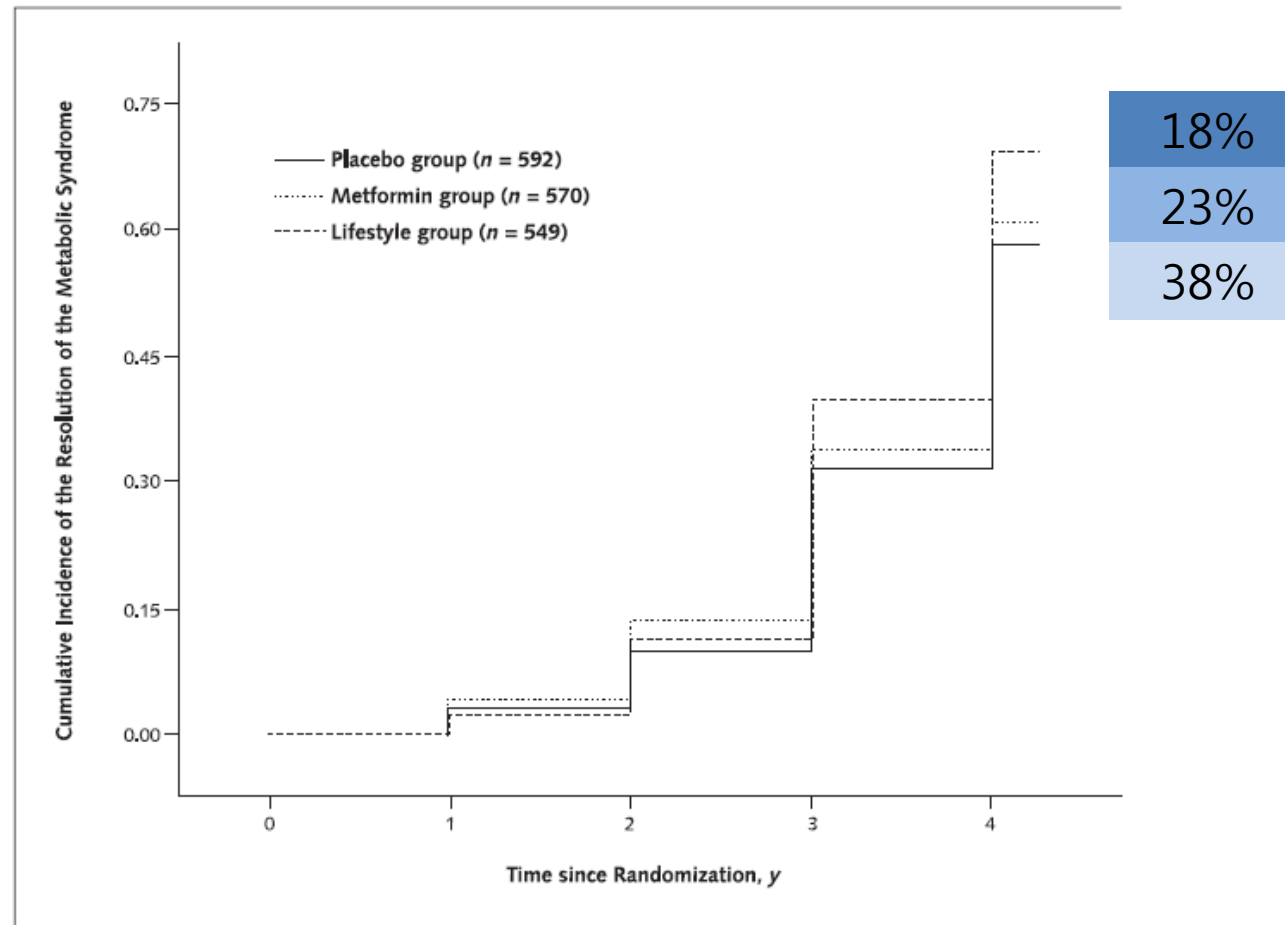


Development of metabolic syndrome by intervention group in the DPP

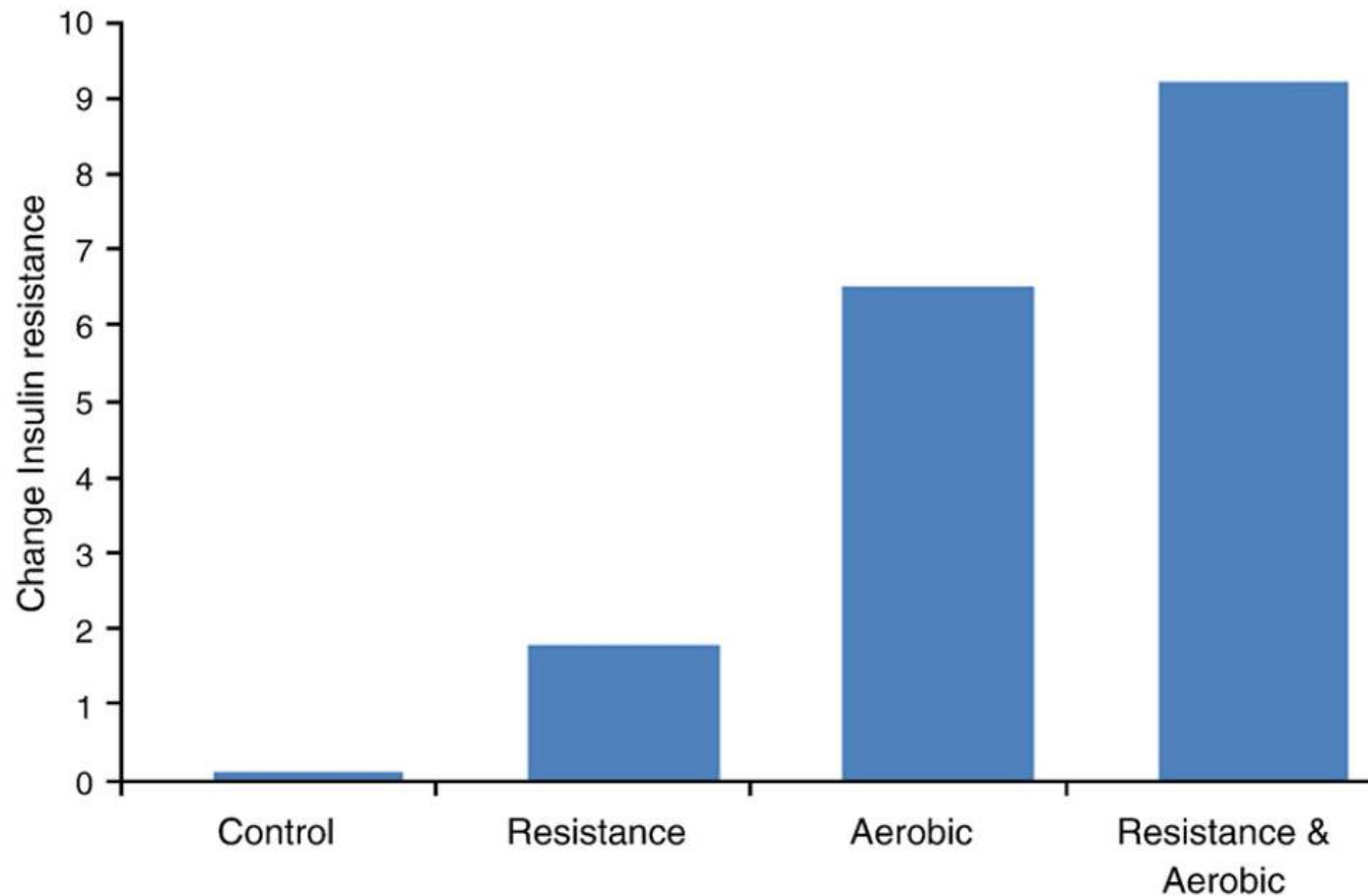


생활습관군이 대조군에 비해 41%, metformin군에 비해 29% 대사증후군 위험율을 감소시킴

Resolution of metabolic syndrome by intervention group in the DPP

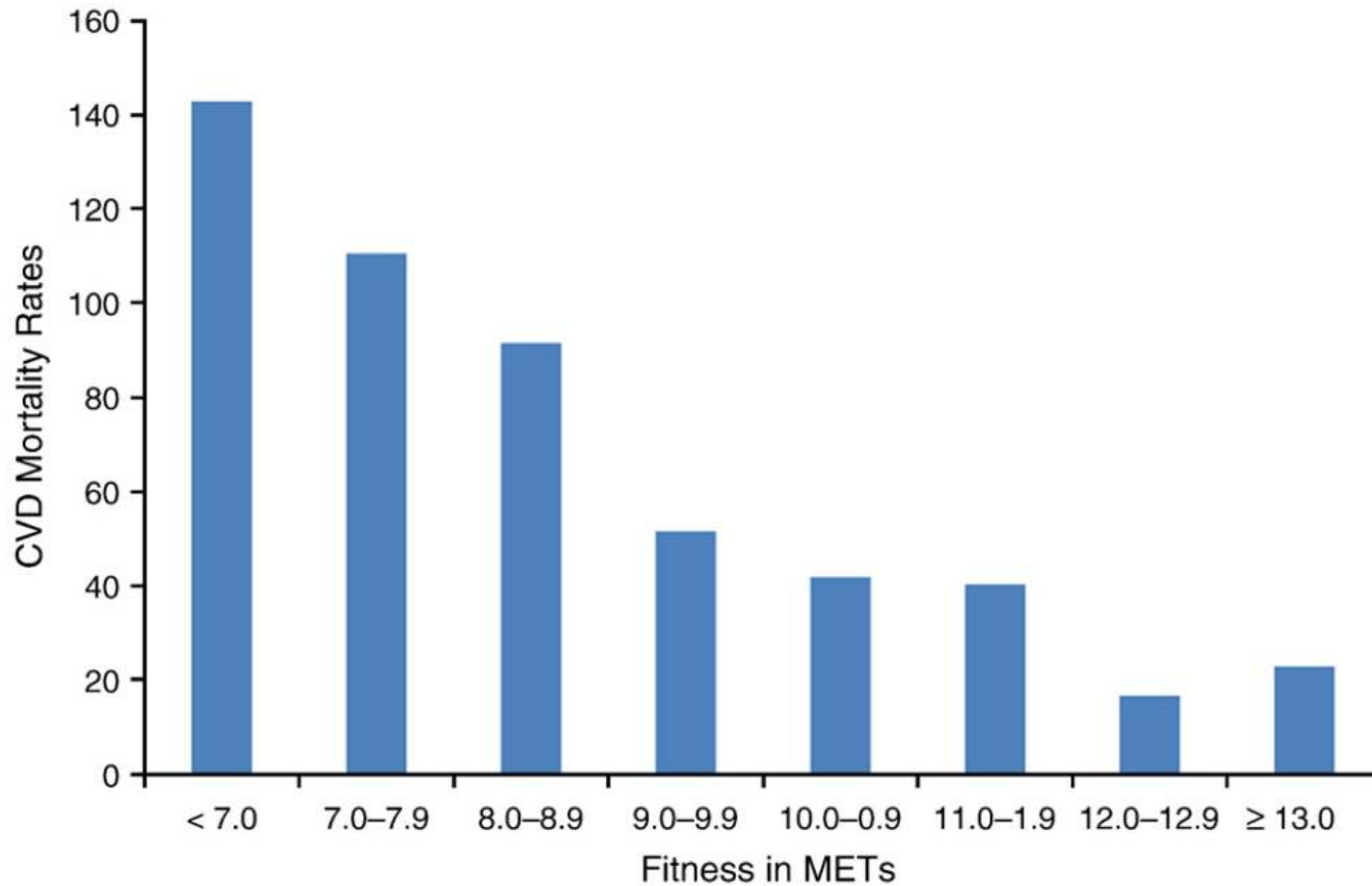


Changes in insulin resistance with RT, aerobic training, and RT+AT



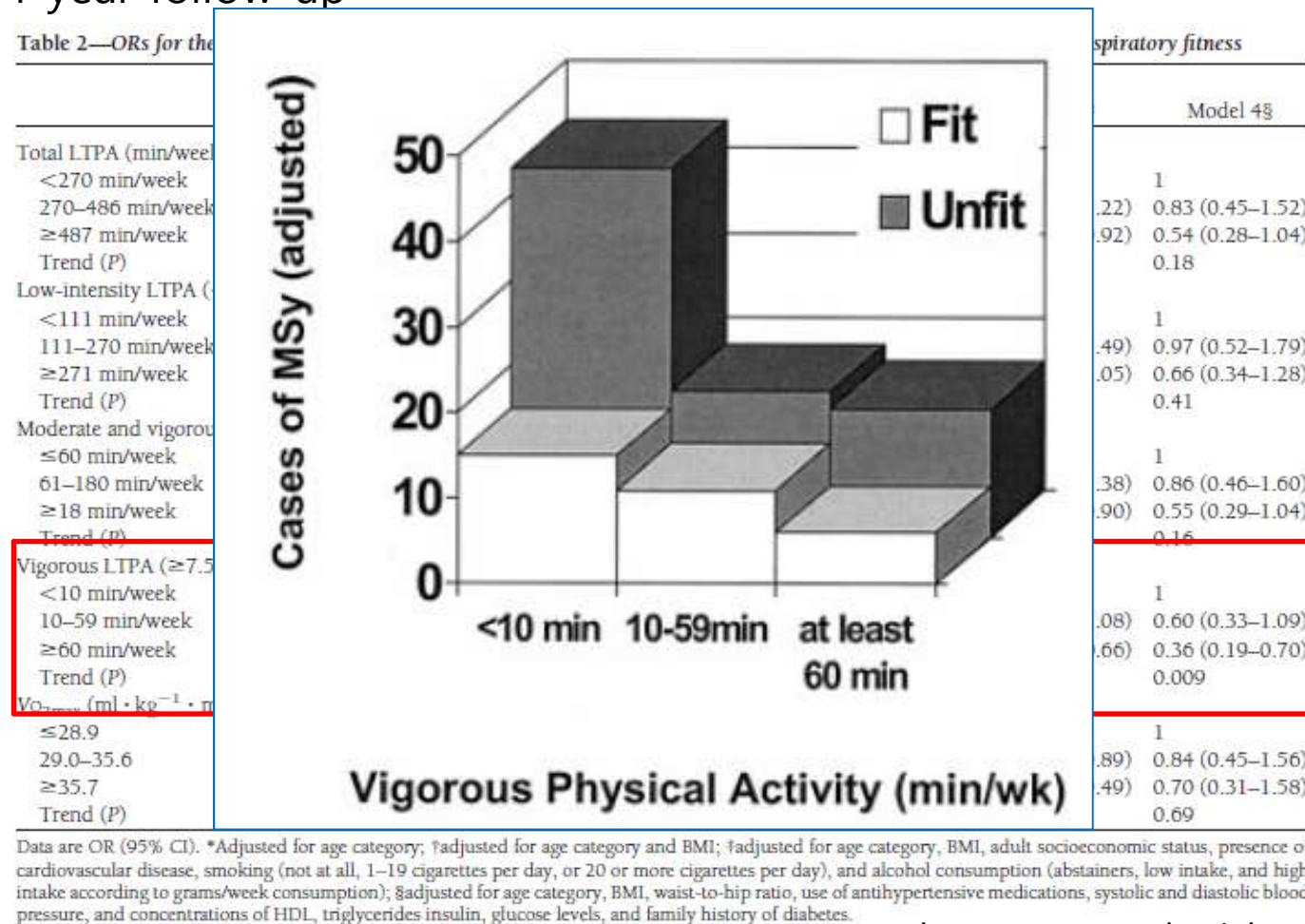
Davidson LE et al. Arch Intern Med
2009;169:122-131

Risk of cardiovascular mortality in men with diabetes across levels of fitness



Low level of leisure-time physical activity and CRF predict development of MS

In 612 middle-aged men without MS at baseline
4-year follow-up



Laaksonen DE et al. Diabetes Care
25:1612-1618, 2002

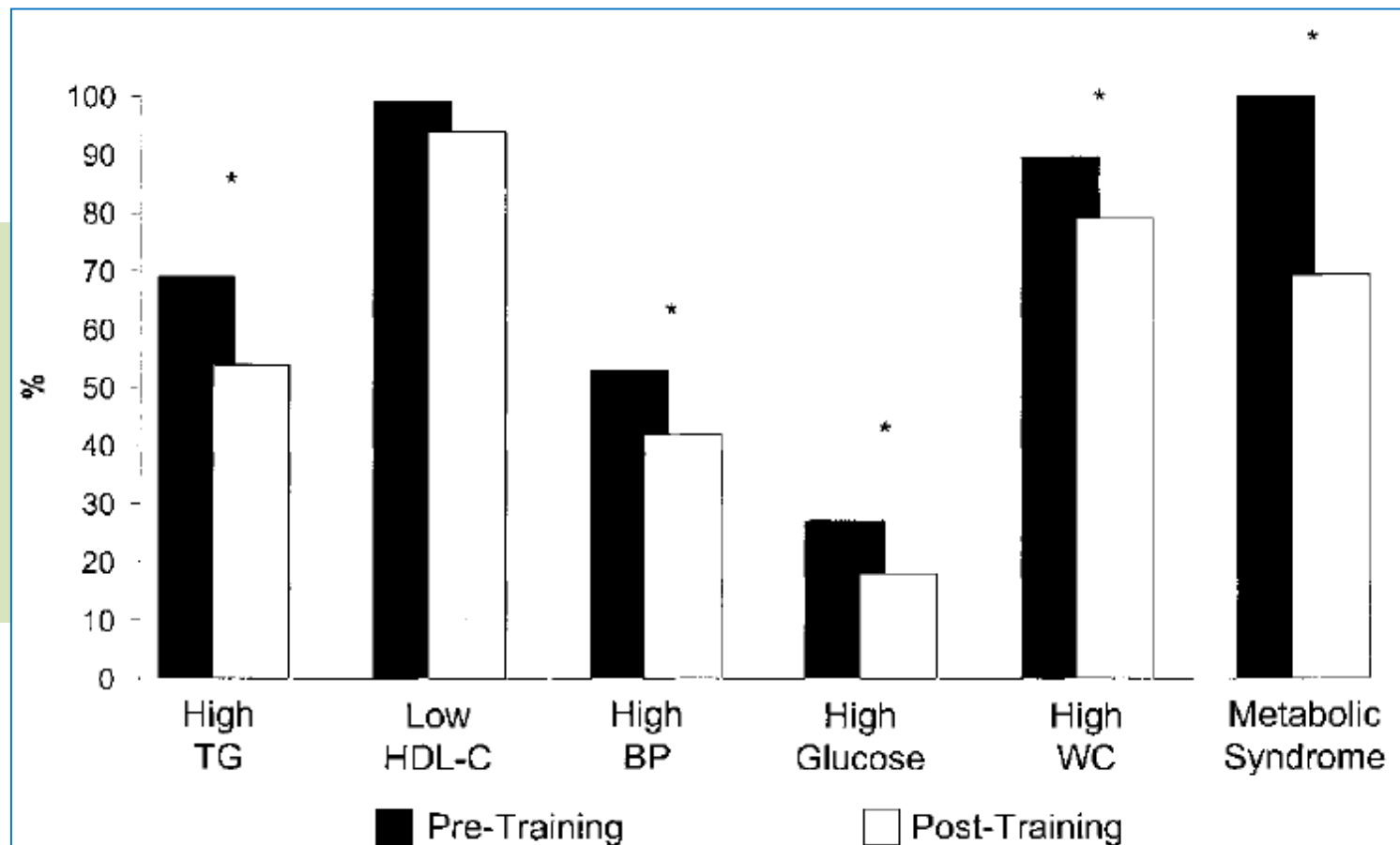


