



# Cardiac Rehabilitation

## - Current Status and Perspectives

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# Talking about...

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- What is cardiac rehabilitation?
- Benefits
- Safety
- Mechanisms of benefits
- Future perspective

# Cardiac rehabilitation

- Agency of Health Care Policy and Research (AHCPR, 1995): Comprehensive long-term services involving medical evaluation, prescribed exercise, cardiac risk factor modification, education, counseling and behavioral interventions – not just exercise training
- AHA scientific statements (2005): Coordinated, multifaceted interventions designed to optimize a cardiac patient's physical, psychological, and social functioning, in addition to stabilizing, slowing, or even reversing the progression of the underlying atherosclerotic processes, thereby reducing morbidity and mortality
- Unfortunately, the most underutilized measure of prevention.

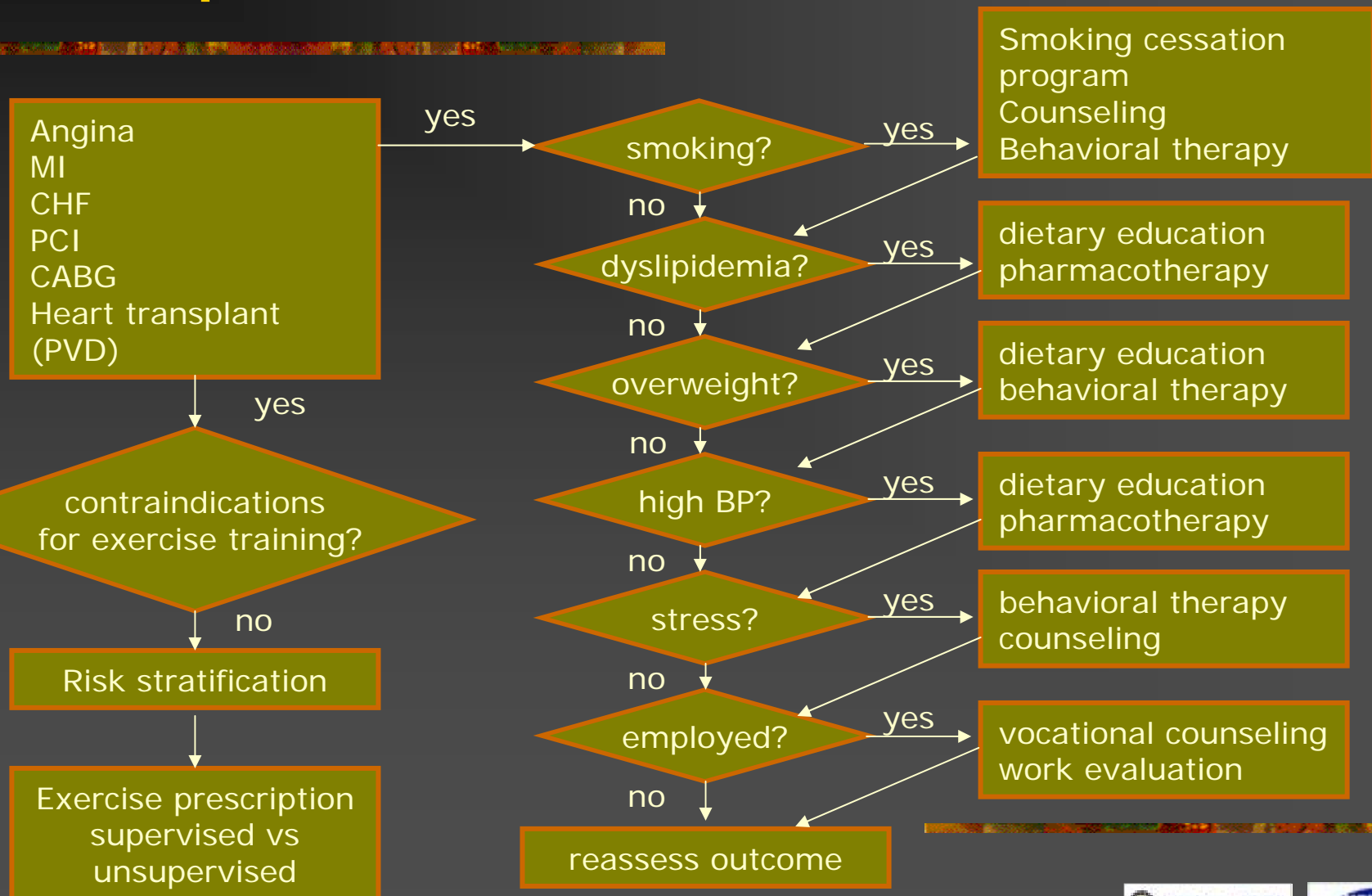
# Brief history

- 1950's: absolute bed rest for 6-8 weeks in post-MI patients (mortality of 30-40%)
- 1960's: attempt for early ambulation – ECG monitoring
- 1970's: clinical trials for cardiac rehabilitation program
- After 1980's: expansion of application of cardiac rehabilitation program

