Cardiac Rehabilitation: Building a Better Life After Heart Disease

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Overview

• Case Studies
• History of Cardiac Rehabilitation.
• Description of Programs.
• Evidence of Benefit.
Billion Dollar Heart Attack

65 y/o male executive, former smoker, experiences “indigestion” after playing 9 holes of golf in Denver

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9/24/1955: Personal Physician summoned at 0200 for chest pain. Given amyl nitrate, morphine and papaverine

Patient slept until 11:00 AM. Awoke with chest pain. ECG anterolateral MI.

Eisenhower’s Billion Dollar Heart Attack

Transferred from inlaw’s home to Fitzsimons Army Hospital

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Oxygen tent and strict bedrest for one month

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9/26/1955: stock market drops 6% ($14 billion, largest one-day drop since crash of 1929

Eisenhower’s Heart Attack 9/24/1955

attempted controversial armchair therapy, but abandoned

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10/11/1955: First allowed to see a cabinet minister

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10/22/1955: sitting in a chair only a few hours per day

Eisenhower’s Heart Attack 9/24/1955

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10/11/1955: First allowed to see a cabinet minister

10/22/1955: sitting in a chair only a few hours per day

11/7/1955: walking and starting to climb stairs

Eisenhower’s Heart Attack 9/24/1955

11/11/1955: Returned to Washington

International Cardiology Foundation, NYC
10/29/1963
Eisenhower’s Heart Attack 9/24/1955

11/11/1955: Returned to Washington

12/10/1955: First full day of work. Three hour midday break including a nap.
Eisenhower’s Heart Attack 9/24/1955

11/11/1955: Returned to Washington

12/10/1955: First full day of work. Three hour midday break including a nap.

2/17/1956: Played first round of golf.
Eisenhower’s Heart Attack 9/24/1955

11/11/1955: Returned to Washington

12/10/1955: First full day of work. Three hour midday break including a nap.

2/17/1956: Played first round of golf.

From first MI in 1955, until death in 1969, suffered additional 7 MIs, 14 cardiac arrests, spent the last 9 months in Walter Reed Hospital.

International Cardiology Foundation, NYC 10/29/1963

Tuesday, March 22, 2011
Heart Health Lessons from The Clinton Case

58 y/o cigar smoking, fast food eating, workaholic male

Clinton at “The Varsity”
Atlanta, 1996

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Five previous negative exercise stress tests, last in 2001 (reached Stage VI)

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2001: Tot chol 233, LDL 177, HDL 47, TG 52. Placed on simvastatin

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Atlanta, 1996
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2001: Tot chol 233, LDL 177, HDL 47, TG 52. Placed on simvastatin

Southbeach Diet, Lost 20 pounds. Stopped simvastatin. LDL 114

Clinton at “The Varsity”
Atlanta, 1996

Heart Health Lessons from The Clinton Case

Early 2004: Developed angina. Thought it was GERD


Clinton Book signing
8/31/2004
Heart Health Lessons from The Clinton Case

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9/2/2004: Evaluated for chest pain at Northern Westchester Hospital

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Heart Health Lessons from The Clinton Case

Early 2004: Developed angina. Thought it was GERD

9/2/2004: Evaluated for chest pain at Northern Westchester Hospital


Post angiogram: Ordered 4 scrambled eggs and 6 slices of bacon

Heart Health Lessons from The Clinton Case


Clinton Campaigning
Philadelphia, 10/24/2004

Heart Health Lessons from The Clinton Case


9/10/2004: D/ced to home. Completes Cardiac Rehab

Clinton Campaigning
Philadelphia, 10/24/2004
Heart Health Lessons from The Clinton Case


9/10/2004: Discharged to home. Completes Cardiac Rehab

10/24/2004: Returns to work

Clinton Campaigning Philadelphia, 10/24/2004
CARDIAC REHABILITATION IN THE OLD DAYS

do everything I tell you, when I tell you, and you’ll be alright
There is a disorder of the breast, marked with strong and peculiar symptoms, considerable for the kind of danger belonging to it, and not extremely rare, of which I do not recollect any mention among medical authors. The seat of it, and sense of strangling and anxiety with which it is attended, may make it not improperly be called Angina Pectoris.
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“I know one who set himself a task of sawing wood for half an hour every day, and was nearly cured”

William Heberden Angina Cure: ”Sawing Wood”

William Stokes-Pedestrian Cure

"the symptoms of debility of the heart are often removable by a regulated course of gymnastics, or by pedestrian exercise"

1804-1878

Stokes W. The diseases of the heart and the aorta. Dublin: Hodges & Smith, 1854.
"the symptoms of debility of the heart are often removable by a regulated course of gymnastics, or by pedestrian exercise"

His "pedestrian cure" consisted of comfortable walking initially on level ground, the distance and gradient being increased as tolerance improved—always, however, cautioning against excessive fatigue, breathlessness, or chest pain.

1804-1878

Stokes W. The diseases of the heart and the aorta. Dublin: Hodges & Smith, 1854.
1912: James B. Herrick described coronary thrombosis in MI. The concept “aroused no interest. It fell like a dud.”
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Recommend patients be managed with 2 months of bed rest.

