Section 8: Clinical Exercise Testing  
Maximal GXT

ACSM Guidelines: Chapter 5  
ACSM Manual: Chapter 8

Outline

• What is the purpose of a maximal GXT?  
• Who should have a maximal GXT (and current medical examination) before starting a moderate or vigorous exercise program?  
• Should a physician be present to supervise the maximal GXT?  
• What are the personnel needs for conducting a maximal GXT?  
• What protocols and procedures should be used with a maximal GXT?  
• What are the maximal GXT contraindications and test termination criteria?
Purposes of the Clinical GXT

• Diagnostic Purposes
  – Best used in patients with an intermediate probability of angiographically significant CAD as determined by age, gender, and symptoms
  • ACSM Table 5-1
  – Diagnostic exercise testing is not usually warranted for asymptomatic individuals (< 10% likelihood of CAD)
  – But, it may be useful for in an asymptomatic person who has multiple risk factors.
  – Also may be indicated for an individual starting a vigorous exercise program.

<table>
<thead>
<tr>
<th>TABLE 5.1. PRETEST LIKELIHOOD OF ATHEROSCLEROTIC CARDIOVASCULAR DISEASE (CVD)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>30–39</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>40–49</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>50–59</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>60–69</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*No data exist for patients who are <30 or >69 years, but it can be assumed that prevalence of CVD increases with age. In a few cases, patients with ages at the extremes of the decades listed may have probabilities slightly outside the high or low range. High indicates >90%; intermediate, 10%-90%; low, <10%; and very low, <5%.


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Purposes of the Clinical GXT

• Disease Severity and Prognostic Uses
  – Useful for the evaluation of disease severity among persons with known or suspected CAD.
  – ST-Segment characteristics often used to look at severity of disease
  – We will discuss this more in Chapter 6

• Exercise Testing after MI
  – Can be performed before or soon after hospital discharge for prognostic assessment, activity prescription and evaluation of further medical therapy or interventions.
    • Submaximal: 4-6 days after acute MI
    • Symptom-Limited: > 14 days after acute MI
Purposes of the Clinical GXT

- **Functional / Therapeutic Purposes**
  - Used to determine functional capacity.
  - Functional capacity is inversely related to risk for CAD and all-cause and CV mortality
  - This information is valuable for:
    - Activity counseling, exercise prescription, return to work evaluation, disability assessment, and to help estimate prognosis.
  - How is functional capacity expressed?
    - Percentile rankings (ACSM Table 4.8)
    - Percentage of expected METs for age using a nomogram (ACSM Figure 5.1)
**Purposes of the Clinical GXT**

![Graph showing data](image)

**Who Should be Tested? / Physician Supervision**

- Depends on risk stratification (see Chapter 2)
- Physician supervision is not necessary in people at low risk
- Physician supervision is recommended in people at moderate and high risk

<table>
<thead>
<tr>
<th>TABLE 2-1</th>
<th>ACSM RECOMMENDATIONS FOR (A) CURRENT MEDICAL EXAMINATION* AND EXERCISE TESTING BEFORE PARTICIPATION AND (B) PHYSICIAN SUPERVISION OF EXERCISE TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Risk</td>
<td>Moderate Risk</td>
</tr>
<tr>
<td>A. Moderate exercise</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Vigorous exercise</td>
<td>Not necessary</td>
</tr>
<tr>
<td>B. Submaximal test</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Maximal test</td>
<td>Not necessary</td>
</tr>
</tbody>
</table>
**Personnel Needs for GXT**

“In all situations where exercise testing is performed, site personnel should at least be certified at a level of basic life support (CPR) and have automated external defibrillator (AED) training. Preferably, one or more staff members should also be certified in first aid and advanced cardiac life support (ACLS).”

Also, see Box 8.2 (ACSM Manual, p. 144)

**Protocols and Procedures for GXT**

- **Mode of Exercise**
  - Treadmill
    - More common form of physiologic stress
    - Higher VO₂ and peak HR (compared to other modes)
    - Handrails should be available
  - Cycle Ergometer
    - Less expensive, require less space, less noisy
    - Better quality ECG recordings and BP
    - Unfamiliar method of exercise and highly dependant on patient motivation
    - Test often ends due to local fatigue
    - Lower values for VO₂ compared to treadmill (5-25%)
  - Arm Ergometry
    - For patients who cannot perform leg exercise
    - VO₂max is 20-30% lower than treadmill
**Protocols and Procedures for GXT**