# In-hospital cardiac rehabilitation

- Traditionally called 'phase I'
- Mobilization and education
- CCU activities in 1-2 METs range
- Ward activities in 2-3 METs range
- On discharge,
  - Should climb on flight of stairs successfully
  - Educational material
  - Teaching related to medication, appropriate activity and signs and symptoms to watch

# Outpatient cardiac rehabilitation



# Indications

- Virtually *all* cardiac patients in stable condition!
  - Recent myocardial infarction
  - Coronary bypass
  - Valve surgery
  - Coronary angioplasty
  - Cardiac transplantation
  - Angina
  - Compensated CHF
  - Peripheral vascular disease

# Cardiac rehab personnel

- Medical director
- Program coordinator
- RN
- Exercise specialist
- Nutritionist
- Psychologist
- Vocational rehab counselor
- Physical therapist, health educator, occupational therapist, pharmacist



# Facility

- GXT
- Exercise program
  - Treadmills, bicycles, stairclimbers, or a walking area
  - Arm ergometers, rowing machines
  - Swimming pool, cross-country ski machine
  - Elastic bands, cuff and hand weights, dumbbells, wall pulleys, multistation weight machines
  - ECG monitoring
- Emergency procedures

# Benefits of cardiac rehabilitation

- Improvement in exercise tolerance.
- Improvement in symptoms.
- Improvement in blood lipid levels.
- Reduction in cigarette smoking(?)
- Improvement in psychosocial well-being and reduction of stress.
- Reduction in mortality.

# Exercise tolerance

- 30 of 36 randomized controlled trials that compared exercise training versus no exercise documented a statistically significant improvement in exercise tolerance in intervention versus control patients.
- Five of the six studies that showed no difference between intervention and control patients **did not specify exercise intensity** in the study methodology.

# Improvements in exercise parameters

	재활요법군				대조군				p
	전		후		전		후		
최대 산소섭취량 (ml/kg/min)	29.6 ± 6.1	35.2 ± 8.4	31.8 ± 7.9	31.4 ± 7.7	p=0.0062				
대사당량	8.6 ± 1.7	10.0 ± 2.2	9.0 ± 2.3	8.9 ± 2.2	p=0.0063				
무산소역치 (L/min)	1.3 ± 0.5	1.5 ± 0.6	1.3 ± 0.5	1.2 ± 0.4	p=0.0274				
최대산소맥 (ml/bpm)	15.3 ± 3.6	17.0 ± 4.3	14.8 ± 3.4	16.1 ± 3.3	p=0.5403, NS				
운동시간 (초)	825.0 ± 98.6	964.6 ± 176.1	875.7 ± 116.8	860.2 ± 133.4	p=0.002				

최대산소섭취량 (maximal oxygen uptake,  $VO_{2max} = \text{Cardiac Output} \times \text{arteriovenous oxygen difference}$ )

대사당량 (metabolic equivalent, MET ; 1MET=3.5ml/kg/min)

무산소역치 (anaerobic threshold)

최대산소맥 (maximal  $O_2$  pulse =  $VO_2 / \text{heart rate}$ )

# Symptoms

- Eight of the 12 randomized controlled trials reported statistically significant improvement in cardiovascular symptoms in intervention groups compared with control groups
- Confounded by inadequate information regarding changes in medication status

