Neural drive to the diaphragm in cervical spinal cord injury

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Background

- Neural control of breathing
- Spinal innervation of the respiratory muscles
  - Diaphragm (C3-C5)
- Cervical spinal cord injury
  - Partial paralysis of diaphragm
  - Reduced inspiratory capacity
  - Increased neural drive following unilateral cervical spinal cord contusion in rodents (Rana et al., 2016)
Aims & Hypotheses

• Determine if there are age-related changes to the neural drive to the diaphragm – Increase in motor unit output

• Determine if there are changes in discharge properties of diaphragm motor units in people with tetraplegia
  – Increase in motor unit output

• Determine if there are neurogenic changes in diaphragm motor units in people with tetraplegia
  – Larger motor unit potentials
Participants:
- Tetraplegia
  - n = 6
  - Aged 59 ± 10 years (mean ± SD)
  - BMI 25 ± 2 kg/m²
  - C3-C6, AIS A-C, chronic
  - MIP: 46 ± 15 cmH₂O
- Able-bodied controls
  - n = 6
  - Aged 59 ± 14 years
  - BMI 26 ± 2 kg/m²
  - MIP: 104 ± 34 cmH₂O

Recording:
- Seated and during quiet breathing
- Ultrasound imaging
- Intramuscular EMG electrode
Motor unit extraction from a participant with tetraplegia
Time & Frequency Plots

SCI (n = 98)
62 sites

Control (n = 166)
71 sites

- <6.0 Hz
- 6.0 - 9.5 Hz
- 9.5 - 13.0 Hz
- 13.0 - 16.5 Hz
- 16.5 - 20.0 Hz
- >20.0 Hz

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### Motor Unit Frequencies & Times

<table>
<thead>
<tr>
<th></th>
<th>Tetraplegia</th>
<th>Able-bodied control</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset discharge frequency (Hz)</td>
<td>10.9 ± 3.3*</td>
<td>8.7 ± 1.8</td>
<td>0.017</td>
</tr>
<tr>
<td>Peak discharge frequency (Hz)</td>
<td>17.2 ± 5.0*</td>
<td>12.4 ± 2.2</td>
<td>&lt; 0.001</td>
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<tr>
<td>Offset discharge frequency (Hz)</td>
<td>9.0 ± 3.8*</td>
<td>6.7 ± 1.6</td>
<td>0.040</td>
</tr>
<tr>
<td>Tidal volume (l)</td>
<td>0.64 ± 0.12</td>
<td>0.70 ± 0.19</td>
<td>0.081</td>
</tr>
<tr>
<td>Inspiratory time (s)</td>
<td>1.65 ± 0.30</td>
<td>1.71 ± 0.39</td>
<td>0.172</td>
</tr>
<tr>
<td>Mean flow (l/s)</td>
<td>0.39 ± 0.05</td>
<td>0.41 ± 0.10</td>
<td>0.322</td>
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</tbody>
</table>

Increase in discharge frequency suggests an increase in neural drive to the diaphragm during quiet breathing in tetraplegia.
Motor Unit Potential Morphology

- **SCI**
  - **duration**
  - **area**

- **Control**
  - **amplitude**

Scale:
- 0.5 mV
- 10 ms
SMU Duration

Mean 10.8

Number/group number x 100%

Duration (ms)

P = 0.186

SCI
Control
SMU Amplitude

Number/group number x 100%

Amplitude (µV)

528 1054

P = 0.025

SCI
Control
Diaphragm motor unit potentials are larger in tetraplegia

Number/group number x 100%

SMU Area

Area (mV.s)

P = 0.016

0 1 2 3 4 5 6 7 8 9 10 11

Diaphragm motor unit potentials are larger in tetraplegia
In tetraplegia:

- Diaphragm motor unit discharge frequencies are higher during quiet breathing
- Diaphragm motor unit potentials are larger
Physiological Mechanisms

Increase in discharge frequency of diaphragm motor units

- Following cervical spinal cord injury, diaphragm muscle strength is reduced
- Diaphragm motor unit discharge frequency increases as an adaptation to maintain ventilation

Increase in size of diaphragm motor unit potentials

- Damaged phrenic motoneurones denervate their diaphragm muscle fibres
- Remaining phrenic motoneurones innervate denervated muscle fibres
- Innervating a larger number of muscle fibres results in a larger motor unit action potential
Acknowledgements

- Dr. Chaminda Lewis
- Dr. Claire Boswell-Ruys
- Dr. Anna Hudson
- Prof. Simon Gandevia
- Prof. Jane Butler
- Participants
- Australia National Health and Medical Research Council & Research Training Program