AEROBIC EXERCISE INTENSITY PRESCRIPTION IN CARDIAC REHABILITATION: THE PHYSIOLOGICAL SIDE OF THE COIN

A. Mezzani

S. Maugeri Foundation, IRCCS - Scientific Institute of Veruno
Exercise Pathophysiology Laboratory - Cardiac Rehabilitation Division
Veruno (NO) - Italy

Geneva - April 14/16, 2011
## Aerobic training intensity prescription in CHF guidelines

<table>
<thead>
<tr>
<th>Intensity</th>
<th>VO₂ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>40%</td>
<td>70%</td>
</tr>
</tbody>
</table>

**ACC/AHA**

*J Am Coll Cardiol* 2009

**EACPR**

*Eur J Cardiovasc Prev Rehabil* 2010
JOINT EACPR/AACVPR POSITION STATEMENT FOR AEROBIC EXERCISE INTENSITY ASSESSMENT AND PRESCRIPTION IN CARDIAC REHABILITATION

A. Mezzani (Co-Chair) 1, L.F. Hamm (Co-Chair) 2, A.M. Jones 3, P.E. McBride 4, T. Moholdt 5, J.A. Stone 6, A. Urhausen 7, M.A. Williams 8

1 Salvatore Maugeri Foundation IRCCS, Scientific Institute of Veruno - Exercise Pathophysiology Laboratory, Cardiac Rehabilitation Division - Veruno (NO), Italy
2 George Washington University Medical Center, School of Public Health and Health Services - Department of Exercise Science - Washington, DC, USA
3 University of Exeter, School of Sport and Health Sciences - Exeter, Devon, United Kingdom
4 University of Wisconsin, School of Medicine and Public Health - Department of Medicine, and Medicine and Family Medicine - Madison, WI, USA
5 Norwegian University of Science and Technology, K.G. Jebsen Center of Exercise in Medicine - Department of Circulation and Medical Imaging - Trondheim, Norway
6 University of Calgary - Calgary, Canada
7 Hospital Centre of Luxembourg - Centre of Locomotor System, Sports Medicine and Prevention - CRP-Santé, Luxembourg
8 Creighton University School of Medicine - Division of Cardiology - Department of Medicine - Omaha, NE, USA

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Criteria for adequate exercise intensity assessment and prescription

1) Knowledge of individual patient’s exercise intensity domains (patho)physiological limits.

2) Knowledge of differences between both physiological response to exercise in different intensity domains and exercise models used for exercise intensity assessment and prescription (incremental vs. constant-work-rate).

3) Knowledge of scientific evidence regarding efficacy and safety of exercise in different intensity domains in specific patients’ populations.
Exercise intensity domains

- Basal
- Light to moderate
- Moderate to high
- High to severe
- Severe to extreme

- Basal
- 1st VT
- 2nd VT
- Peak VO₂
Light to moderate intensity!
Light to moderate


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First ventilatory threshold

\[ VCO_2 \text{ (l/min)} \]

\[ VO_2 \text{ (l/min)} \]

\[ S1 = 0.86 \]
\[ S2 = 1.28 \]

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Light to moderate-intensity aerobic training in CHF

40% peak VO$_2$

23% VO$_2$R

Peak VO$_2$ 16.1 --> 18.9 ml/kg/min

Belardinelli R, J Am Coll Cardiol 1995

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≤50% peak VO$_2$
17-30% VO$_2$R
Peak VO$_2$ 11.5 → 15.0 ml/kg/min

Demopoulos L, J Am Coll Cardiol 1997

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<table>
<thead>
<tr>
<th>Intensity</th>
<th>VO$_2$ steady-state</th>
<th>Lactate steady-state</th>
<th>CWR exercise duration</th>
<th>% peak VO$_2$ (\infty)</th>
<th>% peak W</th>
<th>Training modality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light to moderate</td>
<td>Yes</td>
<td>n.a.</td>
<td>&gt; 30 min</td>
<td>Yes</td>
<td></td>
<td>Continuous</td>
</tr>
<tr>
<td>Moderate to high</td>
<td>Yes</td>
<td>Yes</td>
<td>~ 20-30 min</td>
<td>No</td>
<td></td>
<td>Continuous</td>
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<tr>
<td>High to severe</td>
<td>No</td>
<td>No</td>
<td>3-20 min</td>
<td>n.a.</td>
<td></td>
<td>Interval (3-8 min, repeated)</td>
</tr>
<tr>
<td>Severe to extreme</td>
<td>No</td>
<td>No</td>
<td>≤3 min</td>
<td>n.a.</td>
<td></td>
<td>Interval (15-60 s, repeated)</td>
</tr>
</tbody>
</table>

CWR = constant-work-rate; n.a. = not applicable.
Moderate to high intensity!
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The graph illustrates the relationship between work output (W) and oxygen uptake (VO₂) with zones of light to moderate, moderate to high, and high to severe intensity. The first ventilatory threshold (1st VT) and second ventilatory threshold (2nd VT) are indicated along with the peak VO₂.