# Smoking

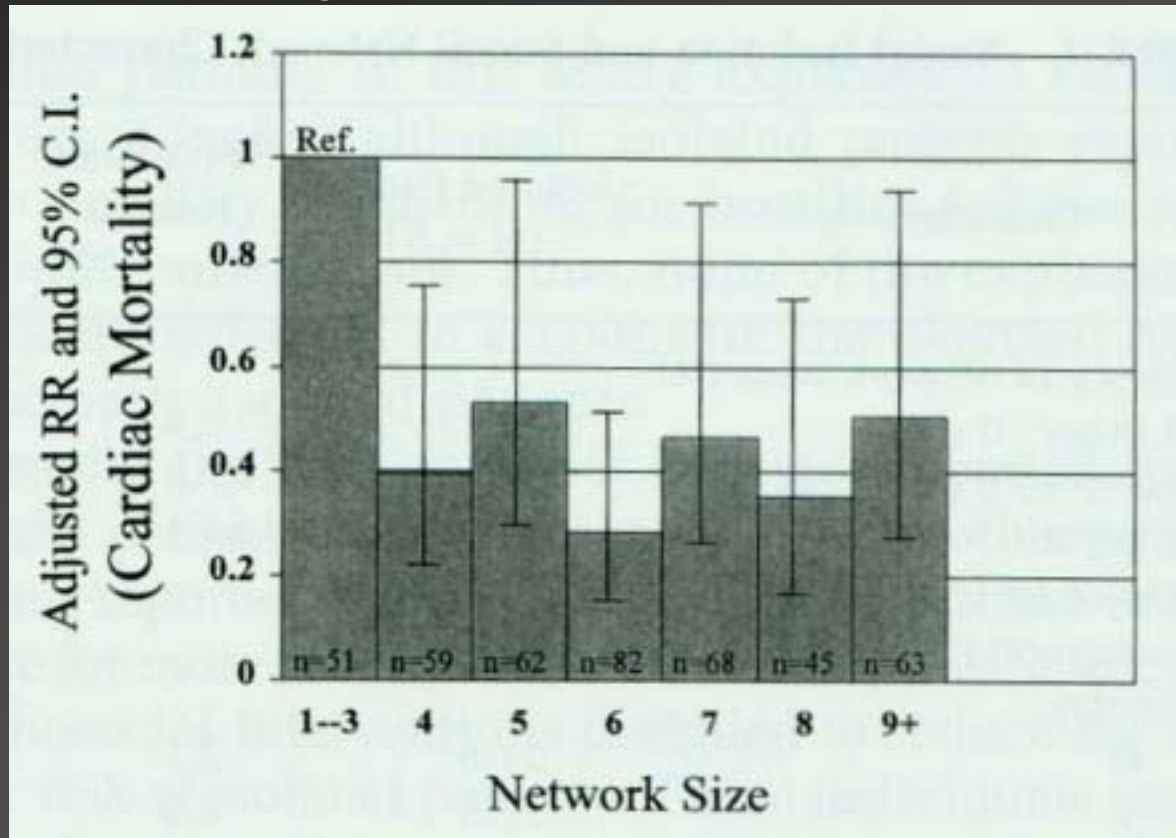
- Exercise training has little or no effect on smoking cessation. Smoking cessation is achieved by specific smoking cessation strategies.
- Specific techniques of proven value in effecting smoking cessation should be incorporated into multi-factorial cardiac rehabilitation.

# Lipid abnormality

- Six of eight randomized controlled trials that reported changes in low-density lipoprotein (LDL) cholesterol levels documented significant lowering of LDL levels in rehabilitation patients compared with control patients. All six involved multi-factorial interventions.

# Psychosocial well-being

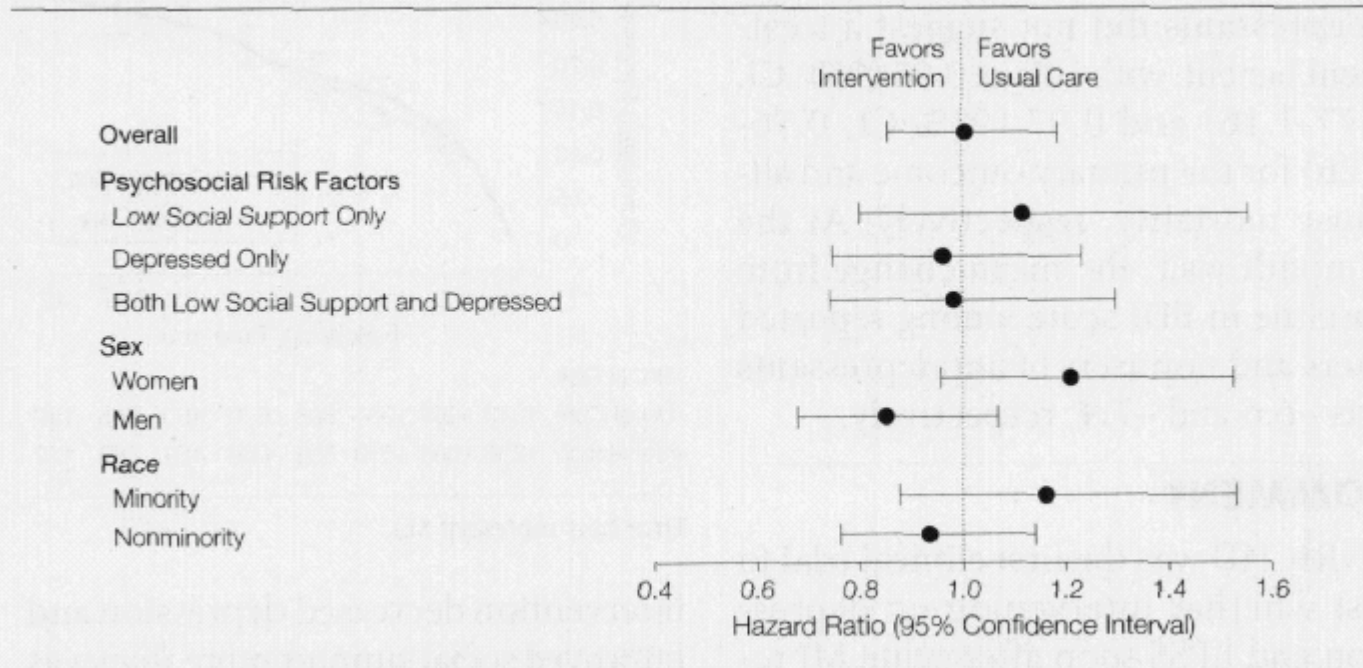
- Depression, anger, anxiety, social isolation...