FIGURE 1—Prevalence of individual risk factors before and after 20 wk of aerobic exercise training in the HERITAGE Family Study among 105 participants with the metabolic syndrome at baseline. * $P < 0.05$ pre- versus posttraining.

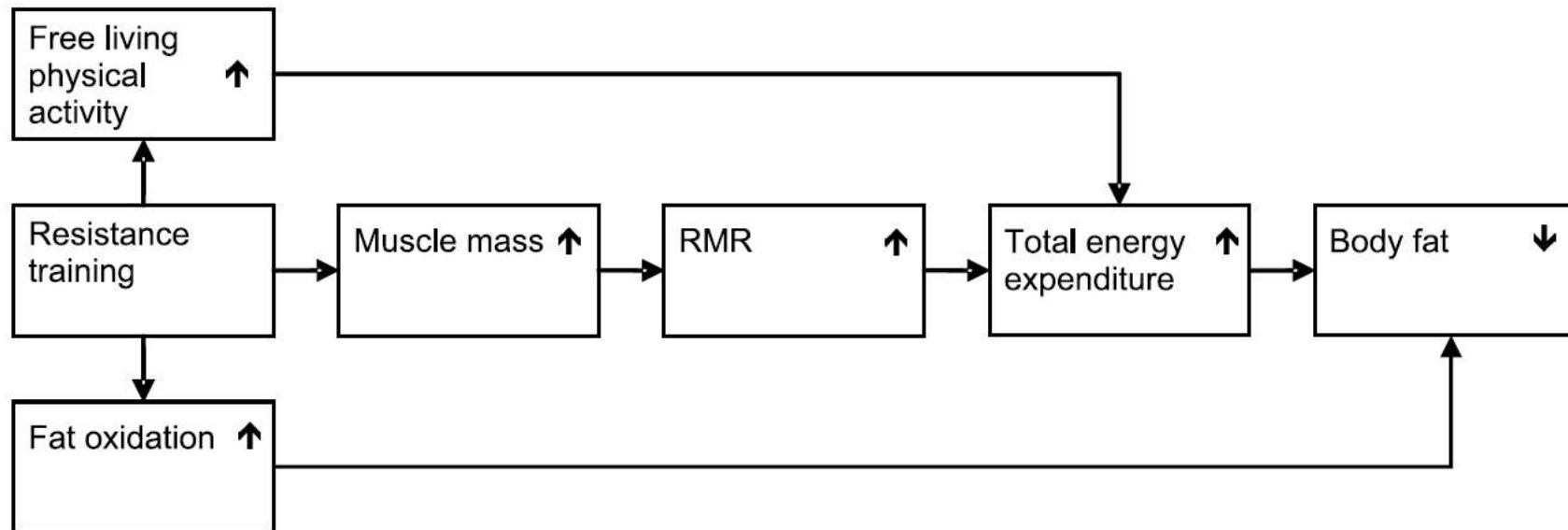
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What kind of exercise?

- 1990년대까지는 대부분 유산소 운동이 권유됨.
- 대부분의 국가에서 걷기를 가장 흔한 recommendation으로 삼고 있었음
- 최근 빠른 걷기나 다른 종류의 중등도 유산소 운동이 효과가 있다는 연구 결과들이 있다.
- Unstructured physical activity, low intensity daily activities: 아직은 확실하지 않다.
- What about resistance training?

Conceptual model of a resistance training and potential effect on energy expenditure



Sarcopenia: a serious problem in the elderly..

- Sarcopenia: loss of muscle mass associated with aging
- Main cause of muscle weakness in the old age -> T2DM, IR
- Etiology: loss of motoneurons, muscle cell apoptosis, muscle fibers decrease
- 50세 이후부터 한 해에 0.46kg의 근육이 줄어드는 것으로 알려져 있다.

Sarcopenia: a serious problem in the elderly..