Fear of aneurysm, CHF, LV rupture, SCD

Herrick JB. Clinical features of sudden obstruction of the coronary arteries. JAMA 1912;59:2015–2020
Extended Bed Rest Treatment

- 1930s Pathology of MI described.
  - 6 weeks from necrosis to scar.
  - Only non-strenuous exercise permitted for 6-8 weeks, post MI (no stairs).
- Few patients ever returned to work.
"Armchair" Treatment of Acute Coronary Thrombosis

"We believe that by getting patients with acute coronary thrombosis promptly out of bed and into a chair, we achieve more rest for the heart than it attained with traditional bed rest procedures."

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81 patients with acute coronary thrombosis received armchair treatment starting at day two of hospitalization. During hospitalization of 15-35 days there were 8 deaths (9.9%), but overall experience considered highly favorable, especially enhanced sense of well-being.

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rehabilitation-exercise cardiologist' was often described as being 'too aggressive,' 'too dangerous,' and even 'barbaric.'

CURRENT THERAPY

The Editorial Board invites your comment.

Rest in Myocardial Infarction*

It is generally agreed that rest is a mandatory adjunct in the treatment of acute myocardial infarction. Any injured body tissue is known to heal more rapidly if the part is kept at rest, and since the injured myocardium must obviously continue to work while it is healing, it seems only rational to keep the work load as light as possible by the avoidance of any activity which would call for an increased cardiac output. There are a few physicians who treat patients with acute infarctions on an ambulatory basis; however, we feel that this procedure definitely entails an increased risk to the patient, to say nothing of the increased risk to the doctor if the patient's family is at all inclined toward malpractice suits. The main points of contention in regard to rest in this disease involve the questions, where, how, and how long.

It is our policy to hospitalize all cases of established or "impending" myocardial infarction for a period at least long enough to permit thorough evaluation. Hospitalization facilitates closer observation of the patient which renders easier the classification into "good risk" or "poor risk." It is much easier to obtain the desired laboratory work including electrocardiograms in the hospital, adequate treatment is more readily obtained, and any complication is likely to be detected much earlier. Some physicians have advanced the argument that it is dangerous to move a patient with an acute infarct to a hospital, particularly if shock is present, but we maintain that the presence of shock is an additional strong reason for getting the patient into the hospital as quickly as possible. This statement is made on the assumption that adequate ambulance service is available, including attendants to carry the patient, and oxygen equipment. It is seldom, if ever, necessary for the ambulance to rush to the hospital at full speed with sirens screaming; most urban patients live within a few miles of a hospital, and the few minutes saved by rushing do not compensate for the increased discomfort to the patient. In the case of the rural population, it is probably true that very long ambulance trips should be avoided even if the patient must be treated in the home. This is becoming less of a problem, however, as more hospitals are being constructed in the smaller communities.

If a patient is established as a good risk case, he may be treated in the home after one or two weeks in the hospital, but if he is considered a bad risk or if any complication develops, he is kept in the hospital for four weeks or longer if necessary. We also keep all patients receiving anticoagulants in the hospital for the duration of such therapy. We have found that the desired degree of rest is often more readily and more uniformly enforced in the hospital: on one occasion one of us was unable to see a patient with an acute infarction when a visit was made to his home at an unexpected time because he was out for a ride!

Our patients with acute coronary occlusion are kept at bed rest from three to six weeks depending upon the severity of the case. The presence of the factors enumerated by Russek and others which cause the patient to be classified as a bad risk will generally keep him in bed longer. On the other hand, the good risk patient is often allowed to use a bedside commode for bowel movements provided he is assisted, and he remains in bed a shorter length of time. During the first two weeks after onset we are more conservative in regard to rest even when dealing with the good risk patient; this period is regarded as a crucial one in the course of this disease. We agree with White that undue activity increases the incidence of ventricular rupture during the first two weeks, and while a certain number of patients will expire in this period regardless of the treatment employed, it is better for them to die in bed than on the floor.

Since Levine's advocacy of the "chair treatment" for myocardial infarction, there has been considerable discussion concerning this type of rest. We feel that the argument of bed rest versus chair rest is more apparent than real: there is little difference between our patient with the head of his bed elevated and the foot lowered and the patient sitting in a chair. We do not favor the chair rest because of the increased demands upon hospital personnel that lifting the patient in and out of bed entails; also, if a patient thinks he is well enough to sit in a chair, he may tend to think he is well enough to walk about or to do other things that he should not be doing. It should be noted that in most instances hospital bed rest is far from the "absolute bed rest" that is commonly ordered: most patients will move about in bed considerably; in fact, if they do not do so of their own accord, they should be encouraged to at least exercise their arms and legs to some extent. This of course does not apply to patients in shock or to those with extreme chest pain. In regard to the latter, we doubt that others would get these patients up in a chair, either.

It has been claimed that extended bed rest is harmful because it favors the development of thromboembolic phenomena. Our experience lends no support to this thesis; rather, it tends to disprove it. In our series of 386 cases of acute myocardial infarction treated with relatively strict bed rest, and without anticoagulants, thromboembolic phenomena occurred in eight (2 per cent). Thrombophlebitis and phlebothrombosis have been extremely rare in our acute coronary patients, whether they received anticoagulants or not.

Diet has a bearing upon the ratio of cardiac rest to cardiac work, and this aspect of diet seems appropriate for inclusion in this discussion, even though the broader subject of diet in coronary disease is beyond the scope of this paper. It is well known that during the digestive process the supply of blood to the organs of digestion is increased to a considerable ex-

*From the Departments of Medicine, Divisions of Cardiology, Ohio State University College of Medicine and White Cross Hospital, Columbus, Ohio.
Get out of Bed!

