Respiratory muscle training in spinal cord injury: Practical applications for patients and athletes

PD Dr. sc. nat. Claudio Perret
Institute of Sports Medicine
Swiss Paraplegic Centre Nottwil
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Content

• Respiratory function and respiratory complications in spinal cord injury (SCI)
• Respiratory muscle training (RMT) methods
• Application of RMT in patients and athletes with SCI
• Practical aspects and conclusions

Respiratory muscle innervation

Schilero et al., 2009

Coughing is a problem!

Respiratory function

Schilero et al., 2009

Restrictive respiratory pattern

Higher lesion = less expiratory function

Lung function and spinal cord injury

Linn et al., 2000
Causes of death in spinal cord injury (SCI)

Year of Death

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>CPI (n = 52)</th>
<th>CPI (n = 104)</th>
<th>CPI (n = 115)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td>39.6</td>
<td>31.5</td>
<td></td>
</tr>
<tr>
<td>Non-respiratory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary</td>
<td></td>
<td>25.9</td>
<td></td>
</tr>
<tr>
<td>E-Valve</td>
<td>2.0</td>
<td></td>
<td>5.7</td>
</tr>
<tr>
<td>others</td>
<td></td>
<td>3.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Pneumonia</td>
<td></td>
<td>4.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Cancer</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Other causes</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

DeCleene et al., 1999

Sleep apnoea and tetraplegia

Respiratory complications

- Alveolar hypoventilation
- Atelectasis

Summary respiratory complications

- Increased mortality (Kelly et al., 2002)
- Prolonged hospitalisation times during first rehabilitation (Winslow et al., 2002)
- Ventilation/respiratory care necessary
- Decreased quality of life (Tator et al., 1993)
- High Pimax prevents from pneumonia (Ruett et al., 2015)

→ Can RMT solve these problems?

Respiratory muscle training (RMT)

- «Endurance training» (isocapnic hyperpnea)
- «Strength training» (resistive loaded breathing)
Optimal training intensity of IH in SCI

Cardiovascular response

<table>
<thead>
<tr>
<th>Intensity [% MVV]</th>
<th>Patients with paraplegia n=11</th>
<th>Patients with tetraplegia n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>11 (1)</td>
<td>9 (1)</td>
</tr>
<tr>
<td>40%</td>
<td>11 (1)</td>
<td>10 (1)</td>
</tr>
<tr>
<td>60%</td>
<td>11 (1)</td>
<td>10 (1)</td>
</tr>
</tbody>
</table>

- Heart rate (bpm): 70 (11) vs 80 (10)
- Systolic blood pressure (mmHg): 140 (24) vs 140 (24)
- Diastolic blood pressure (mmHg): 90 (15) vs 90 (15)
- Respiratory rate (breaths/min): 15 (3) vs 15 (3)
- Respiratory effort (mmHg): 40 (5.7) vs 60 (8.5)

Some potential for cardiovascular training in SCI?
Mueller et al., 2006

Comparison of different training methods

IRT: 90 max. inspiratory manoeuvres with feedback
IH: at 40-50% MVV increasing BF
Incentive spirometry (Placebo) 16x inspiration to TLC

Pi<sub>max</sub> pre and post training

Mueller et al., 2013
Cohen's effect sizes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IRT vs placebo</th>
<th>IH vs placebo</th>
<th>IRT vs IH</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEF</td>
<td>0.05</td>
<td>-0.18</td>
<td>0.86</td>
</tr>
<tr>
<td>Pmax</td>
<td>0.11</td>
<td>-0.15</td>
<td>0.22</td>
</tr>
<tr>
<td>To blow one's nose</td>
<td>0.97</td>
<td>0.67</td>
<td>0.37</td>
</tr>
<tr>
<td>Breathlessness during exercise</td>
<td>0.77</td>
<td>0.81</td>
<td>0.16</td>
</tr>
<tr>
<td>SF-12 physical part</td>
<td>0.93</td>
<td>0.72</td>
<td>-0.18</td>
</tr>
<tr>
<td>SF-12 mental part</td>
<td>0.18</td>
<td>0.03</td>
<td>0.05</td>
</tr>
</tbody>
</table>