- 근육은 glucose와 TG disposal의 target organ이고 RMR의 중요한 determinant
- 즉, 근육의 소실은 muscle strength의 감소, RMR의 감소, lipid oxidation의 capacity 감소, 복부 비만의 증가로 이어짐
- Aging에 따른 adiposity의 증가는 근육에서의 insulin-mediated glucose uptake을 감소시킨다.
- 따라서 근육량을 유지하는 것은 비만, T2DM, dyslipidemia등의 대사질환의 예방에 매우 중요하다.

Grip strength and the metabolic syndrome: Hertfordshire Cohort Study: cross-sectional

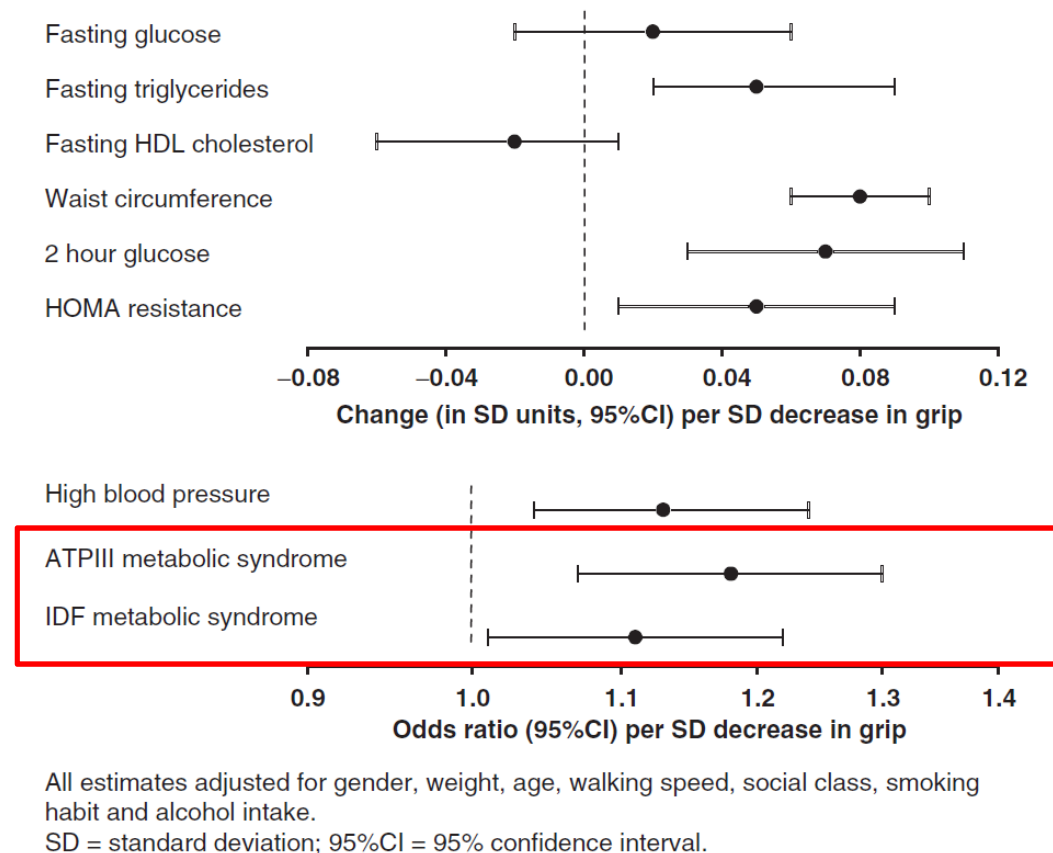
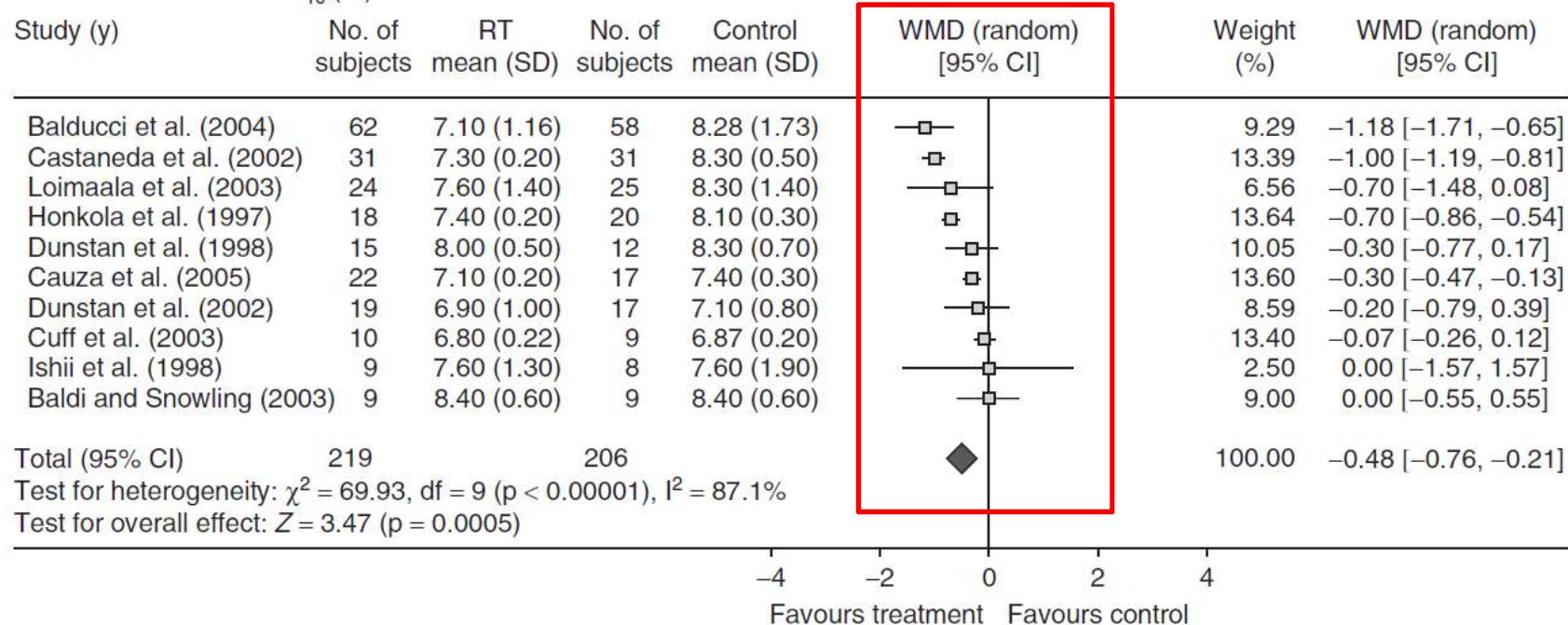


Figure 1. Relationships between grip strength and components of the metabolic syndrome and insulin resistance.

The effects of RT on metabolic parameters: meta-analysis

Review: A systematic review and meta-analysis of the relationship between RT and metabolic risk
 Comparison: 01 RT vs KO
 Outcome: 01 HbA_{1c} (%)

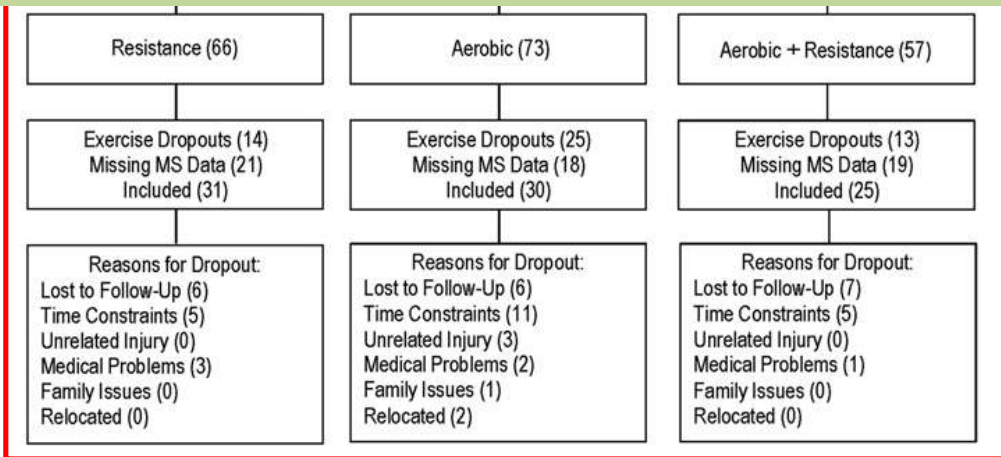


Strasser B et al. Sports Med 40:397-415, 2010

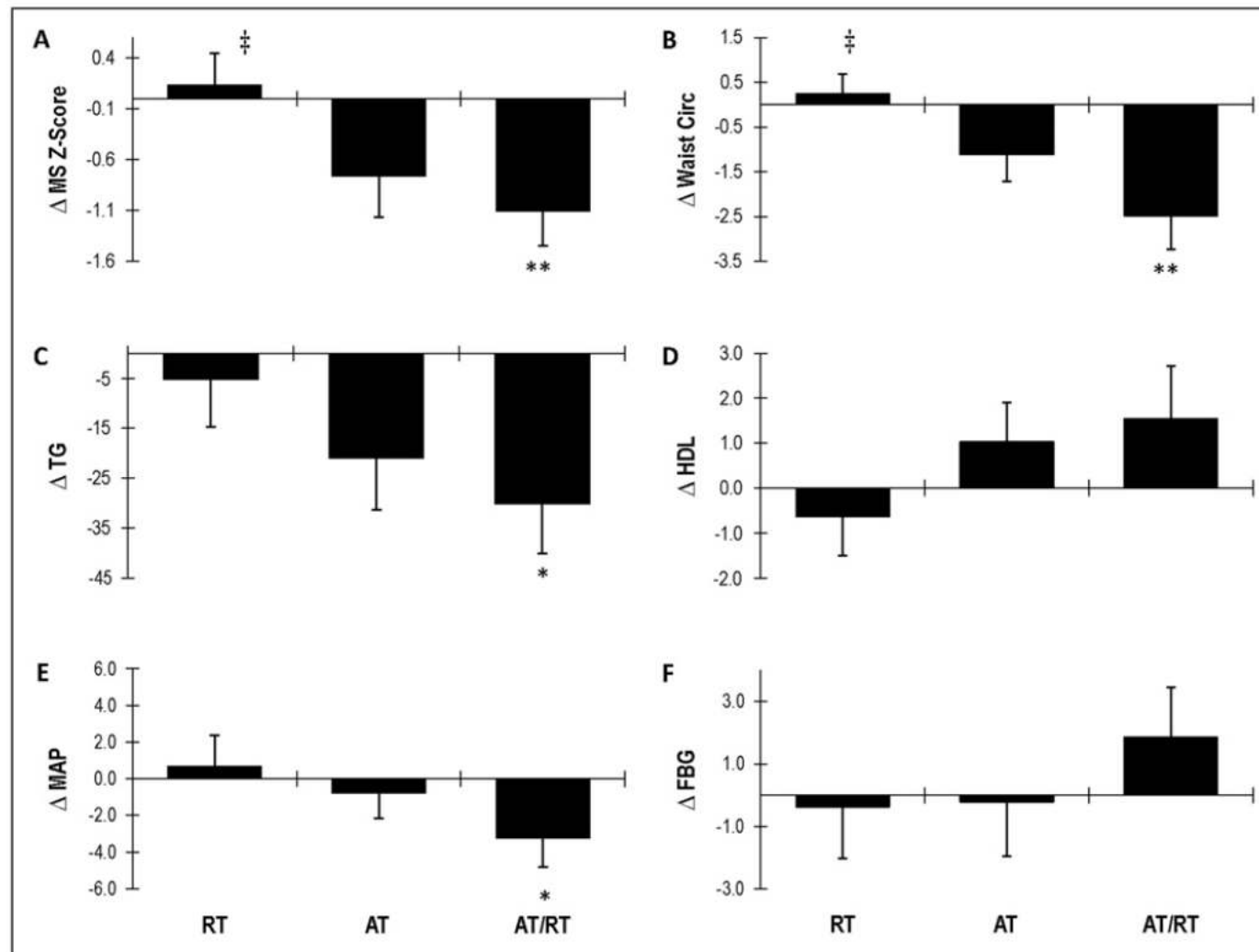
Comparison of aerobic versus resistance exercise training effects on metabolic syndrome (STRRIDE-AT/RT)

RT training

- 3 sessions per week
- 3 sets of 8 to 2 repetitions on 8 Cybex weight lifting machines
- 4 upper body and 4 lower body



Effects of exercise modes on changes in MS and the components



Bateman LA et al. Am J Cardiol 108:838-844, 2011

How much of RT?