**Protocols**
- When choosing a protocol consider:
  - The purpose of the test
  - The specific outcomes desired
  - Characteristics of the individual
- Numerous standardized protocols
- Create your own (not typically done)
- Duration should be between 8 and 12 minutes

**Protocols (cont’d)**
- Bruce Protocol (and Modified-Bruce)
  - Most commonly used protocol
  - Employs relatively large increments (i.e. METs per stage) every 3 minutes
  - Better for screening younger and/or physically active individuals
Protocols and Procedures for GXT

TABLE 8.3. BRUCE TREADMILL PROTOCOL (3)

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME (min:sec)</th>
<th>SPEED (mph)</th>
<th>GRADE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0:00</td>
<td>1.7</td>
<td>10.0</td>
</tr>
<tr>
<td>2</td>
<td>3:00</td>
<td>2.5</td>
<td>12.0</td>
</tr>
<tr>
<td>3</td>
<td>6:00</td>
<td>3.4</td>
<td>14.0</td>
</tr>
<tr>
<td>4</td>
<td>9:00</td>
<td>4.2</td>
<td>18.0</td>
</tr>
<tr>
<td>5</td>
<td>12:00</td>
<td>5.0</td>
<td>18.0</td>
</tr>
<tr>
<td>6</td>
<td>15:00</td>
<td>5.5</td>
<td>20.0</td>
</tr>
<tr>
<td>7</td>
<td>18:00</td>
<td>6.0</td>
<td>22.0</td>
</tr>
</tbody>
</table>

Note: a modification for less fit clients is to add one or two preliminary stages:

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME (min:sec)</th>
<th>SPEED (mph)</th>
<th>GRADE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0:00</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>3:00</td>
<td>1.7</td>
<td>5.0</td>
</tr>
</tbody>
</table>

See Table 8.3 for estimated metabolic equivalent levels.


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Protocols and Procedures for GXT

• Protocols (cont’d)
  – Balke-Ware Treadmill Protocol (and modified)
    • Also, commonly used protocol
    • Smaller increments in exercise intensity (i.e. constant speed of 3.3 mph, gradual % grade increases)
    • Preferable for older or deconditioned individuals or persons with chronic disease
Protocols and Procedures for GXT

• Protocols (cont’d)
  – Ramp Protocols
    • Work rate increases in a constant and continuous manner.
  • Advantages include:
    – Avoidance of large and unequal increments in workload
    – Uniform increase in hemodynamic and physiologic responses
    – More accurate estimates of exercise capacity and ventilatory threshold
    – Individualizing the test
    – Targeted test duration
Protocols and Procedures for GXT

**TABLE 8.5. THE BALL STATE UNIVERSITY (BSU) BRUCE TREADMILL RAMP PROTOCOL (6)**

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME (min:sec)</th>
<th>SPEED (mph)</th>
<th>GRADE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(min:sec)</td>
<td>(mph)</td>
<td>(%)</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>1.7</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.30</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>0.40</td>
<td>1.7</td>
<td>2.5</td>
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<tr>
<td>4</td>
<td>1.00</td>
<td>1.7</td>
<td>3.7</td>
</tr>
<tr>
<td>5</td>
<td>1.30</td>
<td>1.7</td>
<td>5.0</td>
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<tr>
<td>6</td>
<td>1.40</td>
<td>1.7</td>
<td>6.2</td>
</tr>
<tr>
<td>7</td>
<td>2.00</td>
<td>1.7</td>
<td>7.5</td>
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<tr>
<td>8</td>
<td>2.20</td>
<td>1.7</td>
<td>8.7</td>
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<td>9</td>
<td>2.40</td>
<td>1.7</td>
<td>10.0</td>
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<tr>
<td>10</td>
<td>3.00</td>
<td>1.8</td>
<td>10.2</td>
</tr>
<tr>
<td>11</td>
<td>3.30</td>
<td>1.8</td>
<td>10.2</td>
</tr>
<tr>
<td>12</td>
<td>3.40</td>
<td>2.0</td>
<td>10.3</td>
</tr>
<tr>
<td>13</td>
<td>4.00</td>
<td>2.1</td>
<td>10.7</td>
</tr>
<tr>
<td>14</td>
<td>4.20</td>
<td>2.2</td>
<td>10.9</td>
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<tr>
<td>15</td>
<td>4.40</td>
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<td>11.2</td>
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<tr>
<td>16</td>
<td>5.00</td>
<td>2.4</td>
<td>11.2</td>
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<td>17</td>
<td>5.50</td>
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<td>11.8</td>
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<td>5.90</td>
<td>2.5</td>
<td>12.0</td>
</tr>
<tr>
<td>19</td>
<td>6.00</td>
<td>2.6</td>
<td>12.2</td>
</tr>
<tr>
<td>20</td>
<td>6.20</td>
<td>2.7</td>
<td>12.4</td>
</tr>
<tr>
<td>21</td>
<td>6.40</td>
<td>2.8</td>
<td>12.7</td>
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<tr>
<td>22</td>
<td>6.80</td>
<td>3.0</td>
<td>13.1</td>
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<td>23</td>
<td>7.20</td>
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<td>24</td>
<td>7.60</td>
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<td>25</td>
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<td>26</td>
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<td>13.8</td>
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<tr>
<td>27</td>
<td>8.80</td>
<td>3.4</td>
<td>14.0</td>
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<td>28</td>
<td>9.20</td>
<td>3.5</td>
<td>14.4</td>
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<tr>
<td>29</td>
<td>9.60</td>
<td>3.6</td>
<td>14.4</td>
</tr>
<tr>
<td>30</td>
<td>10.00</td>
<td>3.6</td>
<td>14.6</td>
</tr>
</tbody>
</table>