μ ≥ 0.2 small effect, μ ≥ 0.5 medium effect, μ ≥ 0.8 high effect

Mueller et al., 2013

Clinical consequences from our findings

- IRT seems to be superior to IH during first rehabilitation of our patients
- IRT defined as standard training method for our patients
- Installation of a respiratory muscle training group in our clinic since 2010

Cochrane Review on RMT in cervical SCI

- Primary outcomes: Complications, Dyspnoea, VC
- Secondary outcomes: Pimax, Pemax, FEV1, QoL
- 11 RCTs (n=212)

Berlowitz and Tamplin., 2013

Pimax analysis

Some positive effects, but also large variation

Berlowitz and Tamplin., 2013

Pemax analysis

Some positive effects, but also large variation

Berlowitz and Tamplin., 2013

Review conclusions

- Significant effect for VC, Pimax, and Pemax
- No effect for FEV1 and dyspnoea
- Analyses for QoL and respiratory complications not possible
  - Open questions: Optimal training load, intensity, duration?
  - Big gap to overcome in future studies!

Berlowitz and Tamplin., 2013
Wheelchair sports and RMT

Effects of Respiratory Muscle Endurance Training on Wheelchair Racing Performance in Athletes With Paraplegia: A Pilot Study
Gabi Mueller, MD*, Claudia Pernet, PhD† and Marcus T.E. Wagner, MD PhD

10km time trial performance

<table>
<thead>
<tr>
<th>Time of 10km race ± standard error (min)</th>
<th>Training Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>31.1 (0.9)</td>
<td>32.4 (2.0)</td>
</tr>
<tr>
<td>Mean ± standard error (V̇O₂max)</td>
<td>76.3 (4.6)</td>
<td>77.1 (4.8)</td>
</tr>
<tr>
<td>Mean ± standard error (hR)</td>
<td>18.4 (1.5)</td>
<td>18.7 (1.7)</td>
</tr>
<tr>
<td>Mean ± standard error (V̇E)</td>
<td>32.8 (1.6)</td>
<td>33.0 (1.7)</td>
</tr>
<tr>
<td>Mean ± standard error (sR)</td>
<td>1.2 (0.1)</td>
<td>1.2 (0.1)</td>
</tr>
<tr>
<td>Respiratory exchange factor</td>
<td>39.4 (3.8)</td>
<td>39.5 (3.9)</td>
</tr>
<tr>
<td>Mean ± standard error (BRE)</td>
<td>40.0 (3.9)</td>
<td>40.1 (4.0)</td>
</tr>
</tbody>
</table>

Respiratory muscle endurance

* P = 0.007

Training group
Control group

Resistive loaded breathing for warm-up?

- Positive effects on performance in able-bodied athletes
  - increased 2000m rowing performance (Volianitis et al., 2001)
  - increased intermittent running performance (Tang and Fu, 2006)
  - increased 100m swimming performance in combination with conventional warm-up (Wilson et al., 2014)

Also true in wheelchair sports?

Results with handcyclists

Can RMT enhance recovery?

- Decreased blood lactate concentration during cycling exercise after RMT program (isocapnic hyperpnoea) (Spengler et al., 1996)

Do respiratory muscles have the potential to enhance blood lactate elimination after exhaustive upper-body exercise?

Advantages?
- Faster recovery after competitions
- Enhanced refilling of glycogen stores in arm muscles (Ost et al., 1994)
Results: lactate elimination

Practical aspects of RMT

- Time consuming and boring
- Handling (e.g. individuals with tetraplegia)
- Costs
- Coordination of RMT and physical exercise/training
- Stop RMT some days before competitions!
- RMT in the same position as during exercise

Conclusions

- RMT is effective for increasing respiratory muscle strength in persons suffering from SCI
- During the first rehabilitation of patients with SCI IRT is superior to IH
- IH showed some benefits for wheelchair sports and might enhance cardiovascular fitness in SCI

Thank you for your attention!