Chapter 35: Exercise Prescription in Patients with Cardiovascular Disease

Disease-Specific Effects on Physiologic Responses and Fitness

- Heart rate (HR)
  - Normal HR response: Achieve ≥ 85% of predicted maximal HR on maximal stress test
    - 220 – age = predicted maximal HR (SD = 10-12 bpm)
  - Chronotropic incompetence: Failure to achieve at least 85% of predicted maximal HR
    - Patient must not be on β-blockers to make this diagnosis
    - Predictive of cardiac morbidity and mortality
  - HR recovery: Assessment of postexercise HR at 1 and/or 2 minutes after exercise
    - Failure to decrease appropriately indicates increased cardiac mortality risk
    - Related to poor parasympathetic response
Disease-Specific Effects on Physiologic Responses and Fitness

- Blood pressure
  - Exercise response is for SBP to rise and DBP to remain stable or drop slightly as exercise intensity increases.
    - SBP $\uparrow \sim 10$ mm Hg per MET
  - Patients with CAD may have variable responses.
  - Exertional hypertension = peak SBP $>250$ mm Hg OR peak DBP $>115$ mm Hg
    - DBP $\uparrow$ by $10$ mm Hg or more suggests possible CAD and future hypertension risk
  - Drop in SBP (exertional hypotension = $\downarrow$ SBP by $\geq 10$ mm Hg)
  - Exertional hyper- and hypotension related to increased cardiac morbidity and mortality risk
Disease-Specific Effects on Physiologic Responses and Fitness

• Cardiac output (CO)
  - CO = Stroke volume (SV) × Heart rate
    
    • SV = End-diastolic volume – End-systolic volume
  - May be reduced in cardiac populations due to:
    
    • Reduced HR response and reduced peak HR
    • Left ventricular dysfunction due to ischemia or cardiomyopathy
Disease-Specific Effects on Physiologic Responses and Fitness

- Oxygen uptake (VO₂)
  - \( \text{VO}_2 = \text{Cardiac output} \times \text{Arterial-mixed venous O}_2 \text{ difference} \)
  - VO₂ values can be expressed in absolute units (L · min⁻¹) or in relative units (mL · kg⁻¹ · min⁻¹)
  - Typical peak exercise responses:
    - Decrease by ~1% per year
    - 30-45 mL · kg⁻¹ · min⁻¹ for middle-aged, healthy adults
    - 14.5 and 19.3 mL · kg⁻¹ · min⁻¹ for women and men, respectively, who enroll in cardiac rehabilitation
    - Exercise training can increase peak VO₂ by 15%–30%
Scientific and Physiologic Rationale for Exercise Therapy in Patients with Heart Disease

- Scientific and physiologic rationale for exercise therapy in patients with heart disease
  - Angina
    - Typical
    - Atypical
    - Anginal equivalents
  - Ischemic cascade: Result of imbalance between myocardial oxygen demand and supply
    - Cellular abnormalities
    - ECG changes
    - Angina
    - Diastolic and systolic dysfunction
Scientific and Physiologic Rationale for Exercise Therapy in Patients with Heart Disease

- Myocardial oxygen (MVO$_2$) demand
  - Increases as heart rate, LV preload, and contractility increase
  - Surrogate estimate of MVO$_2$ demand
    - Double product (aka, rate-pressure product)
      - Calculated as: HR $\times$ SBP
    - Typical values at peak exercise rise above 25,000
    - Reproducible at the ischemic or angina threshold
## TABLE 35-1. COMPARISON OF PEAK ARM AND LEG RESPONSES IN HEALTHY SUBJECTS AND THOSE WITH HEART FAILURE AND CARDIAC TRANSPLANT