**NOTE:** The protocol is designed for individuals with a heart rate reserve of 90%. The intensity should be adjusted based on the individual's fitness level and heart rate response.

**TABLE 8.6. MODIFIED COSTILL/FOX RUNNING PROTOCOL (14)**

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME (min)</th>
<th>SPEED (km·h⁻¹)</th>
<th>GRADE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmup</td>
<td>6:00</td>
<td>5.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Speed increasing stages</td>
<td>4 each</td>
<td>9.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Grade increasing stages</td>
<td>2 each</td>
<td>12.0</td>
<td>15.5</td>
</tr>
</tbody>
</table>

*Speed and grade increase by 10% every 5 min.*

**TABLE 8.7. AN EXAMPLE OF A CYCLE TEST PROTOCOL**

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME (minutes)</th>
<th>WORK RATE (kg · m·min⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>3.00</td>
<td>600</td>
</tr>
<tr>
<td>3</td>
<td>6.00</td>
<td>900</td>
</tr>
<tr>
<td>4</td>
<td>9.00</td>
<td>1,200</td>
</tr>
<tr>
<td>5</td>
<td>12.00</td>
<td>1,500</td>
</tr>
<tr>
<td>6</td>
<td>15.00</td>
<td>1,800</td>
</tr>
<tr>
<td>7</td>
<td>18.00</td>
<td>2,100</td>
</tr>
</tbody>
</table>

*For the first 3 minutes, the workload should be increased by 30 W. The workload should be increased by 10 W every 3 minutes.*

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Protocols and Procedures for GXT

- Non-Clinical Protocols:
### Protocols and Procedures for GXT

#### Bruce Protocol

Healthy persons (3)

\[
\text{VO}_{2\text{max}} \text{ (mL kg}^{-1} \text{ min}^{-1}) = 6.7 - 2.82 \text{ (men = 1, women = 2)} + 0.056 \text{ (time in sec)}
\]

Healthy men and women (n = 296)

\[
\text{VO}_{2\text{max}} \text{ (mL kg}^{-1} \text{ min}^{-1}) = 3.814 \text{ (time in min)} \pm 3.938 \pm 4.68 \text{ (r = 0.87)}
\]

(Unpublished data -- Ball State University [BSU] Adult Physical Fitness Program)

**BSU-Bruce Ramp Protocol (6)**

Men and women (n = 392)

\[
\text{VO}_{2\text{max}} \text{ (mL kg}^{-1} \text{ min}^{-1}) = 3.9 \text{ (time in min)} \pm 7.0 \pm 3.4 \text{ (r = 0.93)}
\]

**Balke Protocol**

Women (n = 49) -- 3.0 mph protocol with 2.5% (3 min) (11)

\[
\text{VO}_{2\text{max}} \text{ (mL kg}^{-1} \text{ min}^{-1}) = 0.023 \text{ (time in sec)} + 5.2 \pm 2.7 \text{ (r = 0.94)}
\]

Men (n = 51) -- 3.3 mph protocol (10)

\[
\text{VO}_{2\text{max}} \text{ (mL kg}^{-1} \text{ min}^{-1}) = 1.444 \text{ (time in min)} + 14.99 \pm 0.025 \text{ (r = 0.92)}
\]
Protocols and Procedures for GXT

• Heart Rate and Blood Pressure
  – Before, during, and after GXT
  – Hemodynamic responses
  – If SBP decreases with an increase in exercise intensity, it should be retaken immediately
    – > 10 mmHg, test should be stopped