# ENRICHD - Outcomes

**Figure 3.** Effect of Enhancing Recovery in Coronary Heart Disease Patients (ENRICHD) Intervention on Risk of Death or Nonfatal Myocardial Infarction



Error bars indicate 95% confidence intervals.

Berkman LF, Blumenthal J, Burg M, Carney RM, Catellier D, Cowan MJ, Czajkowski SM, DeBusk R, Hosking J, Jaffe A, Kaufmann PG, Mitchell P, Norman J, Powell LH, Raczynski JM, Schneiderman N. Effects of treating depression and low perceived social support on clinical events after myocardial infarction: the Enhancing Recovery in Coronary Heart Disease Patients (ENRICHD) Randomized Trial. *Jama*. 2003;289:3106-16

# ENRICHD – Psychological measures

**Table 3.** Psychological Measures at Baseline Through 6 Months by Treatment\*

	No. of Patients	Scores, Mean (SD)			Mean (95% CI) Treatment Difference
		Baseline	6 Months	Change	
<b>BDI</b>					
Depressed participants only					
Usual care	635	18.0 (7.6)	12.2 (9.1)	-5.8 (8.9)	-2.7 (-3.7 to -1.7)
Intervention	697	17.7 (8.1)	9.1 (8.6)	-8.6 (9.2)	
<b>All</b>					
Usual care	869	15.7 (8.1)	11.0 (8.7)	-4.7 (8.6)	-2.8 (-3.7 to -2.0)
Intervention	916	15.7 (8.5)	8.2 (8.3)	-7.6 (8.8)	
<b>HRSD</b>					
Depressed participants only					
Usual care	646	17.8 (8.4)	9.4 (8.9)	-8.4 (7.7)	-1.7 (-2.5 to -0.9)
Intervention	697	17.7 (8.4)	7.8 (8.7)	-10.1 (7.8)	
<b>All</b>					
Usual care	876	15.5 (7.4)	8.4 (8.8)	-7.1 (7.8)	-1.5 (-2.3 to -0.8)
Intervention	926	15.5 (7.4)	6.9 (8.5)	-8.6 (7.9)	
<b>ESSI</b>					
Participants with LPSS					
Usual care	535	19.2 (4.2)	22.8 (6.7)	3.4 (6.0)	1.8 (1.0 to 2.5)
Intervention	556	19.2 (4.4)	24.4 (6.2)	5.1 (5.9)	
<b>All</b>					
Usual care	886	23.3 (6.3)	25.0 (6.7)	1.7 (6.0)	1.5 (1.0 to 2.0)
Intervention	929	23.1 (6.3)	26.3 (6.2)	3.2 (5.8)	
<b>PSSS</b>					
Participants with LPSS					
Usual care	513	54.4 (14.2)	58.9 (15.7)	4.5 (14.9)	4.5 (2.7 to 6.3)
Intervention	533	53.4 (14.1)	62.4 (15.2)	9.0 (14.9)	
<b>All</b>					
Usual care	859	60.5 (14.9)	62.8 (15.2)	2.3 (13.9)	3.9 (2.6 to 5.2)
Intervention	896	60.1 (15.2)	66.4 (14.3)	6.3 (13.9)	

Abbreviations: BDI, Beck Depression Inventory; CI, confidence interval; ESSI, Enhancing Recovery in Coronary Heart Disease Patients (ENRICH-D) Social Support Instrument; HRSD, Hamilton Rating Scale for Depression; LPSS, low perceived social support; and PSSS, Perceived Social Support Scale.  
\*All P values are <.001 (for comparison between 6 months vs baseline and for group differences in change scores).