- Still controversial due to the heterogeneity of the studies...

오늘 말씀드릴 내용

- 대사증후군의 전반적 개요
- 운동의 효과: 근육, 지방세포
- 대사증후군과 운동의 관계 – Clinical data
- 운동의 양상에 따른 예후
- 운동의 효과-실제 data를 중심으로
- 운동의 방법

Lifecorder



Lifecorder

Name					Report Date	12-31(Sat)
Group Name	obesity					
Comment						
Gender	Female	Age	36	Height	161 cm	Weight 83.5 kg
Data Range	06-16(Thu) - 08-09(Tue)			Effective Date	37	BMI 32.2
Exclusion from Analysis	First Date, Last Date, 50 Step and under/day				Moderate	3 - 5
Institution						
		Activity Cal.	Steps	Total Cal.	Activity Min.	Distance
Target		355 Cal	10000 steps	0 Cal	30 min.	
Average of Effective 37 Days		237 Cal	6069 steps	2184 Cal	63.7 min.	- km
Maximum Day (07-15(Fri))		633 Cal	13536 steps	2695 Cal	127.3 min.	- km

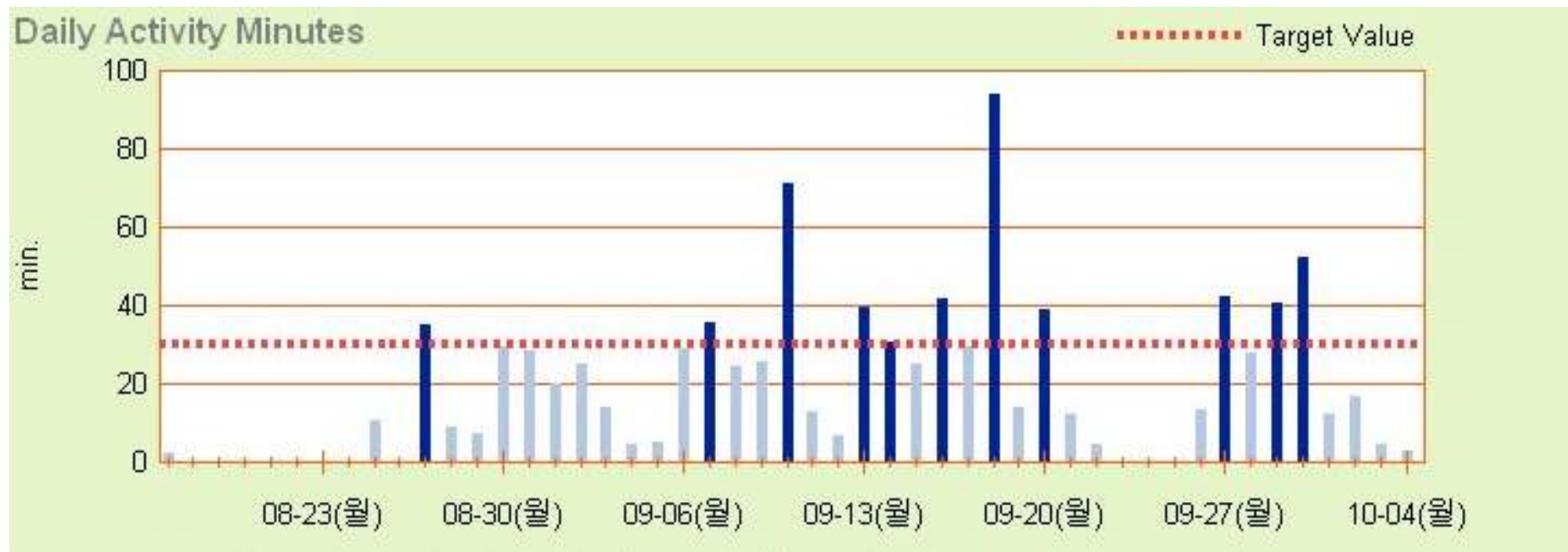
Body Mass Index(BMI)

-18.5	18.5-25	25-30	30-35	30-35	40-
Underweight	Healthy weight	Overweight	Obese i	Obese ii	Obese iii
32.2					

Lifecorder



Lifecorder

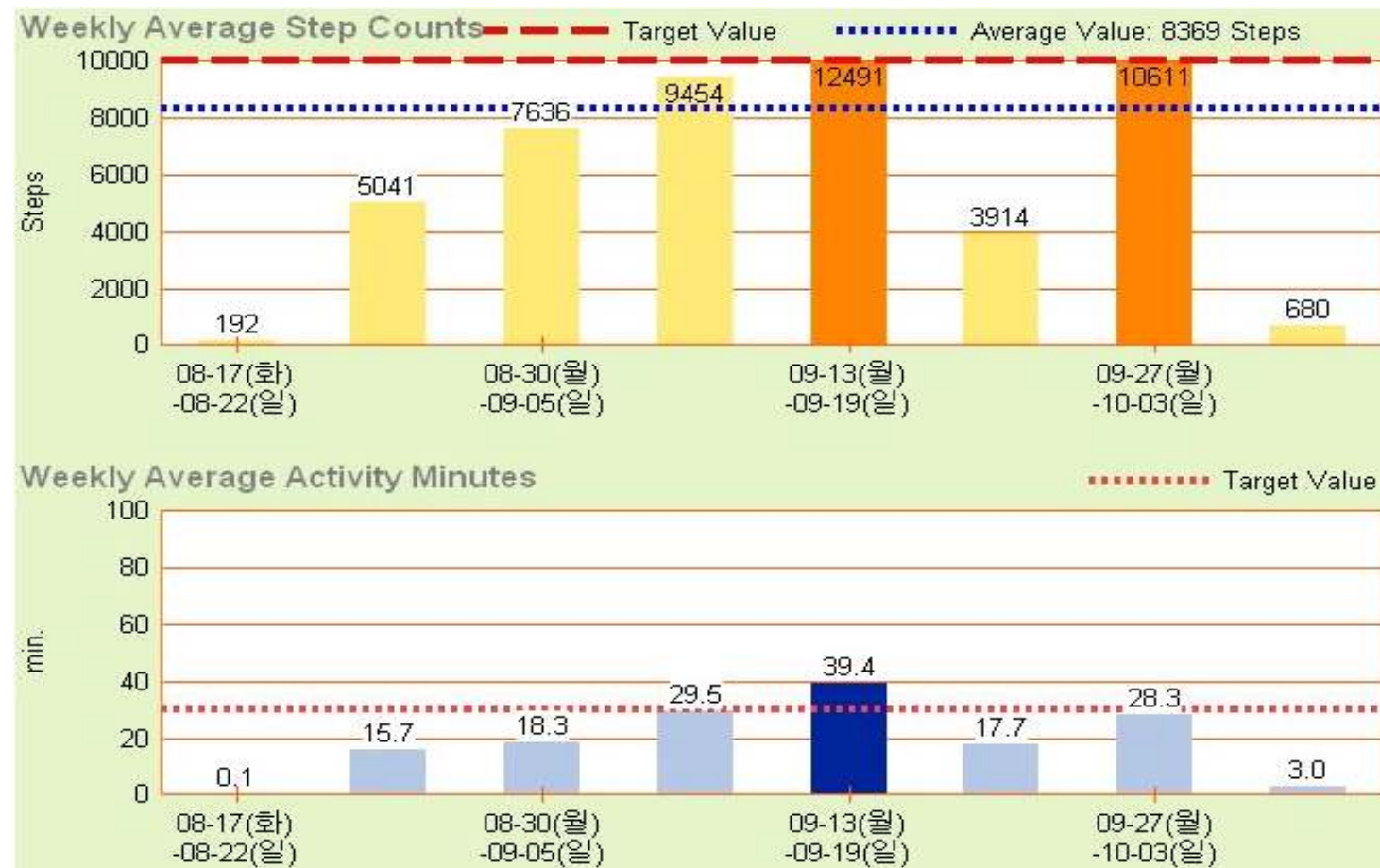


Lifecorder

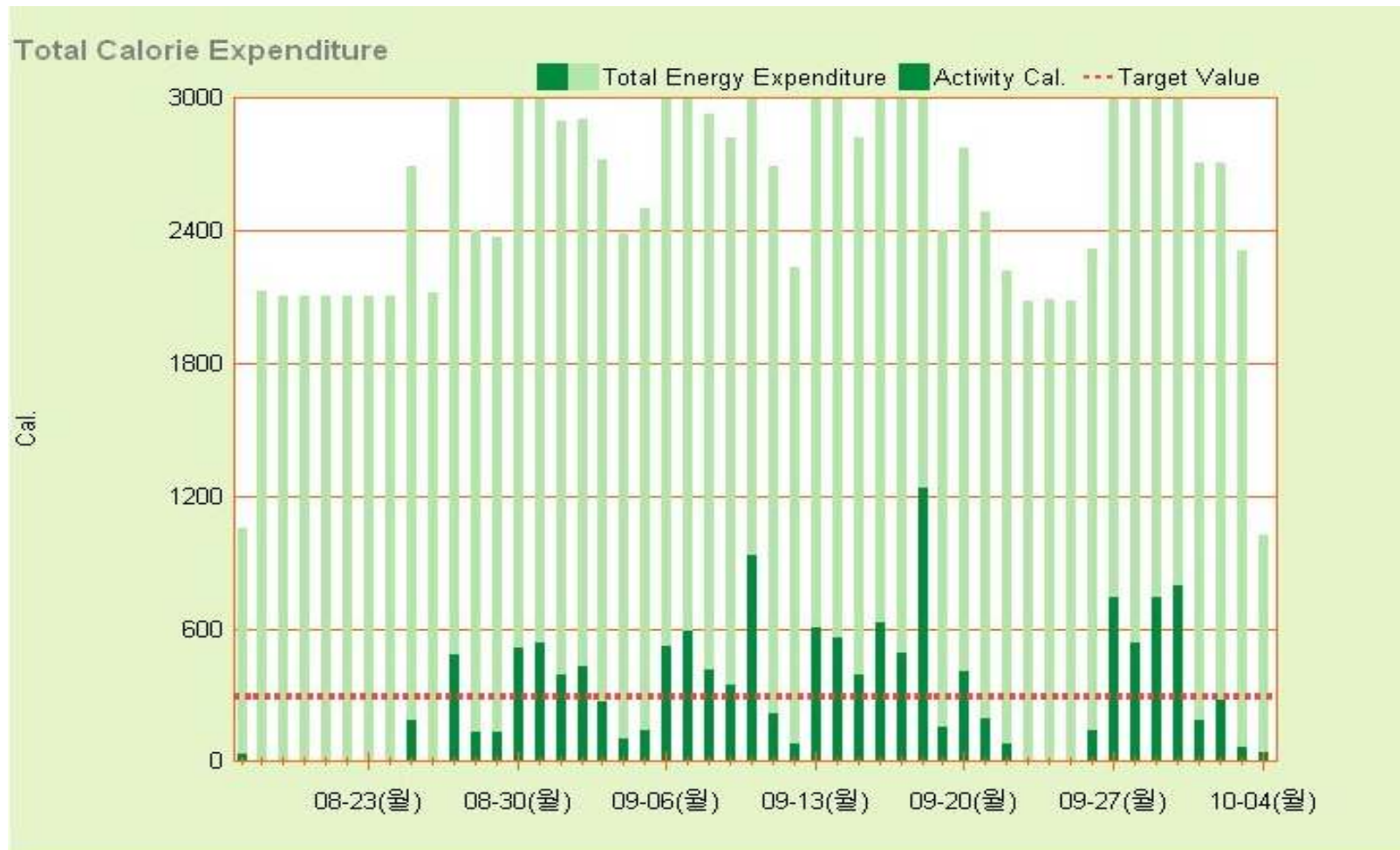
Frequency of Continued Activity (Lasting for 10minutes or above.)



