Cardiorespiratory Fitness (CRF) Evaluation with Muscle Oxygenation

Michael Zhang

Vancouver June 2019
Cardiorespiratory Fitness (CRF)

- Ability to supply/consume Oxygen
- Measured by VO2max
- Clinical Vital Sign
- Can reduce the risk of heart disease
- Can improve chronic disease management
Traditional CRF Evaluation
Disadvantages

• High cost
• Low availability
• Needs exercise with maximum effort
• Final result only, not showing what limits the performance
Submaximal Tests

• Low cost
• High availability
• Less accurate
• Not showing the limitations neither
CRF Evaluation with Muscle Oxygenation

- Submaximal test
- Graded exercise test
- SmO2 monitoring during test
- Improved accuracy
- Physical limitation analysis
SmO2 monitoring device
How SmO2 device works
Exercise design

- Heart Rate and SmO2 monitored during the test
- Treadmill at 5% grade
- Warmup 6 minutes with 60%-65% of HRmax
- Rest for 1 minute
- Start test at warmup speed for 4 minutes
- Increase speed for 0.5 km/h to 1 km/h based on subject’s performance
- Repeat the 4 minutes incremental 2 more times (4 in total)
- Calculate VO2max based on speed at 6km/h
- SmO2 analysis
- Adjust VO2max if it’s not correlated with SmO2 analysis
VO2max Calculation

- VO2max (ml/kg.min) = 15.1 + (21.8 × Speed in mph) - (0.327 × HR) - (0.263 × Speed × Age) + (5.98 × Sex) + (0.00504 × HR × Age) [1]

Sex: Male 1, Female 0
HR and SmO2
Understand the physical limitation
SmO2 performance comparison
SmO2 analysis- overall

• Total SmO2 decline shows the ability of muscle to consume oxygen in general.

• The ratio of SmO2 decline over the first minute in all stages show the ability to quickly consume oxygen and reach the balance.
SmO2 analysis - Stage

• The slope for the first minute after speed increase shows the ability of muscle to quickly consume more oxygen. The lower the better. (negative value)

• The slope for the 3 – 4 minutes after speed increase shows the ability to keep muscle oxygen supply. The higher the better.
SmO2 analysis - Final

• Overall score + average stage score
• Final score will be categorized as poor, fair, good
• VO2max will be adjusted if VO2max category is different with SmO2 category
Normative data for VO2max

Female (values in ml/kg/min)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
<th>Superior</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-19</td>
<td>&lt;25.0</td>
<td>25.0 - 30.9</td>
<td>31.0 - 34.9</td>
<td>35.0 - 38.9</td>
<td>39.0 - 41.9</td>
<td>&gt;41.9</td>
</tr>
<tr>
<td>20-29</td>
<td>&lt;23.6</td>
<td>23.6 - 28.9</td>
<td>29.0 - 32.9</td>
<td>33.0 - 36.9</td>
<td>37.0 - 41.0</td>
<td>&gt;41.0</td>
</tr>
<tr>
<td>30-39</td>
<td>&lt;22.8</td>
<td>22.8 - 26.9</td>
<td>27.0 - 31.4</td>
<td>31.5 - 35.6</td>
<td>35.7 - 40.0</td>
<td>&gt;40.0</td>
</tr>
<tr>
<td>40-49</td>
<td>&lt;21.0</td>
<td>21.0 - 24.4</td>
<td>24.5 - 28.9</td>
<td>29.0 - 32.8</td>
<td>32.9 - 36.9</td>
<td>&gt;36.9</td>
</tr>
<tr>
<td>50-59</td>
<td>&lt;20.2</td>
<td>20.2 - 22.7</td>
<td>22.8 - 26.9</td>
<td>27.0 - 31.4</td>
<td>31.5 - 35.7</td>
<td>&gt;35.7</td>
</tr>
<tr>
<td>60+</td>
<td>&lt;17.5</td>
<td>17.5 - 20.1</td>
<td>20.2 - 24.4</td>
<td>24.5 - 30.2</td>
<td>30.3 - 31.4</td>
<td>&gt;31.4</td>
</tr>
</tbody>
</table>