- 1950s: ambulation advocated.
  - 3-5 minutes of walking 2x/day.
  - Starting 4 weeks post MI.
- **1956**: 1st report of ambulation within 14 days of AMI.
Rehabilitation of the Patient with Acute Myocardial Infarction

Patients transferred after two weeks of hospitalization to Cardiac Rehabilitation Section. Program included:

- Low fat and salt diet
- Smoking discourage
- Medications to reduce anxiety
- Psychological testing & counseling
- Exercise tolerance test on treadmill, physical conditioning
- Weight reduction
- Vasodilators used
- Vocational rehabilitation

Program considered successful - the average hospital stay of 89 days was not felt to be excessive.

Dallas Bed Rest and Training Study
1966, 1996

5 college age males
3 weeks bed rest
diet controlled
no weight gain

30 years later
body fat 13.9 to 28%

### Table 4. Results of Maximal Treadmill Exercise Test: Group Averages

<table>
<thead>
<tr>
<th></th>
<th>1966 Baseline</th>
<th>1966 After Bedrest</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\dot{\text{VO}_2}) max, L/min</td>
<td>3.3 (1.1)</td>
<td>2.4 (1.0)</td>
<td>2.9 (0.7)</td>
</tr>
<tr>
<td>(\dot{\text{VO}_2}) max, mL/kg lean body mass per min</td>
<td>49.7 (10.9)</td>
<td>37.4 (11.4)</td>
<td>42.9 (9.5)</td>
</tr>
<tr>
<td>(\dot{\text{VO}_2}) max, mL (\times) kg(^{-1}) \times) min(^{-1})</td>
<td>43.0 (10.9)</td>
<td>31.8 (11.1)</td>
<td>31.0 (7.6)</td>
</tr>
<tr>
<td>(\text{CO}), L/m</td>
<td>20.0 (4.1)</td>
<td>14.8 (4.8)</td>
<td>21.4 (5.1)</td>
</tr>
<tr>
<td>HR, bpm</td>
<td>193 (8)</td>
<td>197 (7)</td>
<td>181 (16)</td>
</tr>
<tr>
<td>SV, mL</td>
<td>104 (22)</td>
<td>75 (22)</td>
<td>121 (39)</td>
</tr>
<tr>
<td>AVDO(_2) max, mL O(_2)/100 mL blood</td>
<td>16.2 (2.3)</td>
<td>16.4 (3.2)</td>
<td>13.8 (2.0)</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>204 (49)</td>
<td>153 (42)</td>
<td>206 (23)</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>81 (9)</td>
<td>63 (16)</td>
<td>96 (22)</td>
</tr>
<tr>
<td>Mean arterial pressure, mm Hg</td>
<td>122 (21)</td>
<td>93 (24)</td>
<td>133 (15)</td>
</tr>
<tr>
<td>Total peripheral resistance, dyne (\times) sec(^{-1}) \times) cm(^{-5})</td>
<td>484 (72)</td>
<td>525 (148)</td>
<td>519 (138)</td>
</tr>
</tbody>
</table>

Values are averages (SD).
Changes in CO, VO$_2$ max
Historical Perspective

  - LOS falls from 14-10 days following AMI.
  - 6-7 days by the early 1990s.
  - 3-4 days, currently.
- 1980s-1990s: cardiac rehab programs designed to comprehensively reduce risk develop.
What is Cardiac Rehabilitation?

"... the sum of activity required to ensure cardiac patients the best possible physical, mental and social conditions so that they may, by their own effort, regain as normal a place in the community, and lead an active life."

World Health Organization, 1964
Goals of Cardiac Rehab

- Identify, modify, and manage risk factors to reduce disability/morbidity & mortality
- Improve functional capacity
- Alleviate/lessen activity related symptoms
- Educate patients about the management of heart disease
- Improve quality of life
Core Program Components

- baseline patient assessment
- nutritional counseling
- risk factor assessment
- psychosocial management
- physical activity counseling
- exercise training

Organizations Advocating CR

- World Health Organization
- American Heart Association
- American College of Cardiology
- Agency for Health Care Policy & Research
- National Institutes of Health
- American College of Physicians
- American Geriatrics Society
Indications (requires physician referral)

- MI in the last 12 months
- PTCA or coronary stenting
- CABG
- Stable angina pectoris
- Heart valve repair/replacement
- Heart or heart-lung transplant
- CHF
- PVOD
- CVD
- ICD placement/arrhythmia
- Multiple CAD risk factors

Covered by Medicare
Contraindications

- USA
- HCM
- dissecting aneurysm
- high grade AV block, severe cardiac arrhythmia
- acute myocarditis
- severe pulmonary hypertension
- LV thrombus
- uncontrolled diabetes
- severe hypertension (SBP > 200 mm Hg)
- large pericardial effusion
- decompensated CHF
Description of Programs

Phase I

- Inpatient–hospital clinical pathway

Phase II

- Transition care–subacute facility, home care, pretraining at home
- Outpatient programming–cardiac rehabilitation center

Phase III

- Maintenance, lifelong, community facility or at home
Phase I: In hospital.