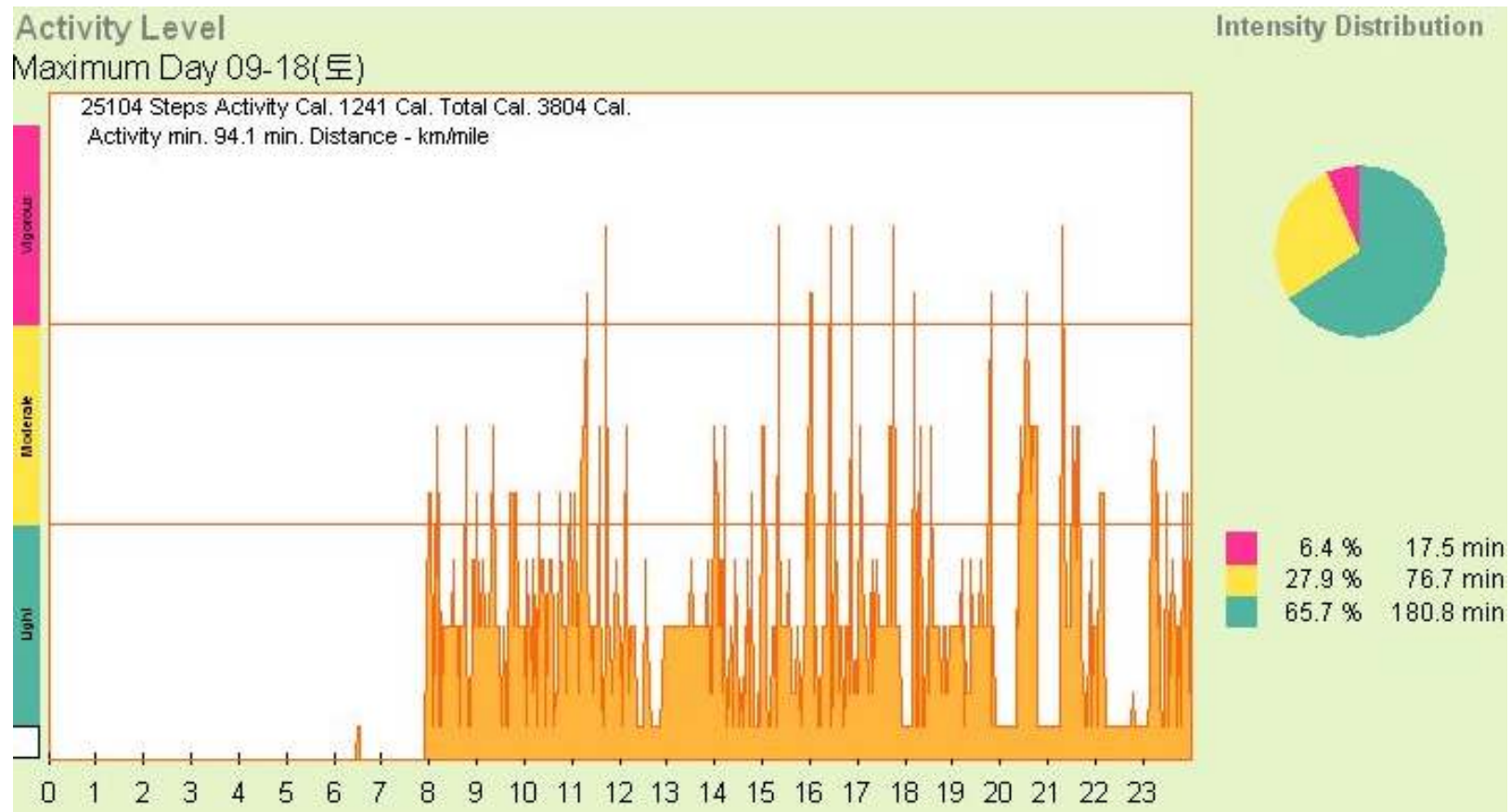
Lifecorder



Lifecorder



Lifecorder

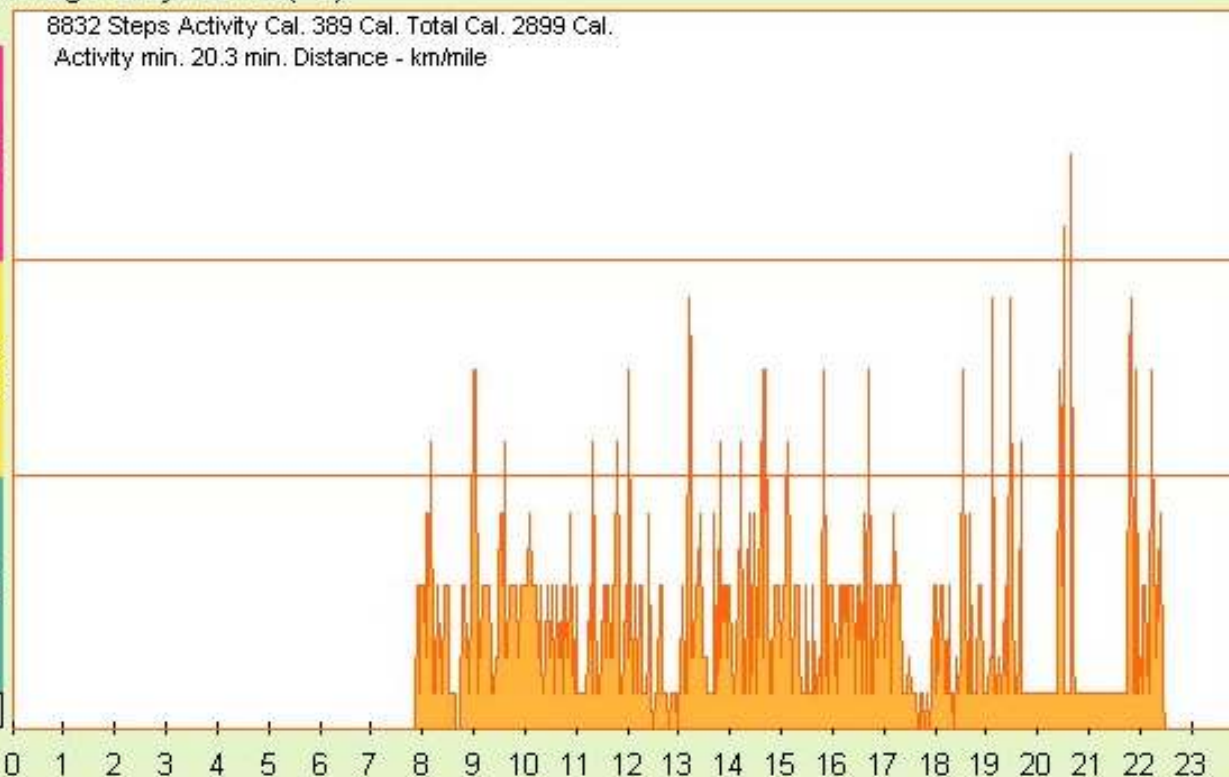


Lifecorder

Average Day: 09-01(㈬)

8832 Steps Activity Cal. 389 Cal. Total Cal. 2899 Cal.
Activity min. 20.3 min. Distance - km/mile

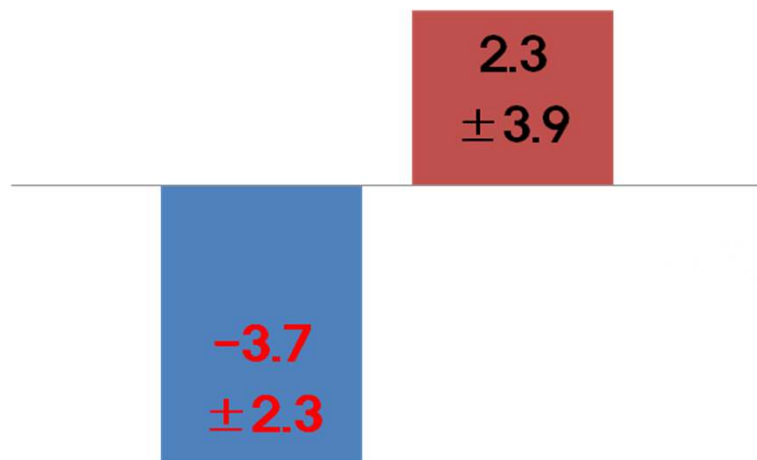
Vigorous
Moderate
Light



3.2 %	3.2 min.
17.0 %	17.1 min.
79.8 %	80.0 min.