Male (values in ml/kg/min)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Excellent</th>
<th>Superior</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-19</td>
<td>&lt;35.0</td>
<td>35.0 - 38.3</td>
<td>38.4 - 45.1</td>
<td>45.2 - 50.9</td>
<td>51.0 - 55.9</td>
<td>&gt;55.9</td>
</tr>
<tr>
<td>20-29</td>
<td>&lt;33.0</td>
<td>33.0 - 36.4</td>
<td>36.5 - 42.4</td>
<td>42.5 - 46.4</td>
<td>46.5 - 52.4</td>
<td>&gt;52.4</td>
</tr>
<tr>
<td>30-39</td>
<td>&lt;31.5</td>
<td>31.5 - 35.4</td>
<td>35.5 - 40.9</td>
<td>41.0 - 44.9</td>
<td>45.0 - 49.4</td>
<td>&gt;49.4</td>
</tr>
<tr>
<td>40-49</td>
<td>&lt;30.2</td>
<td>30.2 - 33.5</td>
<td>33.6 - 38.9</td>
<td>39.0 - 43.7</td>
<td>43.8 - 48.0</td>
<td>&gt;48.0</td>
</tr>
<tr>
<td>50-59</td>
<td>&lt;26.1</td>
<td>26.1 - 30.9</td>
<td>31.0 - 35.7</td>
<td>35.8 - 40.9</td>
<td>41.0 - 45.3</td>
<td>&gt;45.3</td>
</tr>
<tr>
<td>60+</td>
<td>&lt;20.5</td>
<td>20.5 - 26.0</td>
<td>26.1 - 32.2</td>
<td>32.3 - 36.4</td>
<td>36.5 - 44.2</td>
<td>&gt;44.2</td>
</tr>
</tbody>
</table>

VO2max validation

- A comparison has been done among traditional method, Submaximal test and proposed test
- 35 subjects are included in the comparison
- The average accuracy has been increased from 87.3% to 90.1%

**Descriptive data.**

<table>
<thead>
<tr>
<th></th>
<th>n = 35</th>
<th>Submaximal test</th>
<th>after adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>difference from measured VO2max (ml/kg.min)</td>
<td>-15.3 to 6.6</td>
<td>-12.1 to 6.05</td>
<td></td>
</tr>
<tr>
<td>number of 90% accuracy tests</td>
<td>19</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>average difference from measured VO2max</td>
<td>3.9</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>5.6</td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
</table>
Physical limitation validation

• 45 subjects are involved in the validation test
• Intervention group gets instruction on how to exercise based on SmO2 analysis
• Control group did not get any instruction
• The validation test last 3 months
• VO2max and SmO2 are used to analyze the exercise outcome
## Subject Summary

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Sex</th>
<th>Count</th>
<th>Age (average± SD)</th>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>10</td>
<td>47±6.3</td>
<td>160.1±5.4</td>
<td>59.9±6.5</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23</td>
<td>46.4±9.6</td>
<td>172.2±6.1</td>
<td>73.3±11</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Female</td>
<td>7</td>
<td>39.3±15.3</td>
<td>157±8.1</td>
<td>63.7±13.3</td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
<td>38.6±9</td>
<td>172.8±7.6</td>
<td>81.2±18.3</td>
<td></td>
</tr>
</tbody>
</table>
## Validation Result

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>Count</th>
<th>VO2max Increase</th>
<th>Increased Subject</th>
<th>Ratio</th>
<th>SmO2 Increase</th>
<th>Increase Subject</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intervention</strong></td>
<td>Female</td>
<td>10</td>
<td>1.3±2.00</td>
<td>9</td>
<td>0.90</td>
<td>0.4±0.4</td>
<td>7</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>23</td>
<td>0.9±1.65</td>
<td>18</td>
<td>0.78</td>
<td>0.2±0.5</td>
<td>13</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>Female</td>
<td>7</td>
<td>0.1±1.9</td>
<td>3</td>
<td>0.43</td>
<td>-0.1±1.0</td>
<td>2</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>5</td>
<td>0.2±1</td>
<td>3</td>
<td>0.60</td>
<td>0±0.2</td>
<td>2</td>
<td>0.40</td>
</tr>
</tbody>
</table>
CRF Evaluation with Muscle Oxygenation

- Low Cost
- High Availability
- More Complete Model for Evaluation
- Improved accuracy
- Physical limitation detection
- Reliable analysis for exercise instruction
References

Questions??