Normal and Abnormal Exercise Response

Potential Measurements

- Signs and symptoms
- Heart rate and blood pressure
- EKG
- Cardiac output, stroke volume
- VO2
- Anaerobic threshold
- O2 pulse
- Systolic time interval
- Skin temperature
- Wall motion
- Heart sounds
- Not just HR and BP!!

Signs and Symptoms

- Normal Response
  - flush skin, moist
  - shortness of breathe, local muscular fatigue
- Abnormal Response (CAD)
  - cool, clammy skin
  - peripheral cyanosis
  - dizziness, ataxia, nausea, confusion
  - angina during exercise, disappears in recovery

Heart Rate and Blood Pressure

Abnormal HR and BP responses

- ↑HR response
  - poor conditioning, dysrhythmia
- ↓HR response
  - conduction defect, ischemia, LV dysfunction
- ↑BP response (>225/90)
  - future hypertensive
- ↓SBP (exercise-induced hypotension)
  - valve disease, CAD, LV dysfunction

Normal Peak Blood Pressures

<table>
<thead>
<tr>
<th>Age</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP</td>
<td>DBP</td>
</tr>
<tr>
<td></td>
<td>182 ± 11</td>
<td>129 ± 13</td>
</tr>
<tr>
<td>20-29</td>
<td>72 ± 23</td>
<td>106 ± 12</td>
</tr>
<tr>
<td>20-29</td>
<td>75 ± 23</td>
<td>85 ± 12</td>
</tr>
<tr>
<td>70-79</td>
<td>191 ± 27</td>
<td>81 ± 13</td>
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</tbody>
</table>

**CAD HR and BP ex response**

**Delta Heart Rate**

- Difference between resting and maximal HR response
- The lower the delta HR, the higher the mortality

**Pressure Pulse Product (Double Product)**

- SBP x HR
- Index of myocardial oxygen consumption

**Double Product and coronary artery occlusion**

**Cardiac Output, Stroke Volume**

- Invasive measures: Swan-Ganz catheter is introduced into the pulmonary artery
  - Flow sensor: direct Fick
  - Thermistor: thermal dilution
- Non-invasive measures: rebreathing techniques, continuous-wave Doppler

**Cardiac Output vs. Work Rate**

*Thompson 01, pg 5*
**Normal Stroke Volume Response**

In upright position, SV increases initially with exercise.

**EDV and ESV during exercise**

Increase SV with exercise is due to ↑EDV and ↓ESV.

**Cardiac Contractility**

- **Ejection Fraction**
  - \( EF = \text{EDV} - \text{ESV} / \text{EDV} \)
  - Resting value about 60%
  - Exercise value, increases to 80-85%

- **ESV**
  - Volume of blood left in the heart after contraction

**CAD CO, HR, and SV responses**

- CAD patients may have constriction in coronary arteries
- Constriction causes ischemia and ↓pump fn
- Cardiac output may not rise normally
- SV may not increase normally
- HR response may be blunted (independent of drugs) and may even decrease

**Why are VO2 measurements obtained?**

- VO2 measurement is more reliable than estimates from cycle or treadmill eqns
- Peak VO2 is most accurate measurement of functional capacity and index of overall cardiopulmonary health
- Heart and lung diseases will be evident from gas exchange abnormalities

**Oxygen Consumption**

- The most notable result of CAD is ↓VO2max
  - Variable response (depends on amount of myocardium involved and severity of ischemia)
- ↓VO2 at submaximal levels of exercise
- Oxygen kinetics are slower
- More reliance on anaerobic energy production during exercise
Maximal Exercise O2 variables

<table>
<thead>
<tr>
<th>Subject</th>
<th>VO2 (ml/min)</th>
<th>HR (bpm)</th>
<th>SV (ml/b)</th>
<th>CO (l/min)</th>
<th>a-vO2 (ml/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD</td>
<td>1500</td>
<td>175</td>
<td>50</td>
<td>8.8</td>
<td>17.0</td>
</tr>
<tr>
<td>Normal</td>
<td>3000</td>
<td>190</td>
<td>100</td>
<td>19.0</td>
<td>15.8</td>
</tr>
<tr>
<td>Athlete</td>
<td>5600</td>
<td>180</td>
<td>180</td>
<td>32.5</td>
<td>17.0</td>
</tr>
</tbody>
</table>

Anaerobic threshold or ventilatory threshold

- AT has been described as the breakpoint in Ve associated with lactate accumulation and muscle anaerobiosis.
- AT probably reflects a balance between lactate production and removal.
- Exercise beyond AT is associated with metabolic acidosis, hyperventilation, and reduced capacity to perform work.

AT response in CAD

- AT < 40%VO2max is below 95% confidence for sedentary subjects.
- ↓ AT is associated with CAD and is a sign of a condition that limits O2 flow to muscles.
- Other tests are needed to differentiate whether the problem is cardiovascular, respiratory or metabolic.

O2 pulse

- O2 pulse = VO2/HR
- O2 pulse = SV x a-vO2 difference
- With exercise, O2 pulse increases due to ↑ a-v O2 difference and SV (upright).
- In CAD, the rise in O2 pulse is blunted because SV is reduced.
**Skin Temperatures**

- Skin temperatures measured on the chest
  - Thermistors
  - Thermoscan

- During angina, a cold area develops over the heart due to vasoconstriction

- Appears about 1 min before pain

**Systolic Time Intervals**

- Measure by
  - Phonocardiogram
  - Carotid pulse sensor
  - Ballistocardiogram

- Prolonged STI could indicate coronary insufficiency, decreased ventricular function, increased TPR, abnormal wall motions

**Heart Sounds**

1. A-V valves close at onset of systole, blood rumbling (lub)
2. Aortic then pulmonic valves close at onset of diastole (dup)
3. Rapid filling in early diastole, sound occurs with decreased ventricular distensibility
4. Atrial contraction

**Bad Heart Sounds**

- **Sound 1**, should be loud and powerful
  - Mitral murmur, prolapsed mitral leaflet (10% of pop)

- **Sound 2**, splitting may be LBBB and decreased right or left ventricle function
  - Aortic murmur, aortic stenosis

- **Sound 3**, associated with poor ventricular function

- **Sound 4**, common in ischemic heart disease or myocardial disease.

**Conclusions:**

- The predictive value of exercise testing is improved by considering exercise responses in addition to EKG
  - Reduced VO2max
  - Blunted hemodynamic response
  - Lowered AT
  - Lowered O2 pulse
  - Prolonged STI
  - Unusual sounds or palpations