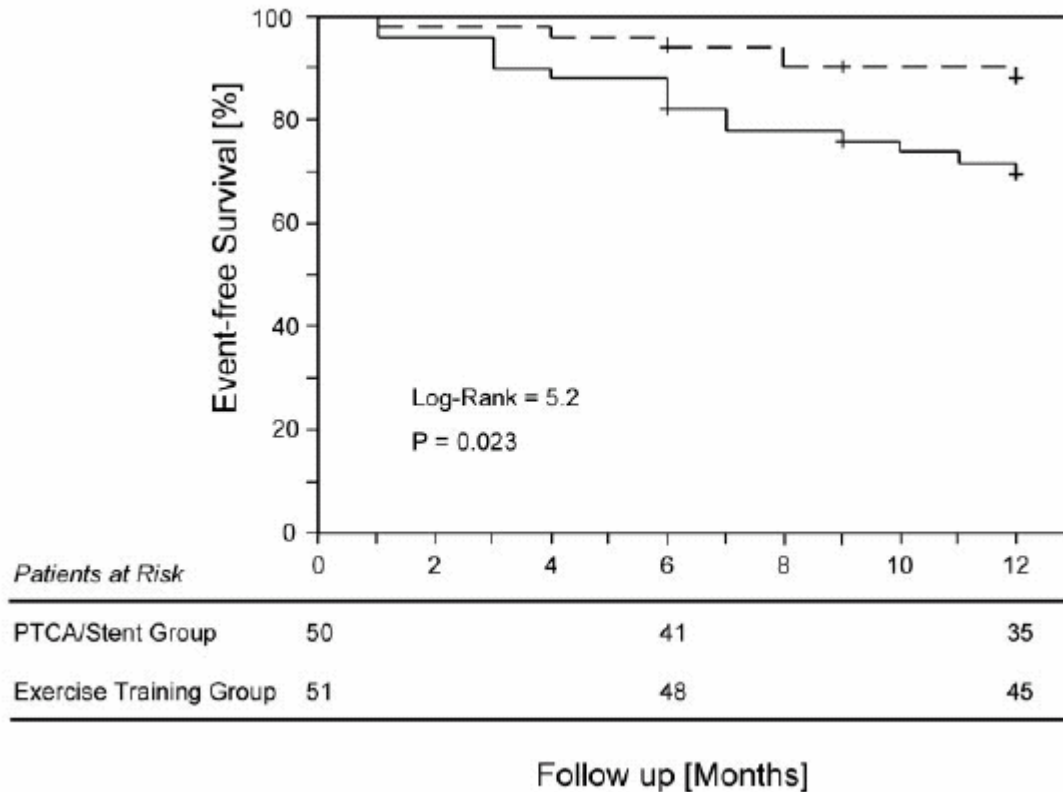
# Mortality – metaanalysis

Outcome	Mean Difference, %	95% Confidence Limit	Statistical Difference
Total mortality	-20	-7% to -32%	$P=0.005$
Cardiac mortality	-26	-10% to -29%	$P=0.002$
Nonfatal MI	-21	-43% to 9%	$P=0.150$
CABG	-13	-35% to 16%	$P=0.400$
PTCA	-19	-51% to 34%	$P=0.400$

Mean difference is the percentage of difference between exercise-trained and usual-care control group. MI indicates myocardial infarction; CABG, coronary artery bypass graft; and PTCA, percutaneous coronary angioplasty.

Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, Skidmore B, Stone JA, Thompson DR, Oldridge N. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. *Am J Med.* 2004; 116:682-92

# Exercise training vs. PCI (1)



# Exercise training vs. PCI (2)

	Exercise Training Group (n=43)		PCI Group (n=33)	
	Baseline	End of Study	Baseline	End of Study
Resting heart rate, bpm	71±2	65±1*†	70±2	70±1
Ischemic threshold, W	98±6	127±8‡	99±5	119±7‡
Maximal heart rate, bpm	131±3	137±3*	132±3	133±3
Physical work capacity, W	133±5	159±5§	130±5	130±5
$\dot{V}O_2$ max, mL · kg <sup>-1</sup> · min <sup>-1</sup>	22.6±0.7	26.2±0.8†	22.3±0.6	22.8±0.9

$\dot{V}O_2$  max indicates oxygen uptake at peak exercise; ischemic threshold, first occurrence of angina pectoris and/or ST-segment depression during stress test.

In the training group of 51 patients, 6 patients with clinical events and 2 dropouts were excluded; in the PCI group of 50 patients, 15 patients with clinical events and 2 dropouts were excluded. Data are mean±SEM.

