Cardiopulmonary Exercise Testing (CPET) & Evaluating Functional Capacity

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History

- CPET for a Clinical Trial in CFS
- Research and Publication
- Disability Evaluation
- Pacific Fatigue Laboratory
  - Research and clinical laboratory focused on measuring function in patients with fatigue-related disorders
What Should be Measured?

☐ What is work?

☐ Work Capacity
  ■ The ability to sustain work for a 40 hour work week

☐ Physical Demands vs Physiological Function

☐ Effort
Functional Capacity Evaluations (FCE)

- Provide little scientific evidence for predicting future work performance.
- Problems with extrapolating data from short term testing to an 8 hour work day.
- Fails to assess the impact of the test itself, APTA.
- Objective physiological measures such as HR and BP and pulmonary analysis are usually not taken.
- Does not take diagnosis into account.
Medico-legal Assessments/ Validity and Reliability

- Cardiopulmonary Exercise Testing
  - Measures aerobic capacity
  - Measures work output
  - Measures ability to sustain work
  - Measures exercise/work limitation and determines which system limits function
  - Objectively measures impairment/disability
CPET: What is it?

- Measuring the cardiovascular, pulmonary and metabolic responses at rest and during exercise.
- Key measures:
  - Peak Oxygen Consumption ($\text{VO}_2$)
  - Anaerobic Threshold (AT)
  - Heart Rate (HR)
  - Blood Pressure (BP)
  - Ventilation (VE)
Uses for Cardiopulmonary Exercise Testing (CPET)

- Diagnostic Tool to Evaluate Cardiac, Vascular, Pulmonary and Metabolic Disorders
- Disability Evaluation
- Clinical Trial Outcome Measure
- Fitness Assessment & Exercise Prescription
What is a good FCE?
Cardiopulmonary Exercise Testing (CPET): The Gold Standard

- American College of Cardiology/American Heart Association (ACC/AHA)
- American Thoracic Society/American College of Chest Physicians (ATS/ACCP)
- Social Security Administration (SSA)
- American Physical Therapy Association (APTA)
- American Medical Association (AMA)
- American College of Sports Medicine (ACSM)
“Direct measures of VO2 are reliable and reproducible and provide the most accurate assessment of functional capacity.” Page 31.
“CPET complements other clinical and diagnostic modalities, and by directly quantitating work capacity improves the diagnostic accuracy of impairment/disability evaluation.”
“When the results of tests with measurement of oxygen uptake are available, every reasonable effort should be made to obtain them.

“How does an ETT with measurement of maximal or peak oxygen uptake (VO2) differ from other ETTs?

While ETTs without measurement of VO2 provide only an estimate of aerobic capacity, measured maximal or peak oxygen uptake provides an accurate measurement of aerobic capacity, which is often expressed in METs (metabolic equivalents).”


http://www.socialsecurity.gov/disability/professionals/bluebook/4.00-Cardiovascular-Adult.htm
Evaluating Disabling Fatigue Based on CPET

- Respiratory Impairment - AMA
  - Peak VO₂

- Circulatory Failure/NYHA
  - Peak VO₂
  - VO₂ at the Anaerobic Threshold

- Functional Aerobic Impairment
  - Percent predicted VO₂
## AMA Disability Classification

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% No Impairment of the Whole Person</td>
<td>10-25% Mild Impairment of the Whole Person</td>
<td>30-45% Moderate Impairment of the Whole Person</td>
<td>50-100% Severe Impairment of the Whole Person</td>
</tr>
</tbody>
</table>

- **FVC** ≥ 80% of predicted,  
  **FEV₁** ≥ 80% of predicted,  
  **FEV₁/FVC** ≥ 70% and  
  OR  
  > 25 ml/(kg•min)

- **FVC** between 60% and 79% of predicted,  
  **FEV₁** between 60% and 79% of predicted,  
  **FEV₁/FVC** between 60% and 69%.  
  OR  
  Between 20 and 25 ml/(kg•min)

- **FVC** between 51% and 59% of predicted,  
  **FEV₁** between 41% and 59% of predicted,  
  **FEV₁/FVC** between 41% and 59%.  
  OR  
  Between 15 and 20 ml/(kg•min)

- **FVC** ≤ 50% of predicted,  
  **FEV₁** ≤ 40% of predicted,  
  **FEV₁/FVC** ≤ 40%.  
  OR  
  < 15 ml/(kg•min)

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## Circulatory Failure/NYHA

<table>
<thead>
<tr>
<th>Severity of Impairment</th>
<th>Functional Class</th>
<th>$\text{VO}_2\text{ Max ml/kg/min}$</th>
<th>$\text{VO}_2\text{ AT ml/kg/min}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>None to Mild</td>
<td>A</td>
<td>$&gt;20$</td>
<td>$&gt;14$</td>
</tr>
<tr>
<td>Mild to Moderate</td>
<td>B</td>
<td>16-20</td>
<td>11-14</td>
</tr>
<tr>
<td>Moderate to Severe</td>
<td>C</td>
<td>10-16</td>
<td>8-11</td>
</tr>
<tr>
<td>Severe</td>
<td>D</td>
<td>&lt;10</td>
<td>&lt;8</td>
</tr>
</tbody>
</table>

