Cardiopulmonary exercise test among children with congenital heart diseases: a multicenter study

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Disclosure Statement of Financial Interest

I currently have, or have had over the last two years, an affiliation or financial interests or interests of any order with a company or I receive compensation or fees or research grants with a commercial company:

Grant/Research Support: **Bayer Healthcare, Actelion Pharmaceuticals, Novartis**

Consulting Fees/Honoraria: **Astra Zeneca, Pierre Fabre**

Major Stock Shareholder/Equity: None

Royalty Income: None

Ownership/Founder: None

Intellectual Property Rights: None

Other Financial Benefit: None
What we already know in adults with chronic heart failure and ACHD

• Adaptation to exercise:
  – Peak VO2 and VE/VCO2 slope related to the severity of the disease
    • NYHA in CHF
    • complex CHD in ACHD
  – Peak VO2 and VE/VCO2 slope correlated to the physical dimension of the QoL

• CPET is recommended in ACHD follow-up

  • Hager et al. *Heart* 2005
  • Kamphuis et al. *Heart* 2002
  • Culbert *Circulation* 2003

  • Baumgartner et al. *EHJ* 2010
Correlation between cardio-pulmonary exercise test variables and health-related quality of life among children with congenital heart diseases

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Aims

• To measure peak VO2 in a large cohort of CHD children
• To compare peak VO2 to a control population
• To correlate peak VO2 to predicted peak VO2 (from Wasserman and Cooper)
• To identify variables that most impacted peak VO2 in CHD children
Method

- Retrospective observational study.
- Children aged 5 to 18 who performed a complete CPET between 2010 and 2015 in 2 French pediatric CHD tertiary care centers.
- CHD group was defined upon L. Houyel's classification.
- Children with no chronic disease, no treatment and normal physical examination were included in the control group.
- Data were adjusted on age and gender.
- The impact of CPET and clinical variables on peak VO2 was studied with multivariate analysis.
Flow chart

CHD  
N:2007 CPET  
Controls

Center 1  
N=101  
Center 2  
N=469  

Non-eligible  
N=74  
- Heart transplant  
- Cardiomyopathy  
- Idiopathic pulmonary hypertension  
- Arrhythmia  
- Kawasaki disease  
- Myopericarditis

Included  
N=496

Center 1  
N=803  
Center 2  
N=634  

Non-eligible  
N=1135  
- Asthma  
- Cystic fibrosis  
- Anthracycline chemotherapy  
- Obesity  
- Drug therapy

Included  
N=302
## Results: population

<table>
<thead>
<tr>
<th>CHD Group</th>
<th>ACC-CHD classification</th>
<th>N</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m^2)</th>
<th>Sex ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td></td>
<td>302</td>
<td>11.1±2.6</td>
<td>150±16</td>
<td>42.2±13.3</td>
<td>18.3 ± 2.9</td>
<td>1.32</td>
</tr>
<tr>
<td>CHD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Heterotaxy</td>
<td>3</td>
<td>9 ±3.6</td>
<td>142.3±19.7</td>
<td>31.7±12.4</td>
<td>15.1 ± 1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>Anomalies of the venous return</td>
<td>13</td>
<td>11.7±4</td>
<td>148.8±18.4</td>
<td>42.1±12.8</td>
<td>18.5±2.2</td>
<td>1.17</td>
</tr>
<tr>
<td>3</td>
<td>Anomalies of the atria and interatrial communications</td>
<td>29</td>
<td>12.3±3</td>
<td>153.9±16.6</td>
<td>44.9±11.1</td>
<td>18.6±2.5</td>
<td>0.52</td>
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<tr>
<td>4</td>
<td>Anomalies of the atrioventricular junctions and valves</td>
<td>27</td>
<td>11.6±3.3</td>
<td>150.2±19.2</td>
<td>42.6±16.9</td>
<td>18.1±3.5</td>
<td>0.8</td>
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<tr>
<td>5</td>
<td>Complex anomalies of atrioventricular connections</td>
<td>5</td>
<td>13±2.4</td>
<td>154.8±16.8</td>
<td>45.8±18.2</td>
<td>18.5±4.6</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>Functionally univentricular hearts</td>
<td>25</td>
<td>12.6±3.5</td>
<td>148.1±18.6</td>
<td>41.9±13.1</td>
<td>18.6±2.7</td>
<td>2.13</td>
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<tr>
<td>7</td>
<td>Ventricular septal defects (VSD)</td>
<td>46</td>
<td>12.7±3</td>
<td>154.4±16.5</td>
<td>46.4±16</td>
<td>18.9±3.9</td>
<td>1.42</td>
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<tr>
<td>8</td>
<td>Anomalies of the ventricular outflow tracts</td>
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<td></td>
</tr>
<tr>
<td>8.1</td>
<td>Transposition of the great arteries</td>
<td>72</td>
<td>11.8±3.3</td>
<td>151.6±19.4</td>
<td>46.6±18.7</td>
<td>19.5±4</td>
<td>4.54</td>
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<tr>
<td>8.2</td>
<td>Tetralogy of Fallot, truncus arteriosus, pulmonary atresia, double outlet right ventricle</td>
<td>93</td>
<td>12.2±3.5</td>
<td>149.7±17.2</td>
<td>41.3±15.1</td>
<td>17.8±3.3</td>
<td>1.21</td>
</tr>
<tr>
<td>8.5</td>
<td>Aortic valve stenosis, Shone syndrome</td>
<td>52</td>
<td>12.5±3.2</td>
<td>150.8±15.6</td>
<td>46±15.8</td>
<td>19.6±3.9</td>
<td>1</td>
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<tr>
<td>8.6</td>
<td>Pulmonary valve stenosis</td>
<td>49</td>
<td>11.6±3.2</td>
<td>148.4±15.5</td>
<td>41±12</td>
<td>18.2±2.6</td>
<td>0.88</td>
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<tr>
<td>9</td>
<td>Anomalies of the extrapericardial arterial trunks</td>
<td>76</td>
<td>12.5±3.3</td>
<td>152±18.2</td>
<td>46±17</td>
<td>19.2±4.2</td>
<td>2.17</td>
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<tr>
<td>10</td>
<td>Congenital anomalies of the coronary arteries</td>
<td>6</td>
<td>11.5±3.2</td>
<td>144±18.5</td>
<td>44.6±22.1</td>
<td>20.2±4.8</td>
<td>0.5</td>
</tr>
</tbody>
</table>
# Peak VO2: global results