\* $P$ <0.01, significantly different, 12 months vs baseline.

† $P$ <0.01, significantly different, exercise training vs PCI.

‡ $P$ <0.05, significantly different, 12 months vs baseline.

§ $P$ <0.001, significantly different, exercise training vs PCI.

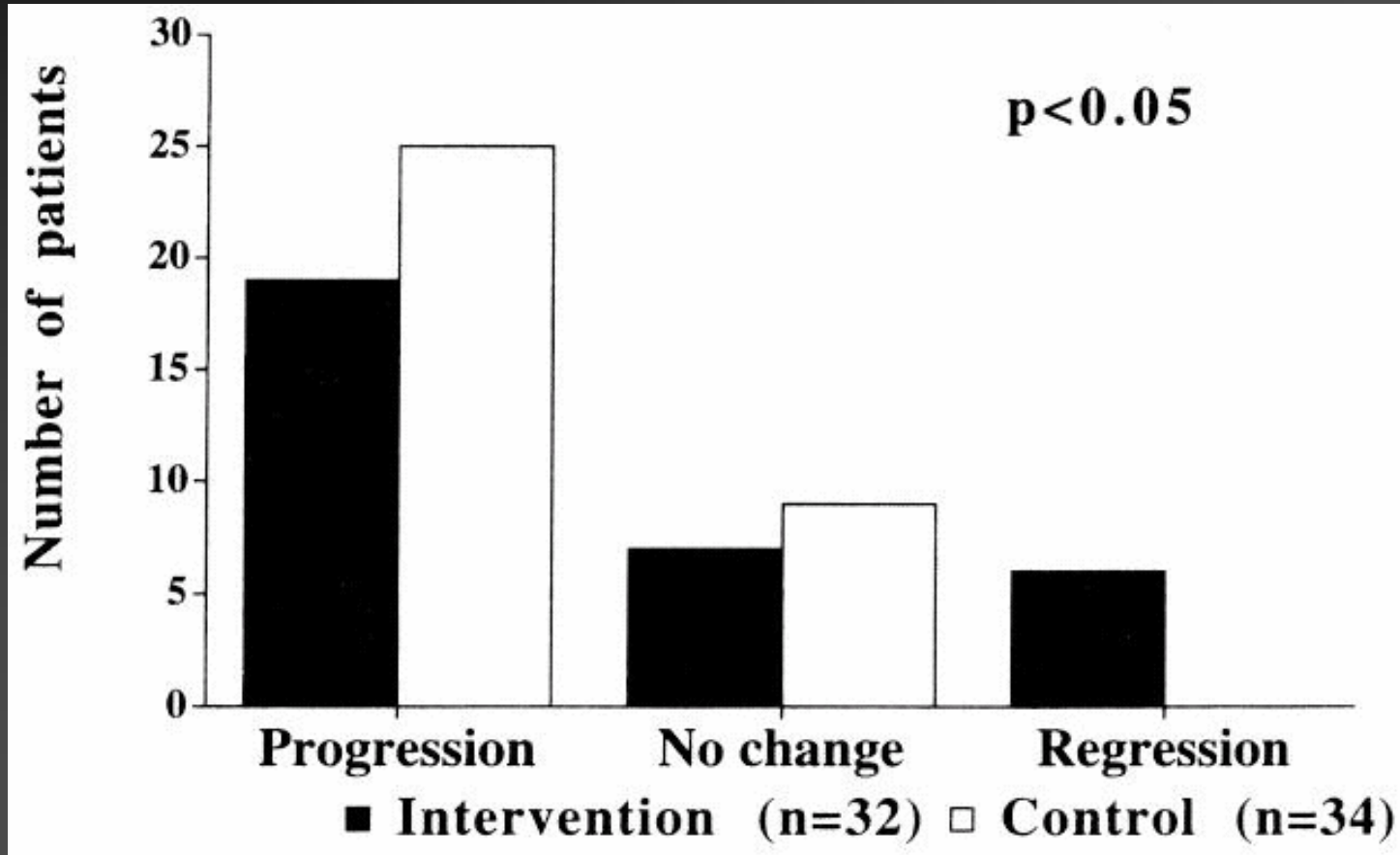
# Safety

- None of the more than three dozen randomized controlled trials of cardiac rehabilitation exercise training in patients with CHD, involving over 4,500 patients, described an increase in morbidity or mortality in rehabilitation compared with control patient groups.
- A survey of 142 cardiac rehabilitation programs in the United States, 1980 to 1984
  - Nonfatal myocardial infarction: 1 per 294,000 patient-hours
  - Cardiac mortality rate: 1 per 784,000 patient-hours
  - A total of 21 episodes of cardiac arrest occurred, with successful resuscitation of 17 patients.