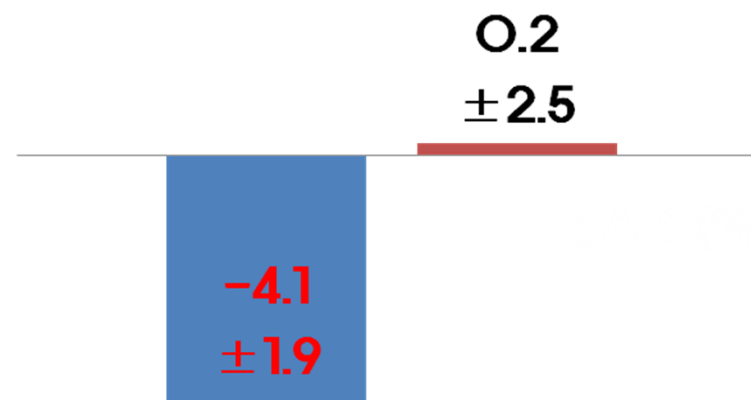
FBS중감률

■ 실험군 ■ 통제군



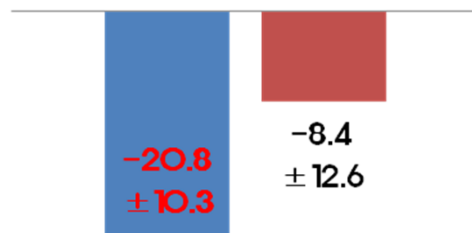
HbA1C 중감률

■ 실험군 ■ 통제군



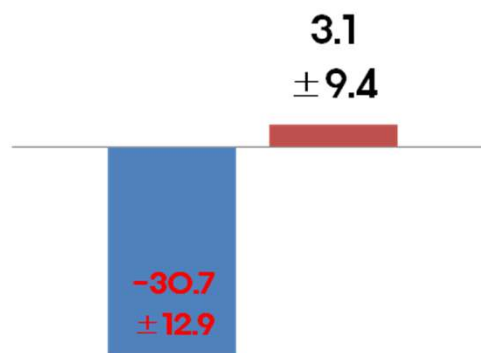
Total-Ch 중감률

■ 실험군 ■ 통제군



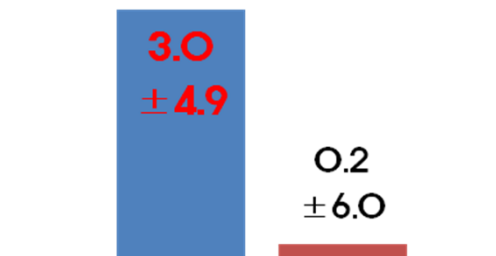
TG 중감률

■ 실험군 ■ 통제군



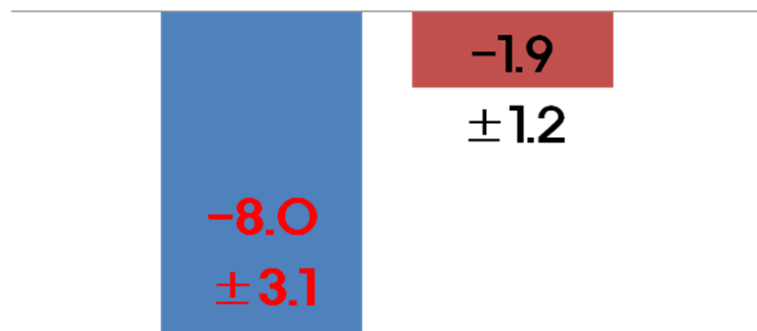
HDL 중감률

■ 실험군 ■ 통제군



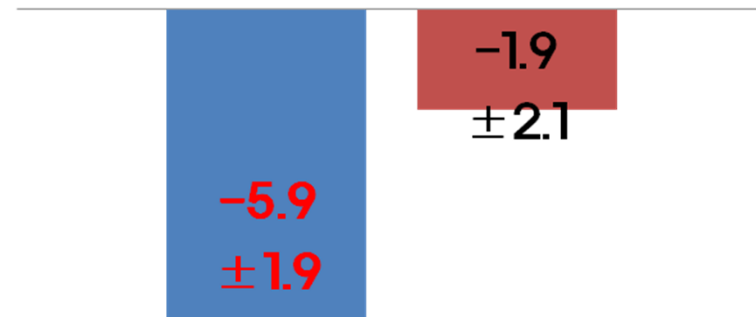
BMI중감률

■ 실험군 ■ 통제군



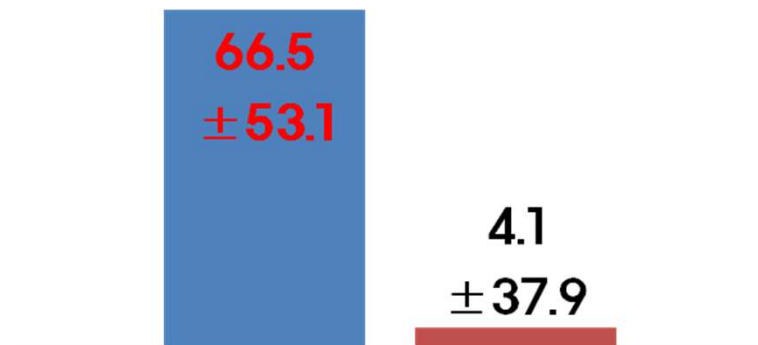
Waist 중감률

■ 실험군 ■ 통제군



TAT중감률

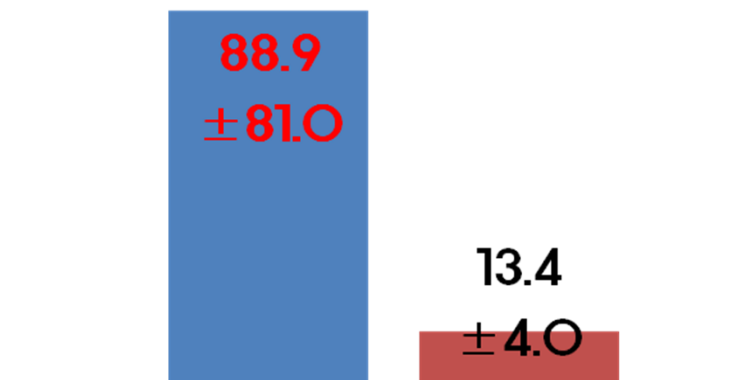
■ 실험군 ■ 통제군



Total Activity Time(%)

TS중감률

■ 실험군 ■ 통제군



Total Step(%)

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- 운동의 방법

체중 감량과 유지를 위한 운동의 원칙

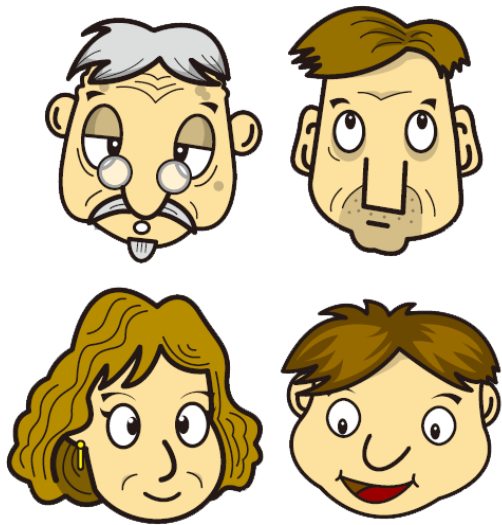
(미국 스포츠의학회 position stand 2009)

원칙	증거
체중 증가를 막기 위한 운동. 주 150~250분의 운동 (energy equivalent of 1200 to 2000 kcal/wk)이 성인에서 3% 이상의 체중 증가를 막는다.	A
체중 감량을 위한 운동. 주당 150분 미만의 운동이 최소의 체중 감량을, 주당 150분 이상의 운동이 중등도의 체중 감량을 (~2-3 kg), 주당 225-420분 이상의 운동이 5~7.5-kg의 체중 감량을 가져오며 운동량과 비례한다.	B
체중 유지를 위한 운동. 보통 주당 200~300분의 운동이 체중 감량 후 이를 유지하거나 증가를 막기 위해서 필요하나, 많이 할 수록 더 좋다. 그러나 증거 불충분.	B
운동과 식사 조절. 운동은, 식사 조절이 적당할때는 증가시키나, 식사 조절이 너무 심할 때는 그 효과를 내지 못한다.	A
저항성 운동 (Resistance training) 이 체중 감량에 미치는 영향. 아직까지는 RT이 유산소 운동만큼 체중 감량에 효과적이라는 결과는 없다. Lean mass를 증가하거나 유지하는데 도움을 준다거나 지방 양을 감소시킨다는 증거도 불충분하며, 만성질환의 위험인자들을 개선하는데 도움을 준다는 연구는 있다 (i.e., HDL-C, LDL-C, insulin, blood pressure).	B

1 단계 : 신체활동 증진



직업이 노동인데, 이게 운동이지



집안일이 얼마나 힘든데, 이게 운동이지



신체활동

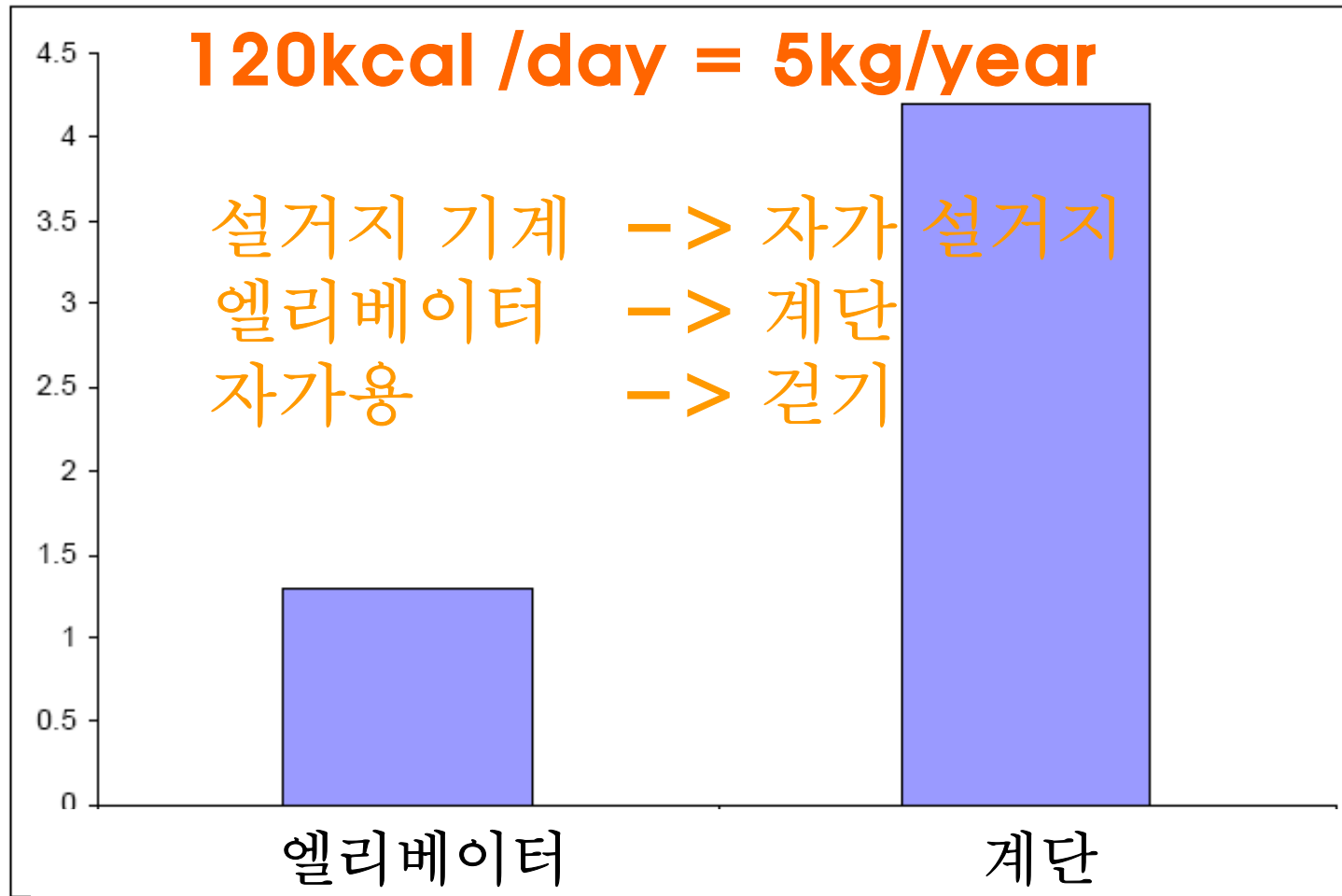
운동

신체의 모든 움직임

- 직업적 신체활동(업무, 일)
- 여가 신체활동(운동, 스포츠)