- Patient referred, visited by Rehabilitation/Preventive Cardiology Specialist (often a nurse).
- Education about RF modification begins.
  - HTN, Lipids, DM, Obesity, Activity, Psycho-social.
  - Smoking Cessation Addressed.
- Supervised Activity begun (PT & OT)
  - Self-care activities, ROM.
  - Lying-->sitting-->standing-->ambulating
Goals for Phase I

- limit loss of functional capacity.
- begin risk factor assessment & reduction.
- progression of activity, increase ADLs.
- training for progression to home walking program.
- referral for Phase II.
Phase II: Monitored Exercise

- History and Physical Exam.
- Risk Factor (Re-)assessment (Lipid Panel, BP, Smoking Hx, BMI, DM, Psychosocial).
- ECG at rest and with exercise.
- Vocational Counseling.
- Goal: Formulate comprehensive plan for risk reduction.
- Communicate/discuss plan to/with PCP.

Tuesday, March 22, 2011
Exercise Component

- 36 sessions typically 3x/wk over 3 months
- goal of 45 minutes aerobic conditioning at 60-70% MHR
  - treadmills
  - stationary bikes/airdyne.
  - recumbent bikes
  - recumbent steppers
- free weights strength training 30 min

Tuesday, March 22, 2011
Safety

- Cardiac Arrest: 1/112,000 pt.-hrs.
- Non-fatal MI: 1/294,000 pt.-hrs.
- Mortality: 1/784,000 pt.-hrs.

Phase III: “Maintenance”

- community & home-based programs.
- Kaiser Multifit
- Stanford Expert Patient Program
Benefits of Exercise
Cardiac Rehab Benefits

- Improvements in exercise capacity (exercise time, peak $O_2$ consumption, ADLs).
Cardiac Rehab Benefits

- Improvements in exercise capacity (exercise time, peak $O_2$ consumption, ADLs).
- Increases angina threshold/reduces myocardial oxygen demand.
Cardiac Rehab Benefits

- Improvements in exercise capacity (exercise time, peak O\textsubscript{2} consumption, ADLs).
- Increases angina threshold/reduces myocardial oxygen demand.
- Increases in stroke work, cardiac output, and LV function.
Cardiac Rehab Benefits

- Improvements in exercise capacity (exercise time, peak $O_2$ consumption, ADLs).
- Increases angina threshold/reduces myocardial oxygen demand.
- Increases in stroke work, cardiac output, and LV function.
- Increases in skeletal muscle capillary density, improvements in endothelial-dependent vasodilation
Cardiac Rehab Benefits

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• Improved collateral circulation.
Cardiac Rehab Benefits

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- Improved collateral circulation.
- Body composition changes.
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- Increased HR variability and autonomic tone.
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- Increases in skeletal muscle capillary density, improvements in endothelial-dependent vasodilation.
- Improved collateral circulation.
- Body composition changes.
- Increased HR variability and autonomic tone.
- Reduced BP and improved lipid profile.
Exercise and Atheroprotection; proposed effects mediated by Akt and NO

Exercise leads to increased blood flow and shear stress, which stimulates Akt and eNOS phosphorylation. This results in an increase in NO production. NO has both paracrine and autocrine effects:

**Paracrine Effects of NO**
- Inhibition of thrombosis
- Vasodilation
- Positive Remodeling

**Autocrine Effects of NO**
- Improvement of endothelial cell survival and function
- Reduction of inflammation

Other Akt targets include angiogenesis, EC migration and proliferation, EC survival, vasculogenesis, and EPC mobilisation and function.


Tuesday, March 22, 2011
Exercise training increases eNOS

<table>
<thead>
<tr>
<th></th>
<th>Training Group (n=17)</th>
<th>Control Group (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>64±4</td>
<td>65±8</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>63±8</td>
<td>66±8</td>
</tr>
<tr>
<td>LVEDD, mm</td>
<td>50±4</td>
<td>50±8</td>
</tr>
<tr>
<td>Previous MI, n</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>No. of affected coronary vessels (2/3), n</td>
<td>6/11</td>
<td>7/11</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>28.0±2.8</td>
<td>28.0±2.9</td>
</tr>
<tr>
<td>Serum glucose, mmol/L</td>
<td>5.8±1.2</td>
<td>5.9±0.8</td>
</tr>
</tbody>
</table>

LVEF indicates left ventricular ejection fraction; LVEDD, left ventricular end diastolic diameter; MI, myocardial infarction; and BMI, body mass index. Data presented are mean ±SD or total number.

No significant difference for all parameters between the 2 groups was detected.
Exercise training increases mRNA and protein expression of eNOS and Ser1177 phospho-eNOS.

LIMA samples at time of CABG
4 weeks pre-op daily exercise

Exercise training increases pAkt at Ser473 in the LIMA of patients with CAD.
Exercise Increases Circulating Endothelial Progenitor Cells