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Incremental exercise

Steady-state obtainable at same relative intensity
Steady-state obtainable at higher relative intensity
High to severe

Light to moderate

Steady-state not obtainable

CP (2nd VT)

1st VT

% Peak VO₂/W

% Peak VO₂

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Critical power

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Second ventilatory threshold

\[ \text{VE/V}O_2 = \text{VE/V}CO_2 \]

\[ 1^{\text{st}} \text{ VT} \]

\[ 2^{\text{nd}} \text{ VT} \]

Geneva – April 14/16, 2011
## Moderate to high-intensity aerobic training in CHF

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title and Journal</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roveda F,</td>
<td>J Am Coll Cardiol</td>
<td>90% of HR at 2\textsuperscript{nd} VT</td>
</tr>
<tr>
<td>Giannuzzi P,</td>
<td>Circulation</td>
<td>60% peak VO\textsubscript{2}</td>
</tr>
<tr>
<td>Beckers P,</td>
<td>EJCP</td>
<td>90% of HR at 2\textsuperscript{nd} VT</td>
</tr>
<tr>
<td>Van Craenenbroeck EM,</td>
<td>Basic Res Cardiol</td>
<td>90% of HR at 2\textsuperscript{nd} VT</td>
</tr>
</tbody>
</table>

*Geneva – April 14/16, 2011*
**ELVD - CHF**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>6 Months</td>
</tr>
<tr>
<td><strong>EDV (ml/m²)</strong></td>
<td>147 ± 41</td>
<td>156 ± 42 *†</td>
</tr>
<tr>
<td><strong>ESV (ml/m²)</strong></td>
<td>110 ± 34</td>
<td>118 ± 34 †</td>
</tr>
<tr>
<td><strong>EF (%)</strong></td>
<td>25 ± 4</td>
<td>25 ± 5 †</td>
</tr>
</tbody>
</table>

* = p < 0.01; † = p < 0.001 for interaction

Giannuzzi P, Circulation 2003
<table>
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<tr>
<th>Intensity</th>
<th>VO₂ steady-state</th>
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<td>Interval (15-60 s, repeated)</td>
</tr>
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CWR = constant-work-rate; n.a. = not applicable.
Pull, please!  High to severe intensity!
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Incremental exercise
Constant-work-rate exercise

Steady-state obtainable at same relative intensity
Steady-state obtainable at higher relative intensity
Steady-state not obtainable

Light to moderate
Moderate to high
High to severe

% Peak VO₂/W
% Peak VO₂

CP (2nd VT)
1st VT

100 90 80 70 60 50 40 30 20 10 0

Steady-state obtainable at higher relative intensity
Steady-state not obtainable

Light to moderate
Moderate to high
High to severe

Incremental exercise
Constant-work-rate exercise

Steady-state obtainable at same relative intensity
Steady-state obtainable at higher relative intensity
Steady-state not obtainable

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High to severe-intensity aerobic training in CHF

- Warm-up
  - 60 - 70% intensity
  - 8 - 10 minutes
  - Active pause: 60 - 70% for 3 minutes
- Interval
- Active pause: 60 - 70% for 3 minutes
- Interval
- Active pause: 60 - 70% for 3 minutes
- Interval
- Active pause: 60 - 70% for 3 minutes
- Cool-down
  - 60 - 70% intensity
  - 3 - 5 minutes

Intensity is expressed as % of individual peak heart rate

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# Aerobic interval training in CHF