# Mechanisms of benefits

- Favorable effects on risk factors such as hypertension, dyslipidemia, diabetes and obesity
- Effect on progression of atherosclerosis
- Improved endothelial function
- Anti-inflammatory effect
- Anti-ischemic effect & Ischemic preconditioning
- Favorable change in autonomic balance
- Anti-thrombotic and fibrinolytic effect

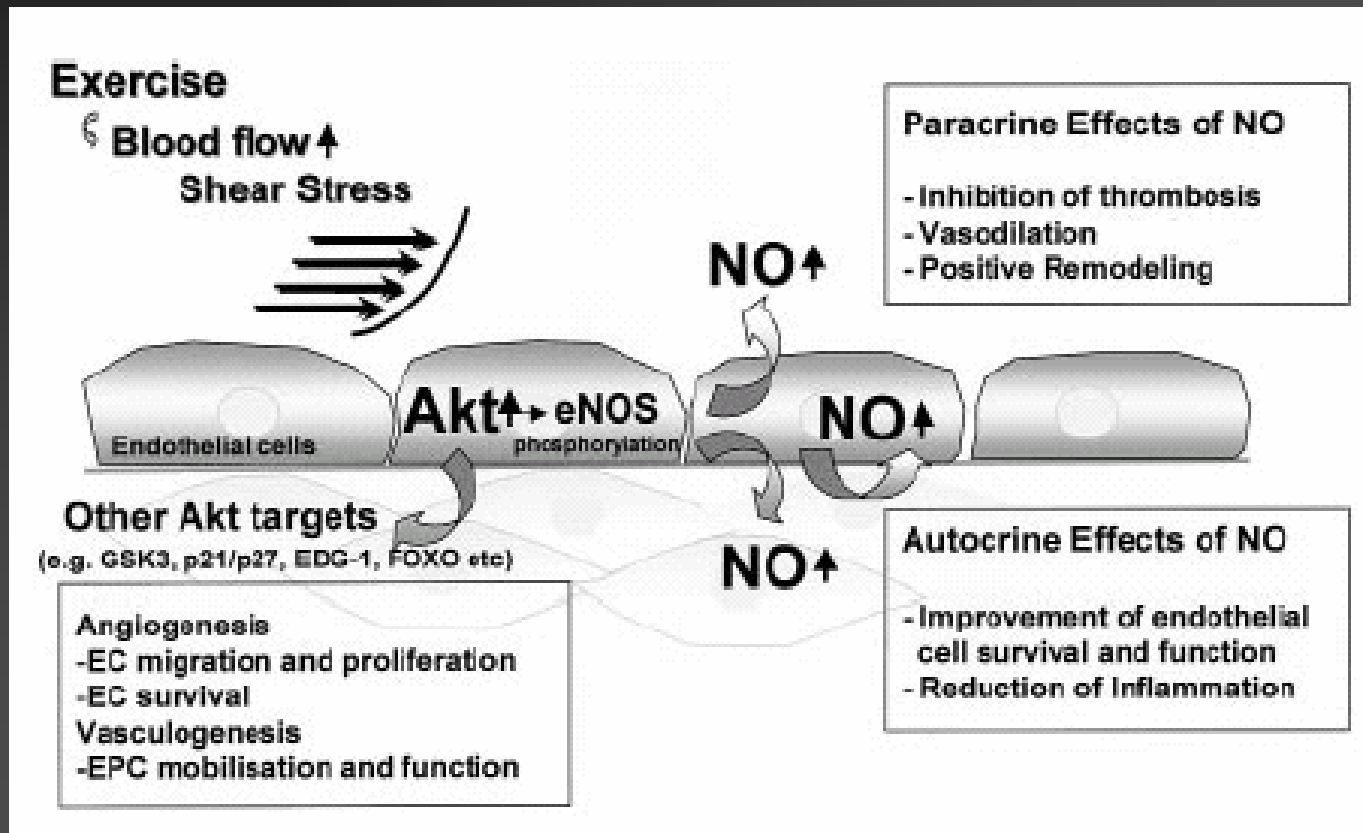
# Multi-factorial risk factor intervention and atherosclerosis progression



Niebauer J, Hambrecht R, Velich T, Hauer K, Marburger C, Kalberer B, Weiss C, von Hodenberg E, Schlierf G, Schuler G, Zimmermann R, Kubler W. Attenuated progression of coronary artery disease after 6 years of multifactorial risk intervention: role of physical exercise. *Circulation*. 1997;96:2534-41