Patient Characteristics (n=19)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>70.1±7.7</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>9/10</td>
</tr>
<tr>
<td>BMI, kg/m^2</td>
<td>27.5±4.5</td>
</tr>
<tr>
<td>Laboratory tests</td>
<td></td>
</tr>
<tr>
<td>CRP, U/L</td>
<td>5.38±1.43</td>
</tr>
<tr>
<td>Creatinine, mg/dL</td>
<td>0.89±0.34</td>
</tr>
<tr>
<td>Cholesterol, mg/dL</td>
<td>154.9±35.78</td>
</tr>
<tr>
<td>LDL, mg/dL</td>
<td>89.2±28.8</td>
</tr>
<tr>
<td>HDL, mg/dL</td>
<td>44.0±11.82</td>
</tr>
<tr>
<td>Triglycerides, mg/dL</td>
<td>116.3±46.6</td>
</tr>
<tr>
<td>Leukocytes, x10^12/L</td>
<td>5.86±1.80</td>
</tr>
<tr>
<td>Hemoglobin, g/dL</td>
<td>12.9±0.90</td>
</tr>
<tr>
<td>Medication, %</td>
<td></td>
</tr>
<tr>
<td>Aspirin</td>
<td>89.5</td>
</tr>
<tr>
<td>β-Blockers</td>
<td>94.7</td>
</tr>
<tr>
<td>ACE-I/AT1-I</td>
<td>89.5</td>
</tr>
<tr>
<td>Calcium antagonists</td>
<td>31.6</td>
</tr>
<tr>
<td>Statins</td>
<td>78.9</td>
</tr>
<tr>
<td>Diuretics</td>
<td>31.6</td>
</tr>
<tr>
<td>Digitalis</td>
<td>5.3</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>5.3</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; CRP, C-reactive protein; and AT1-I, angiotensin II type 1 receptor.

4 weeks
bicycle ergometer and walking
moderate muscle strength training
heart rate goal 60% to 80% of VO_2 max
VO 9.58±4.0 to 11.8±5.80 kg/mL (P<0.05)
6-minute walking 357±98 to 422±112 m (P<0.05)

Evidence of Benefits
Coronary Artery Disease
### Effects of Exercise-Based Cardiac Rehabilitation on Study End Points*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Mean Difference, %</th>
<th>95% Confidence Limit</th>
<th>Statistical Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mortality</td>
<td>–20</td>
<td>–7% to –32%</td>
<td>P=0.005</td>
</tr>
<tr>
<td>Cardiac mortality</td>
<td>–26</td>
<td>–10% to –29%</td>
<td>P=0.002</td>
</tr>
<tr>
<td>Nonfatal MI</td>
<td>–21</td>
<td>–43% to 9%</td>
<td>P=0.150</td>
</tr>
<tr>
<td>CABG</td>
<td>–13</td>
<td>–35% to 16%</td>
<td>P=0.400</td>
</tr>
<tr>
<td>PTCA</td>
<td>–19</td>
<td>–51% to 34%</td>
<td>P=0.400</td>
</tr>
</tbody>
</table>

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.

*Data are derived from Taylor et al.²

- **48 Trials; 8940 patients.**
- **Duration of intervention 0.25-30 months (median 3 mo.).**
- **Follow-up 6-72 months (median 15 months).**
- **67% s/p MI, remainder s/p CABG or PCI.**

Event-free Survival after 12 months Significantly Superior in Exercise Training Group vs PCI Group

101 pts, ≤ 70 y/o
CCS 1-3
≥ 70% stenosis
inducible ischemia
no ACS, recent PCI/CABG

88% Ex
70% PCI

Event-free Survival after 12 months Significantly Superior in Exercise Training Group vs PCI Group

101 pts, ≤ 70 y/o
CCS 1-3
≥ 70% stenosis
inducible ischemia
no ACS, recent PCI/CABG

Ischemic events
repeat PCI, MI, CABG
angina hospitalization

Event-free Survival after 12 months Significantly Superior in Exercise Training Group vs PCI Group


101 pts, ≤ 70 y/o
CCS 1-3
≥ 70% stenosis
inducible ischemia
no ACS, recent PCI/CABG

Ischemic events
repeat PCI, MI, CABG
angina hospitalization

Exercise: 20 min daily bicycle
ergometry (70% MHR) vs. PCI:
$3429 vs. $6956 to gain 1 CCS class
VO_2 max +16% (22.7±0.7 to 26.2±0.8 mL O_2/kg/min)
P<0.001 versus baseline

Tuesday, March 22, 2011
Prevalence of adverse behavioral characteristics in young and elderly patients with coronary artery disease at baseline

<table>
<thead>
<tr>
<th></th>
<th>Young Patients (n=104)</th>
<th>Elderly Patients (n=260)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression</td>
<td>23%</td>
<td>19%</td>
</tr>
<tr>
<td>Anxiety</td>
<td>28%</td>
<td>14%</td>
</tr>
<tr>
<td>Hostility</td>
<td>13%</td>
<td>5%</td>
</tr>
</tbody>
</table>


Tuesday, March 22, 2011
## Changes in risk factors in younger patients after rehabilitation program

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Change after rehabilitation program (%)</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>% body fat</td>
<td>-4.4</td>
<td>0.001</td>
</tr>
<tr>
<td>Body mass index</td>
<td>-1.7</td>
<td>0.01</td>
</tr>
<tr>
<td>HDL</td>
<td>+10.2</td>
<td>0.001</td>
</tr>
<tr>
<td>CRP</td>
<td>-33</td>
<td>0.01</td>
</tr>
<tr>
<td>Resting heart rate</td>
<td>-4.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Resting systolic pressure</td>
<td>-2.3</td>
<td>0.049</td>
</tr>
<tr>
<td>Depression score</td>
<td>-58</td>
<td>0.001</td>
</tr>
<tr>
<td>Anxiety score</td>
<td>-46</td>
<td>0.001</td>
</tr>
<tr>
<td>Hostility</td>
<td>-46</td>
<td>0.001</td>
</tr>
<tr>
<td>Quality of life</td>
<td>+15.8</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Congestive Heart Failure
Exercise & CHF

• CR for CHF currently not covered by Medicare and many insurance plans.