<table>
<thead>
<tr>
<th></th>
<th>PEAK HR (b·min⁻¹)</th>
<th>OXYGEN CONSUMPTION (L·min⁻¹)</th>
<th>RATE PRESSURE PRODUCT × 10³ (b·mm Hg·min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm</td>
<td>140 ± 13</td>
<td>1.50 ± 0.38</td>
<td>28.5 ± 3.9</td>
</tr>
<tr>
<td>Leg</td>
<td>162 ± 45</td>
<td>2.28 ± 0.150</td>
<td>32.5 ± 4.5</td>
</tr>
<tr>
<td>Heart failure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm</td>
<td>128 ± 17</td>
<td>1.08 ± 0.22</td>
<td>20.5 ± 5.2</td>
</tr>
<tr>
<td>Leg</td>
<td>144 ± 14</td>
<td>1.48 ± 0.30</td>
<td>24.1 ± 4.0</td>
</tr>
<tr>
<td>Transplant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm</td>
<td>135 ± 4</td>
<td>1.15 ± 0.07</td>
<td>24.8 ± 2.0</td>
</tr>
<tr>
<td>Leg</td>
<td>145 ± 4</td>
<td>1.60 ± 0.09</td>
<td>27.8 ± 1.9</td>
</tr>
</tbody>
</table>

HR, heart rate.

Rate pressure product = peak HR × peak systolic blood pressure.

Scientific and Physiologic Rationale for Exercise Therapy in Patients with Heart Disease

- Myocardial oxygen (MVO$_2$) supply
  - Ischemia occurs when supply does not match demand
  - Factors affecting MVO$_2$ supply:
    - Coronary artery stenosis with endothelial dysfunction
    - Microvascular dysfunction
    - Abnormalities of the autonomic nervous system
    - Abnormalities of coagulation and fibrinolytic systems
### Table 35-2. Pathophysiologic Effects of Exercise and Exercise Training

<table>
<thead>
<tr>
<th>Pathophysiologic Variable</th>
<th>Acute Exercise</th>
<th>Chronic Exercise Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular stenosis</td>
<td></td>
<td>Partial regression (&gt;2,200 kcal·wk⁻¹)</td>
</tr>
<tr>
<td>Coronary collaterals</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>Endothelial dysfunction</td>
<td></td>
<td>↓</td>
</tr>
<tr>
<td>Capillary flow</td>
<td></td>
<td>↑</td>
</tr>
<tr>
<td>Autonomic nervous symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parasympathetic</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Sympathetic</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Hemostatic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Factor VII</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>Platelet aggregation</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Fibrinolysis</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Viscosity</td>
<td>↑</td>
<td></td>
</tr>
</tbody>
</table>

↑, increase; ↓, decrease; —, no effect.

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Scientific and Physiologic Rationale for Exercise Therapy in Patients with Heart Disease

• Autonomic nervous system (ANS)
  − The ANS controls HR, blood pressure, and vascular tone.
    • Parasympathetic activity reduces HR and, when withdrawn, results in an increased HR.
    • Sympathetic activity increases HR and, when withdrawn, results in a reduced HR.
  − ANS activity is adversely affected by myocardial damage (e.g., heart attack or cardiomyopathy) and diabetes.
  − Measured indirectly by the heart rate variability method
  − Abnormal ANS function can result in increased risk of arrhythmias, increased vascular resistance, elevated resting and reduced peak exercise HR, and worsening heart failure.
  − Exercise training can attenuate and reverse ANS dysfunction.
Morbidity, Mortality, and Safety of Cardiac Rehabilitation

- Cardiac rehabilitation (CR)
  - Several meta-analyses consistently demonstrate a 25% reduction in cardiac mortality but no difference in nonfatal heart attacks.
  - These results factor in only exercise training as an intervention and not lifestyle education.
  - CR: Up to 4 phases
    - I = inpatient
    - II = outpatient with monitoring and supervision
    - III = early maintenance
    - IV = long-term maintenance
  - CR is very safe:
    - 1 fatal MI per 900,000 CR exercise training hours
    - 1 nonfatal MI per 250,000 CR exercise training hours
Exercise Prescription and Programming

- ~24% of the U.S. population is sedentary.
- >30%-40% of the chronically ill population is sedentary.
- Regular exercise and physical activity result in a lower all-cause and cardiac-specific mortality rate.
  - Reduced risk gains increase when weekly energy expenditure increases from 500 to 2,500 kcals per day (Harvard Alumni study).
  - Any increase in fitness reduces all-cause and cardiac-specific risk and cancer risk (Blair Cooper clinic studies).
  - AACVPR stratifies exercise risk based on weekly caloric expenditure of patients with cardiac disease (low risk = >1,500 kcals per week)
  - >2,200 kcals per week of energy expenditure from physical activity may be needed to ‘regress’ CAD (Hambrecht).
Coronary artery disease
- Average patient expends ~830 kcal/week in cardiac rehab, and only 43% expend more than 1,500 kcal/week.
- All patients with CAD are appropriate candidates for cardiac rehabilitation from the inpatient (phase I) setting to the outpatient (phase II) and maintenance (phase III/IV) settings.
- Patients should learn specifics and focus primarily on cardiovascular training with range of motion and resistance training provided for many at some later point.