# Effect on endothelial function



# Anti-inflammatory effect?

Time markers/group		Baseline (mean±SD)	8 weeks (mean±SD)	p*	p <sup>†</sup>
hs-CRP (mg/L)	CR	2.2±3.2	1.9±4.5	NS	0.683
	Control	2.1±1.9	1.4±1.1	NS	
IL-6 (pg/mL)	CR	2.3±3.3	2.2±2.9	NS	0.501
	Control	2.5±2.5	3.9±8.9	NS	
TNF- $\alpha$ (pg/mL)	CR	0.3±1.1	0.5±1.7	NS	0.0001 <sup>‡</sup>
	Control	0.6±0.7	0.1±0.3	NS	

\*: Wilcoxon Signed-rank test between pre and post test, †: Mann-Whitney test between CR and control group, ‡: p<0.05, hs-CRP: high sensitivity C-reactive protein, IL-6: interleukin-6, TNF- $\alpha$ : tissue necrosis factor alpha, SD: standard deviation

Korean Circulation J 2004;34(8):820-827

# Anti-ischemic effect

- Decreasing rate-pressure product and myocardial oxygen demands during physical exertion → raising the ischemic threshold
- Increase coronary flow by
  - improving coronary artery compliance or elasticity
  - Improved endothelium-dependent vasodilatation
  - increasing the luminal area of conduit vessels through remodeling or arteriogenesis and myocardial capillary density by angiogenesis.

# Ischemic preconditioning

- Transient myocardial ischemia enhances tolerance of the myocardium to subsequent more prolonged ischemic stress.
- Protective effect to ischemic myocardial damage and ventricular tachyarrhythmia

# Effect on autonomic balance

- Exercise training enhances parasympathetic (vagal) activity and reduces sympathetic activity
  - Increased heart rate variability
  - Reduced baroreceptor sensitivity.
- May decrease the risk of sudden cardiac death due to ventricular tachyarrhythmias

# Effects on thrombosis and fibrinolysis

- Anti-thrombotic effects
  - Increased plasma volume
  - Reduced blood viscosity
  - Decreased platelet aggregation
  - Enhanced thrombolytic ability.
- Enhanced fibrinolytic activity
  - Increasing the endothelial synthesis of tissue plasminogen activator and reducing the levels of its inhibitor, plasminogen activator inhibitor-1.73
  - Reduced plasma levels of fibrinogen.

# Future perspectives

- Wider application of the program
- Quality of life
- Elderly
- Non-hospital-based program

# Reason for underutilization

- Referral rate: only 10% to 20% of the 2 million eligible patients per year who experience an acute myocardial infarction or undergo coronary revascularization.
- Geographical maldistribution
- Failure of physicians to refer
  - Esp. for elderly, women and ethnic minority
- Reimbursement
- Poor patient motivation
- Lack of public awareness of its benefits



# Resistive training

- Mild-to-moderate resistive exercise training can safely and effectively improve both strength and cardiovascular endurance in low-risk coronary patients who can perform adequate levels of aerobic exercise
- Improves performance in a variety of tasks of daily living, in the workplace, and at leisure activities
- Provides diversity in the exercise regimen and may increase patient interest and adherence

# Low-intensity program

- Traditional target heart rate (THR): 70-85% of maximal HR
- THR of 50-70% of maximal HR
  - Comparable improvement in functional capacity and endurance
  - May provide greater safety during unsupervised exercise
  - Likely to promote long-term adherence to exercise
  - Increased applicability to and the acceptance of exercise training by larger numbers of coronary patients, particularly unfit and elderly patients and those with low exercise capacities

# Tai-chi



# Home-based program

- Reasonable alternative in relatively young low-risk patients
- Components
  - Regular clinic follow-up
  - Planned communication
  - Management by rehabilitation nurses and other specially trained personnel
  - Periodic trans-telephonic ECG monitoring
- Comparable (to conventional supervised program) improvements in functional capacity, without reported complications

# Community-based program

- Uses nurses or other non-physician healthcare providers.
- Local physicians as medical advisors
- Uses local community public facilities, e. g., public schools after student hours

# Corporate-based program

- Adolph Coors
- Boeing
- Advantages
  - Vocational counseling and job-specific training
  - Earlier return to work
  - Retention in the same job and avoidance of retraining
  - Development of primary prevention program

# Conclusion

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- Cardiac rehabilitation program is integrated preventive effort of **proven benefit and safety**.
- One of the most under-utilized preventive strategy, because of many non-medical factors
- Further efforts should be focused on the development of more widely applicable, comprehensive, and regionalized program.