• 1970s & 80s. Safety of exercise in those w/ LV dysfunction established.

• Benefits.
  • Peripheral skeletal muscle changes.
  • Decreased lactate production.
  • Improved aerobic capacity.
Cochrane Collaboration

- Increases in:
  - $\text{VO}_2\text{max}$ by 2.16 ml/kg/min (95% CI 2.82 to 1.49).
  - Greater improvements with higher intensity & duration.
  - Exercise duration by 2.38 min (95% CI 2.85 to 1.9)
  - Work capacity by 15.1 Watts (95% CI 17.7 to 12.6).
  - 6-minute walk distance by 40.9 m (95% CI 64.7 to 17.1).
  - HRQoL (7 of 9 trials).
Table 2
Characteristics of patients included in meta-analysis. Values are numbers (percentages) unless indicated otherwise.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Training (n=395)</th>
<th>Control (n=406)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>88.4</td>
<td>87.2</td>
</tr>
<tr>
<td>Mean (SD) age (years)</td>
<td>60.5 (9.3)</td>
<td>59.7 (13.2)</td>
</tr>
<tr>
<td>Mean (SD) NYHA class</td>
<td>2.6 (0.6)</td>
<td>2.5 (0.6)</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>59.7</td>
<td>58.7</td>
</tr>
<tr>
<td>Mean (SD) left ventricular ejection fraction (%)</td>
<td>27.9 (8.3)</td>
<td>27.0 (8.6)</td>
</tr>
<tr>
<td>Mean (SD) peak oxygen uptake (ml/kg/min)</td>
<td>15.4 (4.0)</td>
<td>15.2 (3.9)</td>
</tr>
<tr>
<td>Mean (SD) renal function (laboratory findings)†:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum creatinine (mg/dL)</td>
<td>1.4 (0.4)</td>
<td>1.4 (0.5)</td>
</tr>
<tr>
<td>Urea (mg/dL)</td>
<td>61.3 (40)</td>
<td>63.7 (38)</td>
</tr>
<tr>
<td>Drugs‡:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angiotensin converting enzyme inhibitors</td>
<td>73.4</td>
<td>73.2</td>
</tr>
<tr>
<td>Anticoagulant</td>
<td>40.0</td>
<td>36.9</td>
</tr>
<tr>
<td>Aspirin</td>
<td>30.1</td>
<td>30.8</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>10.9</td>
<td>12.8</td>
</tr>
<tr>
<td>β adrenergic blockade</td>
<td>12.2</td>
<td>14.5</td>
</tr>
<tr>
<td>Digitalis</td>
<td>50.4</td>
<td>47.8</td>
</tr>
<tr>
<td>Diuretics</td>
<td>68.9</td>
<td>69.5</td>
</tr>
<tr>
<td>Nitrate</td>
<td>40.0</td>
<td>31.0</td>
</tr>
</tbody>
</table>

NYHA=New York Heart Association.
† Renal function known for 146 patients.
‡ Drugs known for 655 patients.
ExTraMatch-Collaborative Meta-analysis of Exercise in CHF

395 exercise training, 406 controls
9 randomized trials
exercise range 8 weeks to one year
typically 30 min/3x/wk at 60-70% MHR

Patients
Mean age 59
88% male
Mean NYHA 2.5
LVEF 27%
59% ischemic
VO₂ max 15 ml/kg/min

BMJ 2004;328:189

Tuesday, March 22, 2011
**Effect of Exercise Training on Mortality**

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th>Control</th>
<th>Hazard ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No of events / No at risk</td>
<td>No of events / No at risk</td>
<td>Death</td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>79/349</td>
<td>95/354</td>
<td>0.60 (0.41 to 0.87)</td>
<td>7.30</td>
</tr>
<tr>
<td>Female</td>
<td>9/46</td>
<td>10/52</td>
<td>1.17 (0.41 to 3.34)</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥60 years</td>
<td>52/202</td>
<td>65/205</td>
<td>0.64 (0.41 to 0.99)</td>
<td>3.97</td>
</tr>
<tr>
<td>&lt;60 years</td>
<td>36/193</td>
<td>40/201</td>
<td>0.65 (0.36 to 1.18)</td>
<td>2.02</td>
</tr>
<tr>
<td><strong>Functional Class</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NYHA I-II</td>
<td>45/206</td>
<td>43/206</td>
<td>0.69 (0.40 to 1.20)</td>
<td>1.75</td>
</tr>
<tr>
<td>NYHA III-IV</td>
<td>43/189</td>
<td>62/200</td>
<td>0.63 (0.40 to 0.99)</td>
<td>4.03</td>
</tr>
<tr>
<td><strong>Cause</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischaemic</td>
<td>54/256</td>
<td>75/253</td>
<td>0.54 (0.35 to 0.83)</td>
<td>7.78</td>
</tr>
<tr>
<td>Non ischaemic</td>
<td>34/130</td>
<td>30/153</td>
<td>0.63 (0.35 to 1.20)</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Left Ventricular Ejection Fraction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥27%</td>
<td>38/193</td>
<td>36/187</td>
<td>0.83 (0.45 to 1.50)</td>
<td>0.40</td>
</tr>
<tr>
<td>&lt;27%</td>
<td>50/202</td>
<td>69/219</td>
<td>0.59 (0.38 to 0.92)</td>
<td>5.54</td>
</tr>
<tr>
<td><strong>Peak Oxygen Consumption</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥15 ml/kg/min</td>
<td>36/177</td>
<td>32/173</td>
<td>0.74 (0.39 to 1.40)</td>
<td>0.86</td>
</tr>
<tr>
<td>&lt;15 ml/kg/min</td>
<td>52/218</td>
<td>73/233</td>
<td>0.63 (0.42 to 0.96)</td>
<td>4.59</td>
</tr>
<tr>
<td><strong>Duration of Training</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥28 weeks</td>
<td>41/216</td>
<td>60/219</td>
<td>0.64 (0.41 to 0.99)</td>
<td>4.08</td>
</tr>
<tr>
<td>&lt;28 weeks</td>
<td>47/179</td>
<td>45/187</td>
<td>0.66 (0.37 to 1.19)</td>
<td>1.88</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>88/395</td>
<td>105/406</td>
<td>0.65 (0.46 to 0.92)</td>
<td>5.92</td>
</tr>
</tbody>
</table>