Exercise prescription
- Gradual increase to 20-60 minutes of continuous aerobic-type exercise
  - Perform most days of week
  - Perform appropriate warm-up and cool-down
- Add dynamic resistance training:
  - 50%-60% of 1 RM
  - Focused on major muscle groups of upper and lower body
  - Perform 2-3 nonconsecutive days per week
  - Use machine weights or elastic bands
  - Limit in those with recent sternotomy (6-12 weeks post surgery)
<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking</td>
<td>By itself: little or no effect</td>
</tr>
<tr>
<td></td>
<td>Exercise should be part of a comprehensive smoking cessation program</td>
</tr>
<tr>
<td>Lipid abnormalities</td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>Little or no effect</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>Little or no effect</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>Mild to moderate increase</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Reduces incidence (especially among white men)</td>
</tr>
<tr>
<td>Systolic</td>
<td>Reduced: average, 6 mm Hg</td>
</tr>
<tr>
<td>Diastolic</td>
<td>Reduced: average, 5 mm Hg</td>
</tr>
<tr>
<td>Obesity</td>
<td>Exercise alone: mild effect</td>
</tr>
<tr>
<td></td>
<td>Exercise should be part of a comprehensive weight-management program</td>
</tr>
</tbody>
</table>

HDL, high-density lipoprotein; LDL, low-density lipoprotein.
<table>
<thead>
<tr>
<th>ILLNESS</th>
<th>INTENSITY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary artery disease</td>
<td>40/50%–85% of HRR</td>
<td>To affect mortality, frequency, duration, and intensity of training should sum to yield a weekly energy expenditure &gt;1,500 kcal · wk⁻¹.¹,²</td>
</tr>
<tr>
<td>Angina or equivalent</td>
<td>40/50%–85% of HRR</td>
<td>Consider a prophylactic nitroglycerin 15 min before anticipated exertion if symptoms limit routine ADLs or ability to exercise.</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>40/50%–85% of HRR</td>
<td>Achieve 1,500–2,000 kcal of energy expenditure through physical activity each week.¹,²</td>
</tr>
<tr>
<td>PTCA with or without stent</td>
<td>40/50%–85% of HRR</td>
<td>Achieve 1,500–2,000 kcal of energy expenditure through physical activity each week.¹,²</td>
</tr>
<tr>
<td>CABG or valve surgery</td>
<td>40/50%–85% of HRR</td>
<td>Restrict upper-body movement until sternum is healed (6–12 wk). If needed, initially guide exercise intensity at 60% of HRR and adjust duration to three bouts of 10 min each, progressing to 30–40 min. As patient progresses, maintain upper rate below ventilatory threshold.</td>
</tr>
<tr>
<td>Heart failure</td>
<td>40/50%–70% of HRR</td>
<td></td>
</tr>
<tr>
<td>Cardiac transplant</td>
<td>RPE 11–14</td>
<td>Restrict upper-body resistance exercises until sternum is healed (6–12 wk).</td>
</tr>
<tr>
<td>Pacemaker, ICD, biventricular, RCT</td>
<td>10% below activation threshold</td>
<td>Avoid activities that stretch the arms. After 8 wk, nonballistic activities may be resumed, and ballistic activities may be resumed after 12 wk.</td>
</tr>
</tbody>
</table>

ADLs, activities of daily living; CABG, coronary artery bypass graft; HRR, heart rate reserve; ICD, implantable cardiac defibrillator; PTCA, percutaneous transluminal coronary angioplasty; RCT, cardiac resynchronization therapy; RPE, rating of perceived exertion.