• ECG
  – Filtered vs. Real-Time Data
  – Constant monitoring
Protocols and Procedures for GXT

- **Subjective Ratings and Symptoms**
  - RPE (Ratings of Perceived Exertion)
  - Angina, Claudication, Dyspnea Scales

- **Gas Exchange and Ventilatory Responses**
  - These measurements are appropriate when:
  - Precise CP response to a specific therapeutic intervention is required
  - When the etiology of exercise limitation or dyspnea is uncertain
  - When evaluation of exercise capacity in patients with heart failure is used to assist in prognosis and need for transplant
  - Research context
  - Assisting in development of exercise prescription

Protocols and Procedures for GXT

Angina Scale

Claudication Scale

Dyspnea Scale

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Protocols and Procedures for GXT

• Post-Exercise Period:
  – For maximal sensitivity, patients should be placed in the supine position
    • Advantageous to record about 10 seconds of ECG while patient is standing upright at end of test
  – For non-diagnostic purposes:
    • Use active cool-down
  – Monitoring should continue for at least 5 minutes post-exercise or until ECG changes return to baseline or significant signs and symptoms resolve.

Contraindications to Exercise Testing

**BOX 3.5 Contraindications to Exercise Testing**

**Absolute**
- A recent significant change in the resting ECG suggesting significant ischemia, recent myocardial infarction (within 2 days), or other acute cardiac event
- Unstable angina
- Uncontrolled cardiac dysrhythmias causing symptoms or hemodynamic compromise
- Symptomatic severe aortic stenosis
- Uncontrolled symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute myocarditis or pericarditis
- Suspected or known dissecting aneurysm
- Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands
Contraindications to Exercise Testing

**Box 5.5 Contraindications to Exercise Testing**

- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Electrolyte abnormalities (e.g., hypokalemia, hypomagnesemia)
- Severe arterial hypertension (i.e., systolic BP of >200 mm Hg and/or a diastolic BP of >110 mm Hg) at rest
- Tachyarrhythmia or bradyarrhythmia
- Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
- Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
- High-degree atrioventricular block
- Ventricular aneurysm
- Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myocardia)
- Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)
- Mental or physical impairment leading to inability to exercise adequately

*Relative contraindications can be overridden if benefits outweigh risks of exercise. In some instances, these individuals can be exercised with caution and/or using low-level end points, especially if they are asymptomatic at rest.*


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Indications for Terminating Test

**Box 5.2 Indications for Terminating Exercise Testing**

**Absolute Indications**

- Drop in systolic blood pressure of >10 mm Hg from baseline
- Blood pressure despite an increase in workload when accompanied by other evidence of ischemia
- Moderately severe angina (defined as 3 on standard scale)
- Increasing nervous system symptoms (e.g., ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties monitoring the ECG or systolic blood pressure
- Patient's desire to stop
- Sustained ventricular tachycardia
- ST elevation (>1.0 mm) in leads without diagnostic Q waves (other than V1 or V6)

ECG, electrocardiogram; PVC, premature ventricular contraction.

*Baseline refers to a measurement obtained immediately before the test and in the same posture as the test is being performed.*


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**Indications for Terminating Test**

**BOX 5.2 Indications for Terminating Exercise Testing**

**RELATIVE INDICATIONS**
- Drop in systolic blood pressure of >10 mm Hg from baseline* blood pressure despite an increase in workload in the absence of other evidence of ischemia
- ST or QRS changes such as excessive ST depression (>2 mm horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response (systolic blood pressure of >230 mm Hg and/or a diastolic blood pressure of >115 mm Hg).

*Baseline refers to a measurement obtained immediately before the test and in the same posture as the test is being performed.


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**Other Tests**

- **Exercise Echocardiography**
  - Exercise increases the specificity and sensitivity of the echocardiography
  - Looks at wall motion and can detect damage due to ischemia
  - Usually performed during cycling or 1-2 minutes after treadmill exercise
Other Tests

• Exercise Nuclear Imaging
  – A radioactive tracer is injected and then resting images are taken 30-60 min post-injection and then the subject exercises
  – Allows for visualization of the heart, perfusion defects, extent and distribution of ischemia

Other Tests

• Pharmacologic Stress Test
  – Used for people unable to undergo exercise stress testing
  – Two most common tests:
    • Dobutamine stress echocardiography
    • Dipyridamole or adenosine stress nuclear scintigraphy.
  – Tests are used for:
    • Diagnosis of CAD
    • Determining myocardial viability before revascularization
    • Assessing prognosis after MI or chronic angina
    • Evaluating cardiac risk preoperatively.