Exercise better vs Exercise worse: .65 (.46 to .92)

BMJ 2004;328:189

Tuesday, March 22, 2011
2331 Patient randomized control trial of exercise training in patients with heart failure

- Sponsored by NIH/NHLBI (~$40 million direct cost)
- Randomized to exercise training or usual care
- Primary endpoint of all-cause mortality over 30 months of follow up

Protocol

- 36-Facility based training sessions.
- Home exercise & periodic facility sessions.
- CPX Testing: Baseline, 3 mo., 12 mo., 24 mo.
- QoL, Depression, Cost Data.

HF-Action, cont.

- Hypotheses.
  - 20% lower death rate and hospitalization.
  - Non-zero rate of exercise related complications.
  - Improved exercise tolerance ($\text{VO}_2\text{max}$, ventilatory threshold, 6 min walk).
  - Improved HRQoL.

Baseline Characteristics

- LV Systolic Dysfunction. Class II-IV.
- Trial length: 2 years.
- Randomized: Usual care or Usual care + Exercise Training.

adjusted for exercise duration, LVEF, Beck Depression, afib/flutter

Secondary Endpoint

adjusted for exercise duration, LVEF, Beck Depression, afib/flutter

### Table 3. Clinical Events

<table>
<thead>
<tr>
<th>Event</th>
<th>No. (%) of Patients</th>
<th>HR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause mortality or all-cause hospitalization (primary end point)</td>
<td>796 (68)</td>
<td>0.93 (0.84-1.02)</td>
<td>.13</td>
</tr>
<tr>
<td>Cardiovascular mortality or cardiovascular hospitalization</td>
<td>677 (58)</td>
<td>0.92 (0.83-1.03)</td>
<td>.14</td>
</tr>
<tr>
<td>Cardiovascular mortality or heart failure hospitalization</td>
<td>393 (34)</td>
<td>0.87 (0.75-1.00)</td>
<td>.06</td>
</tr>
<tr>
<td>Cardiovascular mortality or heart failure hospitalization or cardiac transplantation or left ventricular assist device</td>
<td>403 (34)</td>
<td>0.87 (0.75-1.00)</td>
<td>.06</td>
</tr>
<tr>
<td>All-cause mortality, all-cause hospitalization, emergency department visit, or urgent clinic visit for heart failure exacerbation</td>
<td>906 (77)</td>
<td>0.99 (0.90-1.08)</td>
<td>.79</td>
</tr>
<tr>
<td>All-cause mortality</td>
<td>198 (17)</td>
<td>0.96 (0.79-1.17)</td>
<td>.70</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td>143 (12)</td>
<td>0.92 (0.74-1.15)</td>
<td>.47</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; HR, hazard ratio.  
*Follow-up data forms were not available for 1 patient.

### Change in Exercise

**Table 4.** Change in 6-Minute Walk Test and Cardiopulmonary Exercise Test Results

<table>
<thead>
<tr>
<th></th>
<th>Median (IQR)</th>
<th>Exercise Training</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Usual Care</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Baseline to 3 mo</strong>a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of 6-minute walk, m (n = 1835)</td>
<td>5 (−28 to 37)</td>
<td>20 (−15 to 57)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cardiopulmonary exercise time, min (n = 1914)</td>
<td>0.3 (−0.6 to 1.4)</td>
<td>1.5 (0.3 to 3.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Peak oxygen consumption, mL/kg/min (n = 1870)</td>
<td>0.2 (−1.2 to 1.4)</td>
<td>0.6 (−0.7 to 2.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Baseline to 12 mo</strong>b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of 6-minute walk, m (n = 1444)</td>
<td>12 (−30 to 55)</td>
<td>13 (−28 to 61)</td>
<td>.26</td>
</tr>
<tr>
<td>Cardiopulmonary exercise time, min (n = 1476)</td>
<td>0.2 (−1.0 to 1.7)</td>
<td>1.5 (0 to 3.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Peak oxygen consumption, mL/kg/min (n = 1442)</td>
<td>0.1 (−1.5 to 1.8)</td>
<td>0.7 (−1.0 to 2.5)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range.

a Complete case analysis. Expected 2284 patients at 3 months.

b Complete case analysis. Expected 2159 patients at 12 months.