### Subclassifying CFS Using Impairment Ratings

#### American Medical Association Guidelines

<table>
<thead>
<tr>
<th>Severity of Impairment</th>
<th>Peak VO$_2$ (ml/kg/mi)</th>
<th># of patients</th>
<th>Group VO$_2$ (ml/kg/min)</th>
<th>Predicted VO$_2$ (ml/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None to Mild</td>
<td>&gt;25</td>
<td>33</td>
<td>29.5 ± 0.9</td>
<td>38.6 ± 1.2</td>
</tr>
<tr>
<td>Mild to Mod</td>
<td>20-25</td>
<td>72</td>
<td>22.1 ± 0.2</td>
<td>35.3 ± 0.8</td>
</tr>
<tr>
<td>Mod to Severe</td>
<td>15-20</td>
<td>77</td>
<td>17.2 ± 0.2</td>
<td>34.2 ± 0.6</td>
</tr>
<tr>
<td>Severe</td>
<td>&lt;15</td>
<td>21</td>
<td>12.1 ± 0.5</td>
<td>33.0 ± 0.6</td>
</tr>
</tbody>
</table>

*VanNess et al, 2003*
Post Exertional Malaise (PEM)

- Canadian Case Definition for CFS
- PEM & Cardiopulmonary Exercise Testing
Maximal exercise "induces" a controlled and defined post-exertional state.
Days to Recovery

- Within 24 hours, 85% of CON indicated full recovery in contrast to 0% of CFS patients.
- The remaining 15% of CON recovered within 48 hours.
- Only one CFS patient recovered within 48 hours.

Stevens et al, 2007
Control Symptoms

Symptoms Reported in Controls

- Fatigue
- Light-headedness/vertigo
- Muscular/joint pain
- Cognitive dysfunction
- Headache
- Nausea
- Weakness/instability, trembling
- Insomnia
- Sore throat/swollen glands

Stevens et al, 2007
CFS Symptoms

Symptoms Reported in CFS

- Fatigue
- Light-headedness/vertigo
- Muscular/joint pain
- Cognitive dysfunction
- Headache
- Nausea
- Weakness/instability, trembling
- Insomnia
- Sore throat/swollen glands

Stevens et al, 2007
Test-Retest Strategy

Pre-testing

Test 1

Test 2

“Post-Exertional State”
Test, Retest:

“Stevens’ Protocol”

- New way to look at fatigue through the prism of post exertional malaise.
- It is the best technique to capture the delayed effects of physical stress.
- “One test is not enough”. Severe impairment is the exception.
## Test, Re-test

<table>
<thead>
<tr>
<th></th>
<th>CONTROL</th>
<th>CFS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test 1</td>
<td>Test 2 (v)</td>
</tr>
<tr>
<td>Peak VO2</td>
<td>28.4</td>
<td>28.9 (2%)</td>
</tr>
<tr>
<td>VO2 at AT</td>
<td>17.5</td>
<td>18.0 (3%)</td>
</tr>
<tr>
<td>Peak RQ</td>
<td>1.19</td>
<td>1.21 (2%)</td>
</tr>
<tr>
<td>HR%</td>
<td>94.8</td>
<td>97.6 (3%)</td>
</tr>
</tbody>
</table>

VanNess et al, 2007
Metabolic Dysfunction

Oxidative Impairement in the Post-Exertional State

![Graph showing oxidative impairment in the post-exertional state. Peaks VO2 values for CFS and control groups in Test 1 and Test 2.](image)
Justification

☐ Single test describes physical function in a rested state and creates the stressor necessary to induce PEM.

☐ The second test measures the patient in the PEM state.

☐ Allows for the determination of metabolic dysfunction.
Top Rebuttal Questions

- Effort
- Deconditioning
- Obesity
The Florence Nightingale Effect

- Florence’s behavior in those years of illness prejudiced severely her reputation and achievements
- Influenced by the failure to diagnose an organic illness, biographers suggest that she lied about her health for her own ends
- It is a sad irony that the founder of modern nursing should be remembered as history’s most famous invalid and possibly its most successful malingerer
Assessment of Maximal Effort

2 of the below criteria must be met for the test to meet criteria for maximal effort.

<table>
<thead>
<tr>
<th>Maximal Test Criteria</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Criteria Met Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ ≥ 1.1</td>
<td>1.33</td>
<td>1.22</td>
<td>Yes</td>
</tr>
<tr>
<td>RPE ≥ 17</td>
<td>20</td>
<td>19</td>
<td>Yes</td>
</tr>
<tr>
<td>Plateau in VO2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>HR ≥ 90% of pred</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Tester Determination</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Deconditioning

- Reproducibility of two day testing
Reproducibility of CPET in Other Fatiguing Illnesses

- Other pathologies: Reproducible CPET results
  - Pulmonary Hypertension
  - End Stage Renal Disease
  - Cystic Fibrosis
  - Heart failure
  - Lung diseases

- Even in patients with severe functional limitations exercise testing is reproducible.

- **Failure to reproduce documents metabolic dysfunction**
Obesity in US

- 67% Americans are obese yet are able to work a 40 hour week.
Conclusions

- CPET is the Gold Standard for measuring functional capacity.
- A single test is often inadequate to describe fluctuations in function due to fatigue or pain.
- Test-retest reductions provide objective evidence of metabolic dysfunction.
- CPET objectively documents the fluctuations experienced by patients.
FCE References


Overtraining Syndrome

Sustained reductions in performance often accompanied by other biochemical, physiological and psychological changes
“The specific disease doctrine is the grand refuge of weak, uncultured, unstable minds, such as now rule in the medical profession. There are no specific diseases; there are specific disease conditions.”

Florence Nightingale, 1860