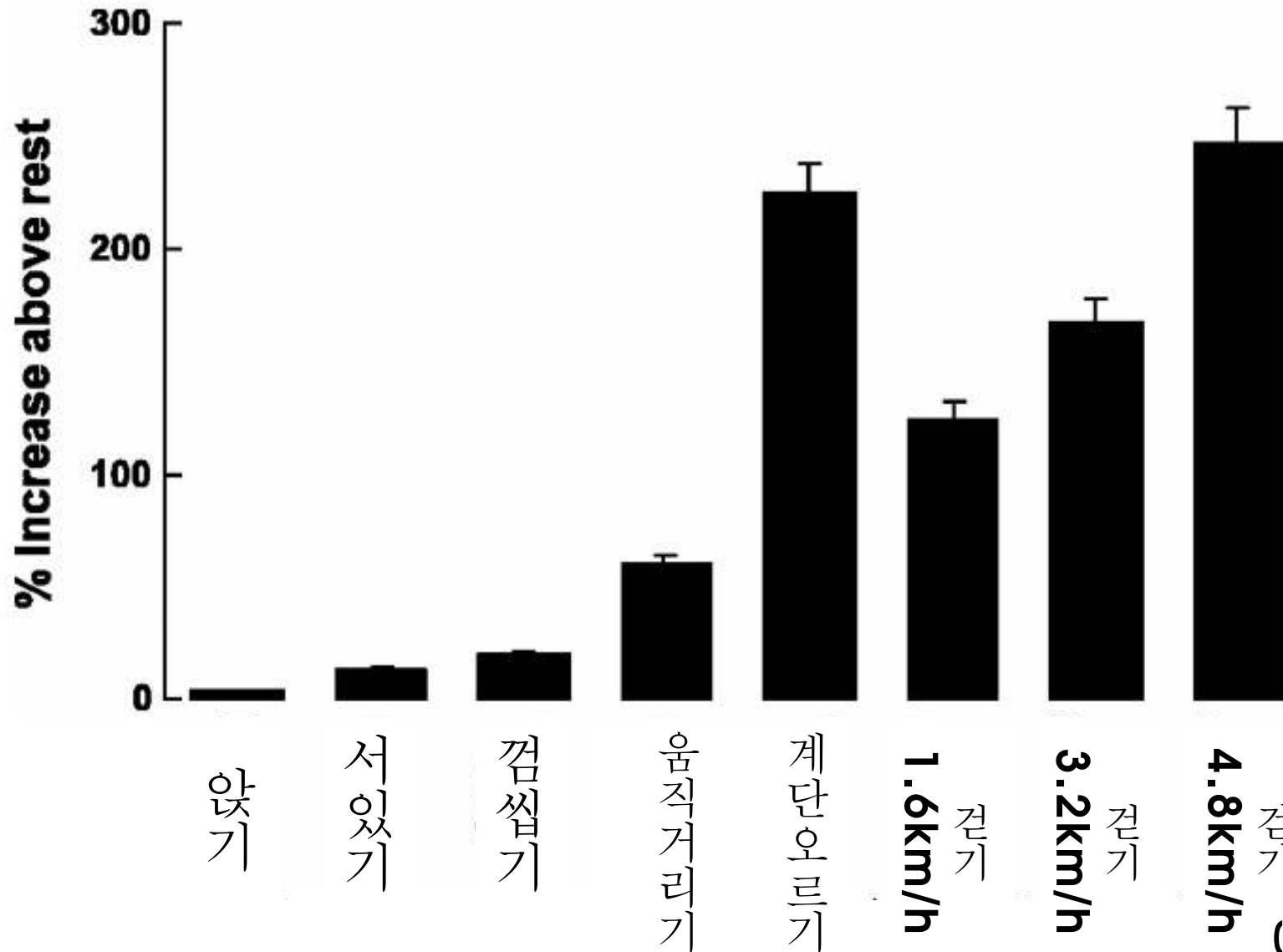
체력을 유지시키거나
향상 시키기 위해 행해지는
계획적, 반복적 신체활동

몸을 많이 움직이자!



(Lanningham et al 2003)

활동별 칼로리 소모량



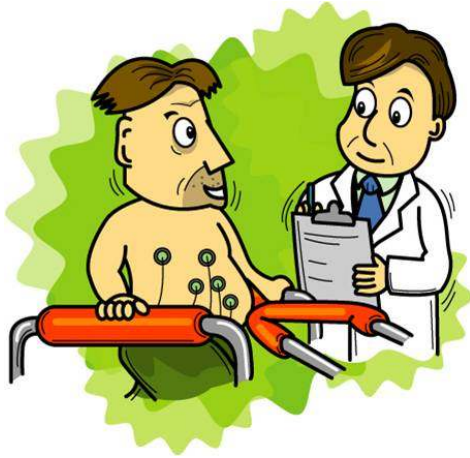
생활습관을 바꾸자!

1. 가까운 거리는 걸어 다니기
2. 걸을 때는 의식적으로 속보로 걷기
3. 에스컬레이터 대신 계단 이용하기
4. 틈틈이 스트레칭 실시하기
5. 차는 목적지보다 멀리 주차하여 걷는 시간 늘려주기
6. 텔레비전 시청 시 직접 움직여서 채널 변경하기

2단계 : 규칙적인 운동



운동 검사 전 위험성 진단



1개 이상이 해당되는 경우 의사와 상의 후 운동 참여!

당신은 심장질환이 있어 운동을 시작할 경우, 주치의와 상의하도록 안내를 받은 적이 있습니까?	
---	--

당신은 운동을 할 때 가슴통증을 느낀 적이 있습니까?	
-------------------------------	--

당신은 지난 몇 달 동안 운동을 하지 않았는데도 가슴통증을 느낀 적이 있습니까?	
--	--

당신은 정신을 잃거나 현기증 때문에 균형을 잃은 적이 있습니까?	
-------------------------------------	--

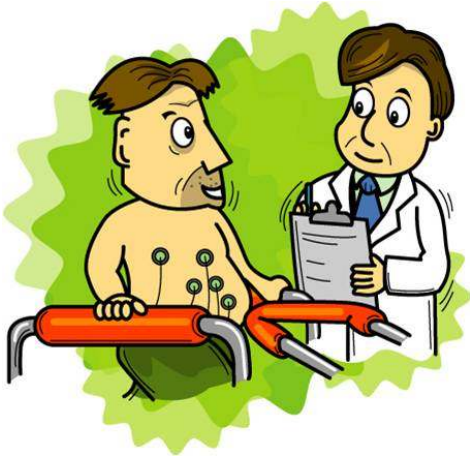
당신은 최근 뼈나 관절에 문제가 있습니까?	
-------------------------	--

당신은 현재 혈압 또는 심장 문제로 의사가 처방한 약을 복용하고 있습니까?	
---	--

운동을 할 수 없는 그 밖의 이유가 있습니까?	
---------------------------	--

미국 스포츠 의학회 「건강관련 신체 체력평가 메뉴얼」

운동 검사가 필요한 경우



심장 운동 부하 검사

연령 > 35세

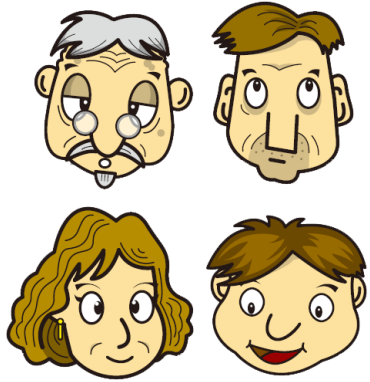
관상동맥질환이 의심되거나 진단받은 경우

15년 이상 된 **1형** 당뇨병 환자

10년 이상 된 **2형** 당뇨병 환자

미세혈관합병증, 말초혈관질환

자율신경병증

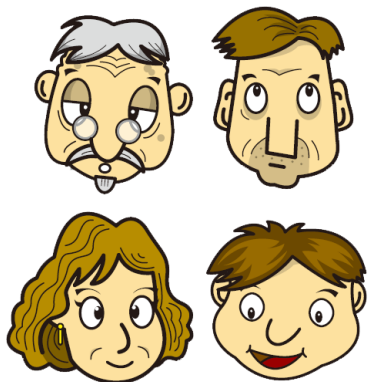


운동 계획 세우기

운동 종류를 선택하여(질병, 선호도, 기타 요건 고려)

일주일에 **약 700kcal~2000kcal** 에너지 소모하도록

횟수는 적어도 **3회 이상** 실시하도록



운동 시간

주당 150분 이상(= 700kcal 이상)

주 3회	50분씩
주 4회	40분씩
주 5회	30분씩

개인 체력 고려!
최소 10분씩 3번 = 한번에 30분



운동 강도

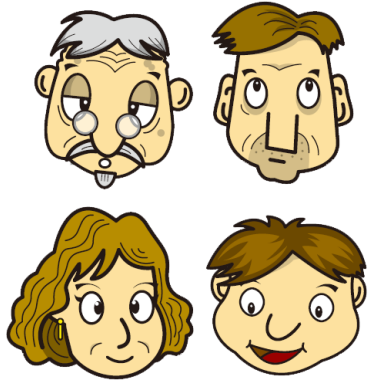
[1] 심박수 계산 법

$[(\text{최대 심박수} - \text{안정시 심박수}) * 0.5 \sim 0.75]$
+ 안정시 심박수

최대심박수 = $220 - \text{나이}$

안정시 심박수 = 1분 심박수

자율신경장애, 심혈관계질환자는 사용하지 못함.



운동 강도

[2] 자각 인지법

운동 효과 미비

옆 사람과 대화가 가능한
약간 숨차게

상해 위험, 질병 악화

강도 분류

매우 가볍다

가볍다

약간 힘들다

힘들다

매우 힘들다

운동 전, 후

준비운동/정리운동



스트레칭 체조

약 5~10분 정도 실시합니다.