<table>
<thead>
<tr>
<th>CHD</th>
<th>Controls</th>
<th>CHD versus controls *</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Mean peak VO2 (ml/kg/min)</td>
<td>Mean peak VO2 (ml/kg/min)</td>
</tr>
<tr>
<td>496</td>
<td>38.1 ± 8.1</td>
<td>93%</td>
</tr>
</tbody>
</table>

* Values adjusted on age and gender
## Peak VO2 and CHD

<table>
<thead>
<tr>
<th>Peak VO2</th>
<th>Group</th>
<th>CHD</th>
<th>% of the controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>8.6</td>
<td>Pulmonary valve stenosis</td>
<td>94%</td>
</tr>
<tr>
<td>Very good</td>
<td>3</td>
<td>ASD</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Anomalies of the extra-pericardial arterial trunks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.1</td>
<td>TGA</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>2</td>
<td>Abnormal venous return</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Anomalies of the atrioventricular junction and valves</td>
<td>80-90%</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>VSD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.2</td>
<td>Fallot, truncus arteriosus, pulmonary atresia, DORV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.5</td>
<td>Aortic stenosis, Shone</td>
<td></td>
</tr>
<tr>
<td>Moderately impaired</td>
<td>6</td>
<td>Functionally univentricular hearts</td>
<td>72%</td>
</tr>
</tbody>
</table>
Peak VO2: comparison between CHD and predicted values from Wasserman and Cooper

• The % of predicted peak VO2 > 85% in our cohort of CHD children

• Except for:
  – group 5 (complex anomalies of atrioventricular connections): 79.7%
  – and group 6 (functionally univentricular hearts): 76.4%
Report of the % of predicted peak VO2 (Wasserman and Cooper). The thick line indicates the mean values. The fine lines indicate the 1st and 3rd interquartile.
Determinants of peak VO2

*Univariate analysis*

- **Restrictive syndrome** $p < 0.001$
- **Right ventricle hypertension** $p < 0.001$
- **Valvular regurgitation:**
  - mitral valve $p < 0.001$,
  - aortic valve $p = 0.001$,
  - tricuspid valve $p = 0.006$
  - pulmonary valve $p = 0.003$
  - correlation between the degree of pulmonary and tricuspid regurgitations and peak VO2
- **Altered systemic ventricle ejection fraction** $p = 0.004$
Determinants of peak VO2

Multivariate analysis

- female gender
- existence of a genetic anomaly
- number of cardiac catheterization
- tricuspid regurgitation
- number of heart surgery
- aortic regurgitation
- pulmonary regurgitation
- age: VO2 alters with age in CHD but not in the controls
Limits

- Retrospective study
- Control population: selected at the hospital
- Selection in tertiary care centers: over-representation of complex CHD
Perspectives

• Other CPET variables :
  – Anaerobic threshold
  – VE/VCO2 slope
  – OUES
  – Oxygen pulse

• Evolution in time

• Rehabilitation in CHD children : need for a controlled randomized study
Conclusion

• Peak VO2 among children with CHD is not as altered as in adults but remained significantly lower than normal children.

• Normal CPET can participate to promote physical activity and sports in CHD children

• Peak VO2 and QoL can be used as endpoint in CHD clinical trials

• Should we recommend performing CPET in routine follow-up of CHD children?
Thanks to Montpellier CHD team

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Collaboration with:
Pediatric and Congenital Cardiology, - La Timone University Hospital, Marseille, France - Toulouse University Hospital

Hôpitaux de Toulouse