Exercise Prescription and Programming

- Angina
  - Result of myocardial oxygen supply-demand mismatch
  - Exercise training goal is to increase the intensity threshold at which angina occurs (see next slide).
  - Set training HRs at least 10 beats below initial occurrence of ischemia.
  - Staff and patient must recognize typical angina symptoms with respect to location, precipitating factors, associated symptoms, and radiation pattern.
  - Should not exercise with angina pain; if it occurs, then reduce intensity or stop exercise.
  - Consider pre-exercise nitroglycerine and/or prolonged warm-up to reduce occurrence.
Figure 35-1. Regular exercise training attenuates myocardial O$_2$ demand during exercise, as estimated by the rate-pressure product. HR = heart rate; SBP = systolic blood pressure.
Exercise Prescription and Programming

- Myocardial infarction
  - Begin CR as soon as possible after infarction
  - 3 days per week in CR
  - Additional home exercise recommended
  - Maintain 40%-60% HR reserve initially, with progression up to 85%
Exercise Prescription and Programming

• Revascularization (coronary artery bypass graft [CABG] and percutaneous coronary intervention [PCI])
  - These likely elevate the exercise intensity of the angina/ischemia threshold
  - Candidates for CR
    • CABG: 2 weeks post-surgery
    • PCI: immediately after procedure
  - 20-60 minutes on 3-4 days per week for aerobic mode exercise
  - Light upper body activities 4-8 weeks if sternotomy and resistance training after healed (~6-12 weeks)
Exercise Prescription and Programming

- Valve dysfunction/repair/replacement
  - Exercise training will not improve valve function, but patients will incur general fitness benefits.
  - Sports are typically okay, except for moderate/severe aortic stenosis.
  - Surgery is often used to correct valve dysfunction.
- Aerobic training
  - 85% of HR reserve
  - 3-4 days per week
  - 20-60 minutes
Exercise Prescription and Programming

- Heart failure
  - Exercise ability is reduced by at least 30%-40% compared to age-matched normal persons.
  - Generally candidates for CR, although insurance reimbursement may not be available, specifically for nonischemic Medicare patients.
  - Moderate intensity aerobic mode exercise is safe and results in a 15%-30% peak VO₂ improvement.
  - Initial intensities and durations may need adjusting to allow patient to adequately exercise.
  - Goal is 30+ continuous minutes at 60%-70% HR reserve.
    - May need to begin with shorter discontinuous bouts
    - Should begin at 50%-60% HR reserve for several exercise bouts
    - If available, intensity should not exceed the anaerobic (i.e., ventilatory derived) threshold.
Exercise Prescription and Programming

- Cardiac transplant
  - 3,000 performed annually with ~80% 3-year survival
  - Exercise ability is reduced by at least 40%-50% compared to age-matched normal persons but can increase 15%-40% with exercise training.
  - Loss of autonomic innervation post surgery results in a high resting HR (~90-100 bpm), reduced HR response and peak HR, and delayed HR recovery.
    - Cannot use HR to guide exercise intensity
    - Use 11-14 on the Perceived Exertion (Borg 6-10) Scale
    - Other aerobic mode training is standard with respect to modes, duration, frequency, and progression—compare to heart failure
      - Immune suppression medications increase the risk of infections, hyperlipidemia, hypertension, osteoporosis, diabetes, certain cancers, and accelerated atherosclerosis.
      - Standard resistance training (after sternotomy is healed) can improve strength and reduce osteoporosis risk.
Exercice Prescription and Programming

- Pacemakers and implantable cardiac defibrillators (ICD)
  - ICDs do not affect exercise prescription or training.
    - Exercise HR should always be at least 10 beats below the device target HR.
    - Typically not a concern as most take a β-blocker, which reduces HR response.
  - Pacemakers may result in some improvement in exercise capacity.
    - Biventricular pacers in those with heart failure
    - Pacers that result in higher peak exercise HRs (used in those with chronotropic incompetence); these are termed rate-responsive pacers
    - Standard aerobic mode training with respect to mode, frequency, and duration
    - HR may not be effective to assess exercise intensity; may need to use Perceived Exertion Scale (range: 11-14)