### Subgroups

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>No. of Patients</th>
<th>No. of Events</th>
<th>Hazard Ratio (95% CI)</th>
<th>Favors Exercise</th>
<th>Favors Usual Care</th>
<th>P Value for Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>2331</td>
<td>1555</td>
<td>0.93 (0.84-1.02)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>≤70</td>
<td>1896</td>
<td>1226</td>
<td>0.92 (0.82-1.03)</td>
<td></td>
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</tr>
<tr>
<td>&gt;70</td>
<td>435</td>
<td>329</td>
<td>0.96 (0.78-1.20)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>661</td>
<td>420</td>
<td>0.83 (0.68-1.00)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1670</td>
<td>1135</td>
<td>0.97 (0.87-1.09)</td>
<td></td>
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<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Black or African American</td>
<td>749</td>
<td>523</td>
<td>0.95 (0.80-1.12)</td>
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<tr>
<td>White</td>
<td>1426</td>
<td>926</td>
<td>0.94 (0.83-1.07)</td>
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<tr>
<td>Other</td>
<td>121</td>
<td>84</td>
<td>0.86 (0.56-1.33)</td>
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<tr>
<td>Etiology of heart failure</td>
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<tr>
<td>Ischemic</td>
<td>1197</td>
<td>834</td>
<td>0.94 (0.82-1.08)</td>
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<tr>
<td>Nonischemic</td>
<td>1134</td>
<td>721</td>
<td>0.91 (0.78-1.05)</td>
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<tr>
<td>Baseline NYHA class</td>
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<td></td>
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</tr>
<tr>
<td>II</td>
<td>1477</td>
<td>907</td>
<td>0.95 (0.83-1.08)</td>
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<tr>
<td>III/IV</td>
<td>854</td>
<td>648</td>
<td>0.85 (0.73-1.00)</td>
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<tr>
<td>LVEF, %</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>≤25</td>
<td>1217</td>
<td>865</td>
<td>0.94 (0.83-1.08)</td>
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<tr>
<td>&gt;25</td>
<td>1110</td>
<td>687</td>
<td>0.91 (0.78-1.06)</td>
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<tr>
<td>Previous revascularization</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>No</td>
<td>1428</td>
<td>925</td>
<td>0.94 (0.83-1.07)</td>
<td></td>
<td></td>
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<tr>
<td>Yes</td>
<td>903</td>
<td>630</td>
<td>0.90 (0.77-1.06)</td>
<td></td>
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<tr>
<td>History of MI</td>
<td></td>
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<tr>
<td>No</td>
<td>1352</td>
<td>869</td>
<td>0.91 (0.79-1.03)</td>
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<tr>
<td>Yes</td>
<td>979</td>
<td>666</td>
<td>0.96 (0.82-1.11)</td>
<td></td>
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<tr>
<td>ACE inhibitor use at baseline</td>
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<td></td>
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</tr>
<tr>
<td>No</td>
<td>595</td>
<td>415</td>
<td>0.81 (0.67-0.99)</td>
<td></td>
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</tr>
<tr>
<td>Yes</td>
<td>1736</td>
<td>1140</td>
<td>0.97 (0.87-1.09)</td>
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<td>β-Blocker use at baseline</td>
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<tr>
<td>No</td>
<td>128</td>
<td>94</td>
<td>1.08 (0.72-1.62)</td>
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<tr>
<td>Yes</td>
<td>2203</td>
<td>1461</td>
<td>0.91 (0.83-1.01)</td>
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</table>

Benefits to Payers

- Reduction of subsequent morbidity and mortality rates for CAD
- Disease management intervention
- Reduced office visits and hospitalizations
- Case management system of care


Ades, P.A. and Coello, C.E.  Effects of exercise and cardiac rehabilitation outcomes.
Benefits to Payers

• Cost effectiveness
  – Studies, adjusted for quality of life, show savings of $4,950 - $9,200 per year of life saved
  – This compares favorably with the cost effectiveness of other preventive measures, except smoking cessation


Participation Rates Poor

• Only 10-20 percent of eligible patients participate in formal rehab programs.

• Most studies show that the elderly participate 1.5 to 2 times less than younger patients.

• referral & participation rates even lower among Women.
Patient’s Willingness to Participate

- “denial.”
- h/o depression.
- dependent spouse at home.
- hassle factors, distance, parking.
- comorbidity: too much else going on.
- physician’s referral is best predictor.
Compliance, long term

- 50% at one year (64% w/ anti-HTN, 82% w/ LLA).
- Interventions that improve compliance:
  - Gradual transition from center-based to home based regimens improved compliance to 92% vs. 76% at 6 months.
  - Use of low-intensity exercise, nurse case-managers, & patient’s signed agreements.
  - Research ongoing about creative modes of delivery (e.g. tele-medicine).
Summary

- CR should be an integral component of care
- Proven reductions in mortality
- Proven reductions in disease related comorbidities
- Improved quality of life
- Requires a physician referral
Indications (requires physician referral)

- MI in the last 12 month
- PTCA or coronary stenting
- CABG
- stable angina pectoris
- heart valve repair/replacement
- heart or heart-lung transplant
- CHF
- PVOD
- CVD
- ICD placement/arrhythmia
- multiple CAD risk factors

covered by medicare
“What fits your busy schedule better, exercising one hour a day or being dead 24 hours a day?”
Figure 2. Hypothesized response of arteries to increased flow and shear stress following varying durations of exercise training