**Wisløff U, Circulation 2007**

## Table 3. LV Volumes and Resting Hemodynamics

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>MCT</th>
<th>AIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Follow-Up</td>
<td>Baseline</td>
</tr>
<tr>
<td>LVDD, mm</td>
<td>67.2 ± 8.1</td>
<td>67.8 ± 12.5</td>
<td>69.1 ± 8.6</td>
</tr>
<tr>
<td>LVSD, mm</td>
<td>56.2 ± 9.2</td>
<td>56.7 ± 13.7</td>
<td>56.6 ± 8.8</td>
</tr>
<tr>
<td>LVEDV, mL</td>
<td>250.5 ± 64.4</td>
<td>242.1 ± 62.3</td>
<td>245.5 ± 53.1</td>
</tr>
<tr>
<td>LVESV, mL</td>
<td>187.8 ± 53.0</td>
<td>186.6 ± 58.6</td>
<td>172.9 ± 48.7</td>
</tr>
<tr>
<td>HR at rest, bpm</td>
<td>60 ± 11</td>
<td>59 ± 11</td>
<td>55 ± 10</td>
</tr>
<tr>
<td>SV, mL</td>
<td>53.4 ± 15.3</td>
<td>55.0 ± 13.7</td>
<td>63.5 ± 12.7</td>
</tr>
<tr>
<td>CO, L/min</td>
<td>3.1 ± 0.6</td>
<td>3.2 ± 0.5</td>
<td>3.5 ± 0.9</td>
</tr>
<tr>
<td>EF, %</td>
<td>26.2 ± 8.0</td>
<td>26.6 ± 9.7</td>
<td>32.8 ± 4.8</td>
</tr>
</tbody>
</table>

Data are mean ± SD. LVDD indicates LV diastolic diameter; LVSD, LV systolic diameter; LVEDV, LV end-diastolic volume; LVESV, LV end-systolic diameter; HR, heart rate; SV, stroke volume; CO, cardiac output; and EF, ejection fraction.

*Different from baseline, P<0.01; †different from controls and moderately trained, P<0.02.
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<td>Interval (15-60 s, repeated)</td>
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CWR = constant-work-rate; n.a. = not applicable.
Aerobic training intensity prescription in CHF guidelines

60% ----> 80% peak VO$_2$

ACC/AHA
J Am Coll Cardiol 2009

40% ----> 70% peak VO$_2$

EACPR
Eur J Cardiovasc Prev Rehabil 2010
### CHF patients in stable NYHA class I-III

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Physiological upper limit</th>
<th>Performance upper limit</th>
<th>Perceived exertion upper limit</th>
<th>Exercise type/duration</th>
<th>ACSM classif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light to moderate</td>
<td>~50% peak VO$_2$/VO$_2$R</td>
<td>Work rate at 1$^{st}$VT</td>
<td>&lt;12 RPE Borg scale</td>
<td>Continuous ≥30 min</td>
<td>VL to Mod.</td>
</tr>
<tr>
<td></td>
<td>~60% peak HR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>~50% HRR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate to high</td>
<td>n.a.</td>
<td>~ 70% peak work rate</td>
<td>12-15 RPE Borg scale</td>
<td>Continuous 15-30 min</td>
<td>Mod. to H</td>
</tr>
<tr>
<td>High to severe</td>
<td>Peak VO$_2$</td>
<td>≥ 100% peak work rate</td>
<td>16-18 RPE Borg scale</td>
<td>Interval (3-8 minutes, repeated)</td>
<td>H to Max.</td>
</tr>
<tr>
<td>Severe to extreme</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

VO$_2$R = VO$_2$ reserve; HR = heart rate; HRR = heart rate reserve; 1$^{st}$VT = first ventilatory threshold; RPE = rating of perceived exertion; n.a = not applicable.
Patients with implanted LVAD

<table>
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<th>Performance upper limit</th>
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<tr>
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<td>Work rate at 1st VT</td>
<td>~60% peak HR</td>
<td>Continuous ≥30 min</td>
<td>VL to Mod.</td>
</tr>
<tr>
<td></td>
<td>~50% HRR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate to high</td>
<td>?</td>
<td>?</td>
<td></td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>High to severe</td>
<td>?</td>
<td>?</td>
<td>?</td>
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<td>Severe to extreme</td>
<td>?</td>
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VO₂R = VO₂ reserve; HR = heart rate; HRR = heart rate reserve; 1stVT = first ventilatory threshold; RPE = rating of perceived exertion; n.a = not applicable.
The choice of the aerobic training stimulus intensity in the individual cardiac patient is still largely a matter of clinical judgement. The concept put forward in this paper is that aerobic exercise prescription should be based on the choice of one exercise intensity domain according to both the patient’s clinical and pathophysiological picture and the peculiar response to and the evidence-based benefits of exercise in that intensity domain. The importance of patients’ functional evaluation through exercise testing prior to starting a training program is strongly stressed, and cardiopulmonary exercise testing is proposed as the gold standard for a physiologically meaningful exercise intensity assessment and prescription.