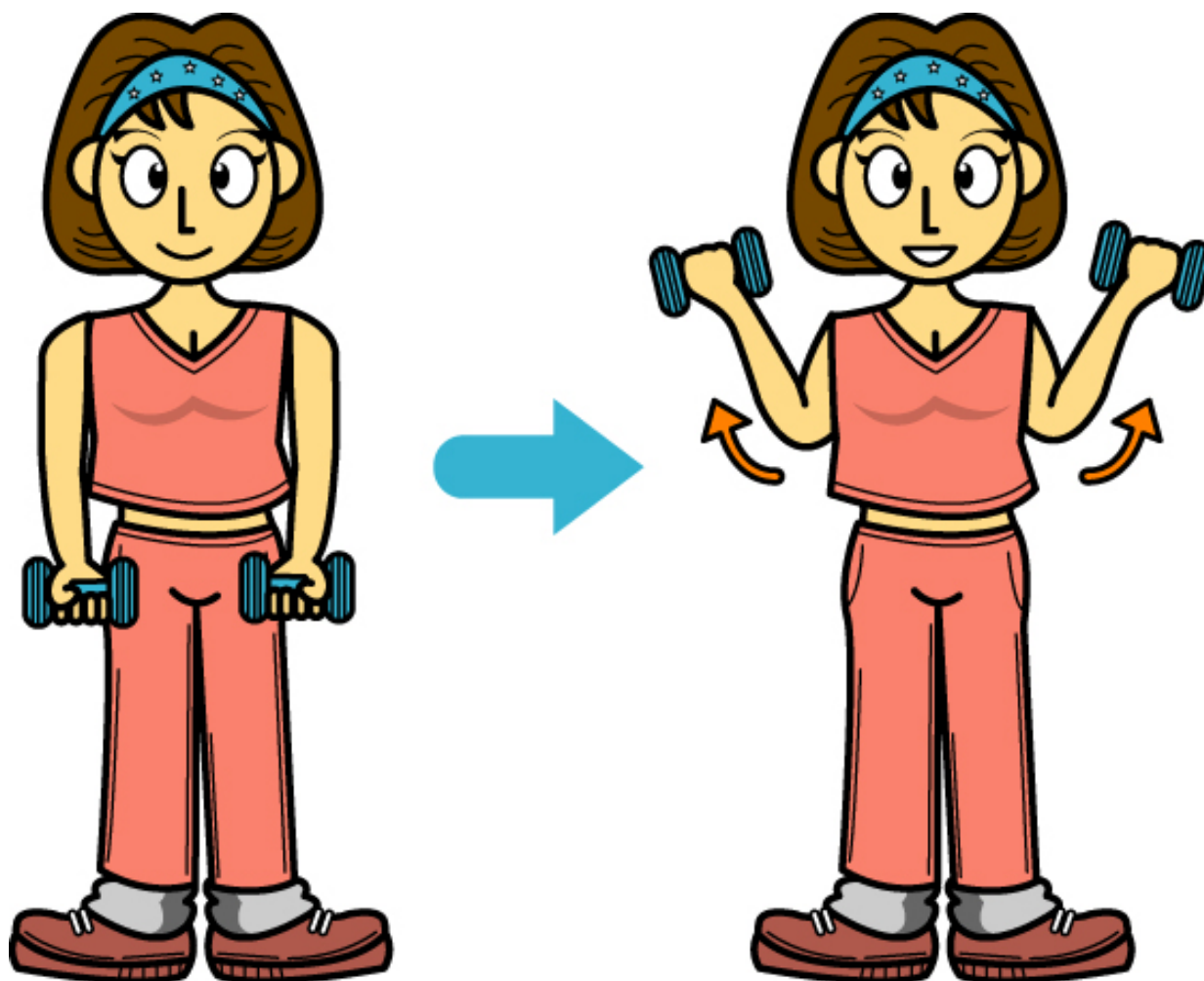
8~10초 정도 유지, 3회 반복

호흡 유지

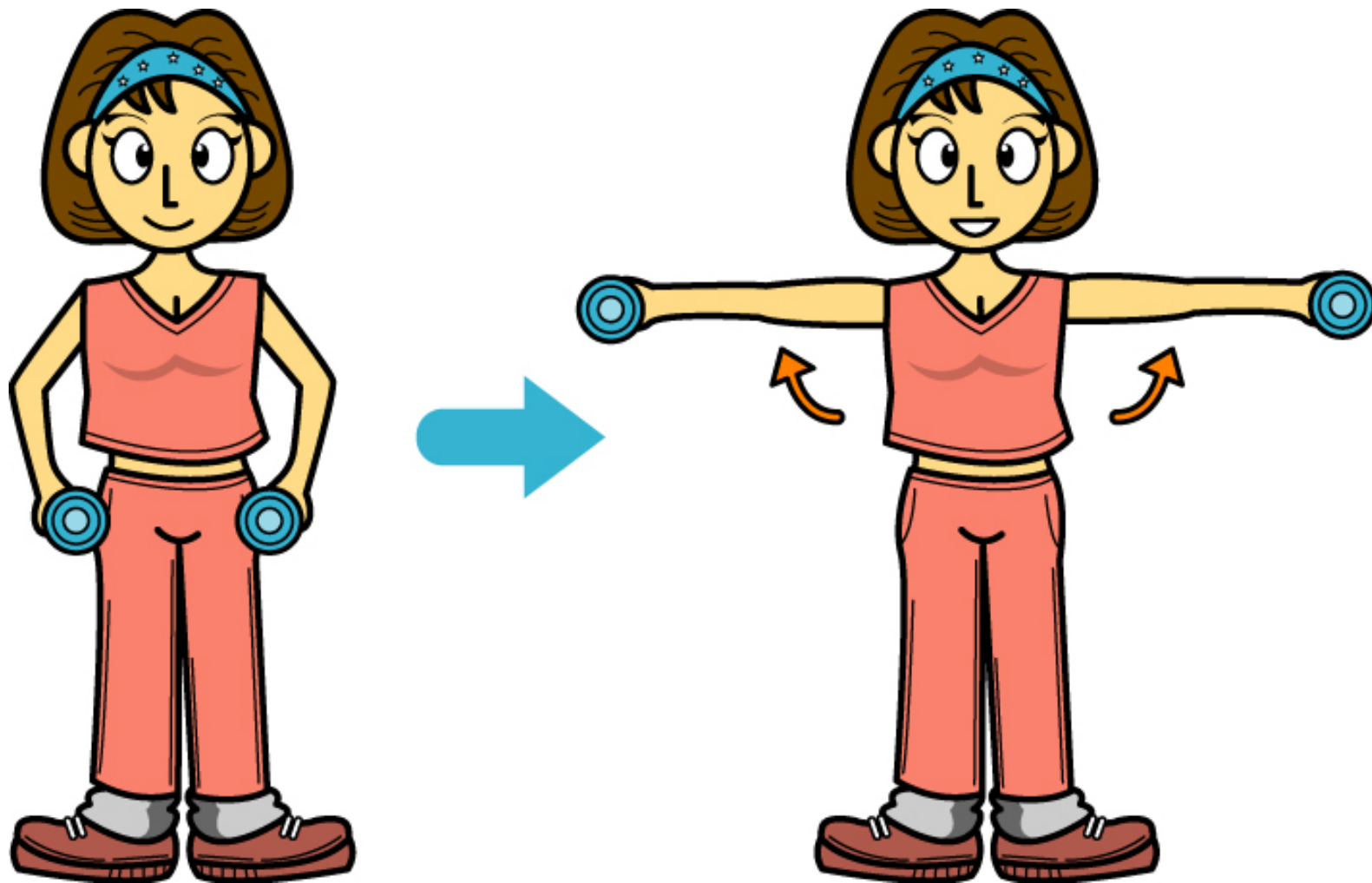
근력 운동 방법

- 어깨, 허리, 가슴, 복부, 다리 근육 운동
- 큰 근육 먼저->작은 근육(가슴->팔)
- 8~12회 반복하는 것은 2~3회 실시
- 반복 횟수 사이 휴식 시간 30초~1분
- 지속적으로 호흡을 유지하는 것이 중요

팔 근력 운동 방법



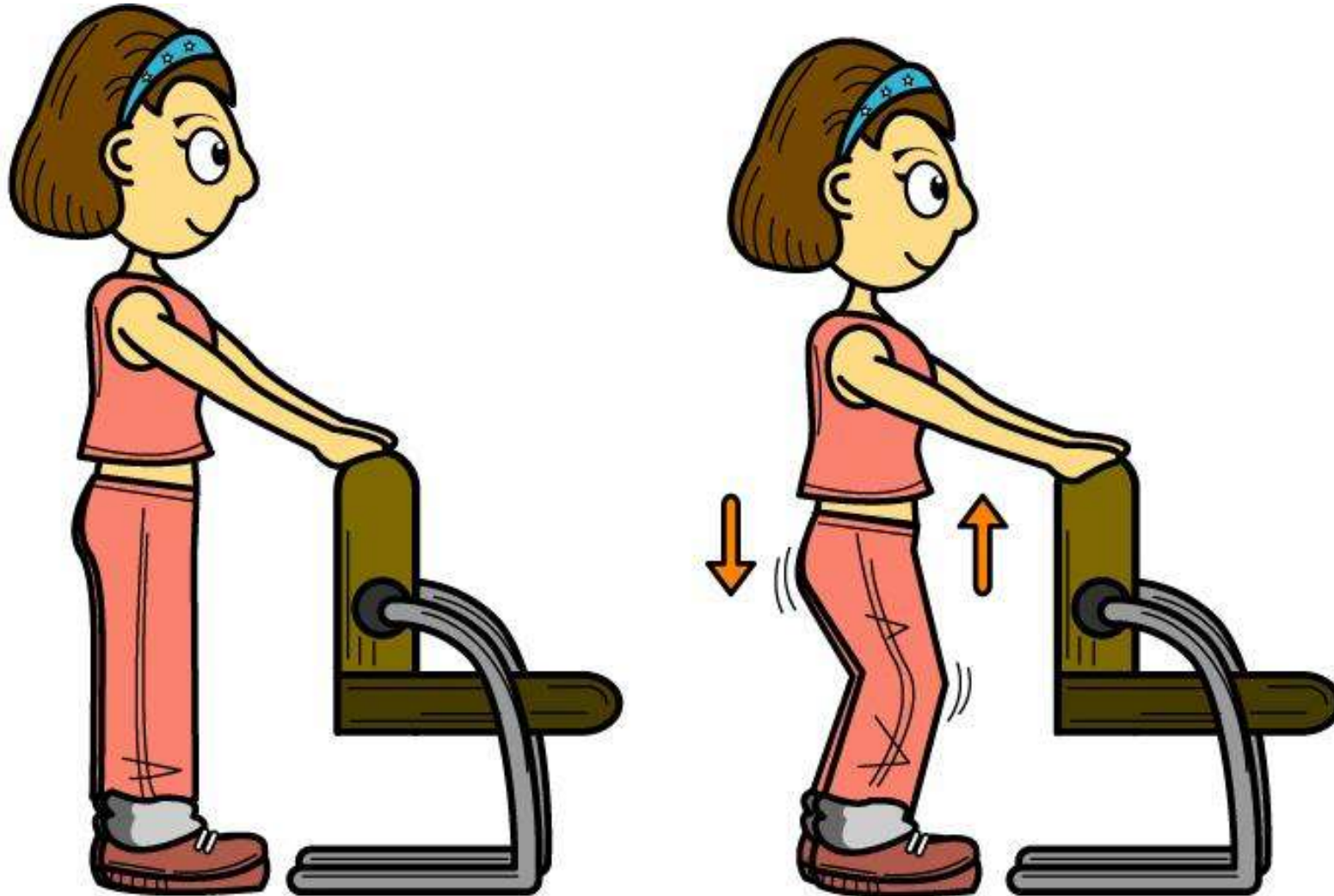
어깨 근력 운동 방법



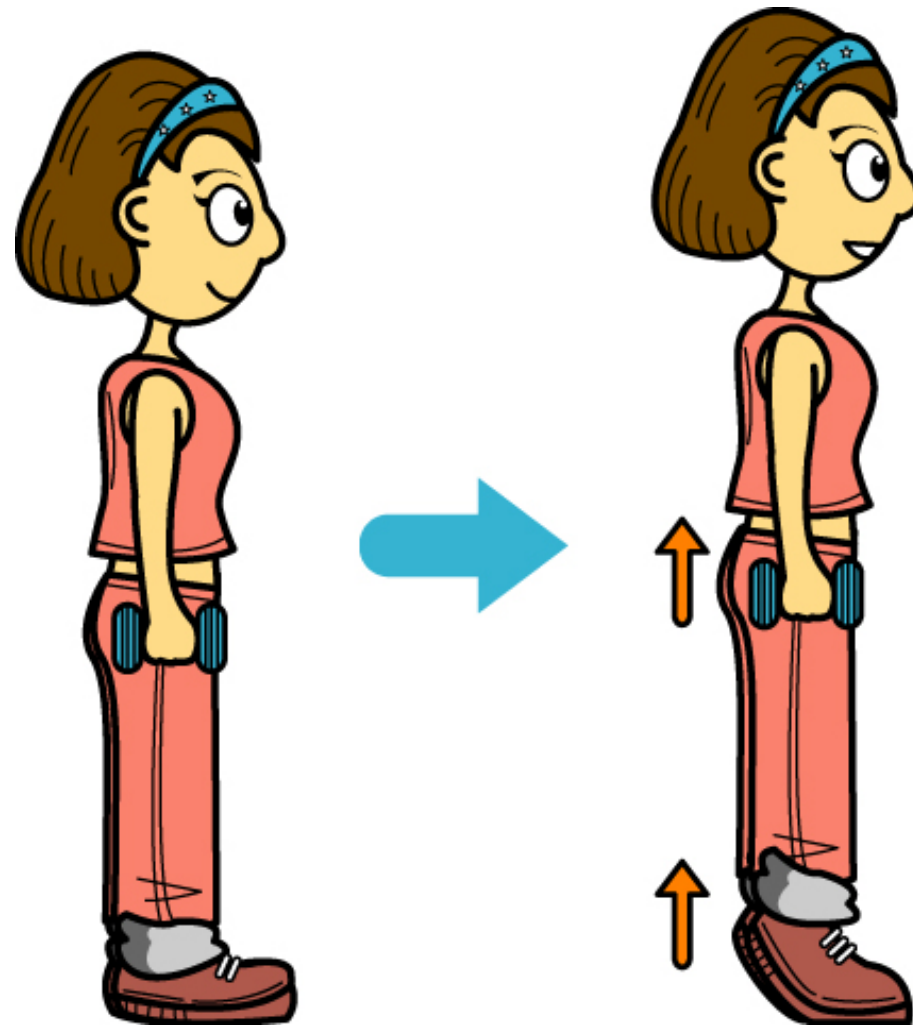
배 근력 운동 방법



허벅지 근력 운동 방법



종아리 근력 운동 방법



결론

- 운동과 PA는 대사증후군을 감소시키는데 효과가 있다
- AT, RT 모두 근육, 지방에서의 인슐린저항성 개선, 여러 대사증후군 인자들의 향상에 효과가 있다.
- 운동은 교육을 통해 이루어져야 한다.



성균관의대 강북삼성병원 당뇨전문센터(2011. 12. 21)