EXERCISE BAROREFLEX AND IMPLICATION FOR SPORT CONCUSSION: A CASE STUDY

Scott A Bishop¹,², Ryan Dech¹, Jytopal Singh¹, J Patrick Neary¹
¹Faculty of Kinesiology and Health Studies, University of Regina, Regina
²School of Rehabilitation Sciences, College of Medicine, University of Saskatchewan

Funding Disclosure
This study was supported in part by grants from the Canadian Institutes of Health Research and Saskatchewan Health Research Foundation.

Contact Information
For further information regarding this study, contact Dr. J. Patrick Neary, Faculty of Kinesiology and Health Studies, University of Regina, Regina, SK, S4S 0A2. Phone: (306) 585-4484. Email: patrick.neary@uregina.ca

BACKGROUND

▪ When starting exercise, the brain changes how it regulates and monitors blood flow-pressure to itself, which includes monitoring CO₂ (3).
▪ Exercise can induce symptom exacerbation, but the underlying mechanism is still unknown. It is thought that flow-pressure monitoring and regulation may be altered, and may induce oxidative stress at a cellular level (1).
▪ Several sport concussion studies have measured cerebrovascular physiology, and have reported altered brain blood flow and blood pressure metrics post-injury (4-5).
▪ The cerebrovascular physiology is perturbed for periods of time that overlap with the Consensus Statement on Concussion in Sport’s recommendation for starting exercise post-injury (4-5).
▪ These same cerebrovascular sport concussion studies report athletes returning to play prior to physiologic recovery with no complications (1-2,4-5).
Exercise also challenges the ability of blood pressure reflexes (AKA baroreflexes), to operate as they would under resting conditions.

Baroreflexes protect from hyper- or hypo- cerebral perfusion pressure, and operate within a 5 second timespan.

Decreased heart rate and blood pressure reflexively occur when cerebral perfusion pressure is high, and the inverse when cerebral perfusion is low.

Baroreflexes can be elicited through postural changes, such as a cyclical 10 second squat-stand (10SS) maneuver.

Few projects investigate how the brain regulates healthy baroreflexes pre- and post-exercise, and none have investigated baroreflexes with exercise post-concussion (6-7).

There is a need to develop a protocol which can be used to help decide if–and-when an athlete should attempt exercise.

The protocol should attempt to challenge brain blood flow-pressure (as it will likely challenge the ability to prevent oxidative stress).

Additionally, there are likely differences in how blood flow-pressure is managed in concussed athletes versus the general population, but are not well understood.

A baroreflex may further aide clinicians when deciding about activity progression post-concussion.

Lastly, the physiology of exercise-induced symptom exacerbation must be better understood.

**PURPOSE**

To investigate the cardiorespiratory responses to a 10SS postural baroreflex, pre- and post-exercise, in a recreationally active college-aged male.

**PROCEDURE & DATA ANALYSIS**

**PROCEDURE**

**EQUIPMENT SET UP:** ECG (heart rate – HR; R-Rinterval, finger plethysmography (mean arterial pressure – MAP), and expired gases that derive volumetric flow and capnography (respiration rate – RR; pressure end-tidal carbon dioxide - PETCO₂), were calibrated and measured for all phases of data collection.

**PHASE 1:** 5 minutes of seated rest with eyes open.

**PHASE 2:** 5 minute squat-stand baroreflex test (15 cycles of 10s squatting followed by 10s of stand - 10SS).
PROCEDURE CONT.

- PHASE 3: 3-minute warmup, and 15 minutes of cycle ergometer exercise (70% HRmax, 140-145 bpm). A 1 minute transition was used to dismount the cycle ergometer.

REST AND EXERCISE DATA ANALYSIS

- ECG R-R intervals underwent Fast Fourier Transformation (only the last 5 minutes of exercise was used).
- This analysis creates spectral power, low frequency power (LF), high frequency power (HF), and an LF/HF ratio. Heart rate standard deviation (HRSD), MAP, RR, PETCO₂ were also calculated.

10SS PRE-POST EXERCISE DATA ANALYSIS

- MAP and HR during squatting and standing (seconds 4-7) were averaged over the 15 cycles.
- A 5 minute average of RR, PETCO₂, and Fast Fourier Transformation of ECG variables were also calculated.

RESULTS

EXERCISE

- A 70% exercise bout increased MAP, HR, RR, and PETCO₂. Changes in LF and HF power and LF/HF were also apparent (see table 1).
- The Fast Fourier Transformation metrics indicate a shift towards the LF spectrum, with concomitant decreased total spectral power. The LF spectrum may be more dominant than what by the LF/HF values show.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rest</th>
<th>Exercise (70% HRmax)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP (mmHg)</td>
<td>92.7</td>
<td>108.8</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>70.6</td>
<td>145.5</td>
</tr>
<tr>
<td>Respiration Rate (breaths/minute)</td>
<td>6.4</td>
<td>25.0</td>
</tr>
<tr>
<td>PETCO₂ (mmHg)</td>
<td>27.9</td>
<td>30.8</td>
</tr>
<tr>
<td>HRSD (bpm)</td>
<td>10.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Total Power (ms²)</td>
<td>11489.2</td>
<td>19.3</td>
</tr>
<tr>
<td>LF Power (ms²)</td>
<td>31.1</td>
<td>0.61</td>
</tr>
<tr>
<td>HF Power (ms²)</td>
<td>5.3</td>
<td>0.14</td>
</tr>
<tr>
<td>LF/HF</td>
<td>5.8</td>
<td>4.2</td>
</tr>
</tbody>
</table>
RESULTS

10SS PRE-POST EXERCISE

- The post-exercise range in blood pressure and heart rate from the peak 4-7s of squatting to the peak 4-7s of standing, was greater for blood pressure (pre-exercise range = 68.7 mmHg, post-exercise range = 89.4 mmHg), but not for heart rate (pre-exercise range = 61.3 bpm, post-exercise range = 27.8 bpm).
- The 0-6s time periods for squatting and standing have different flow-pressure dynamics pre- and post-exercise. See Figure 1 below for a full metric breakdown and data visualization.

![Figure 1](image1.png)

**Table 1:** Comparison of Blood Pressure and Heart Rate Changes Pre- and Post-Exercise

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data Transformation</th>
<th>Resting Baroreflex</th>
<th>Post-Exercise Baroreflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Arterial</td>
<td>Squat Pressure (4-7sec)</td>
<td>131.5</td>
<td>139.9</td>
</tr>
<tr>
<td>Pressure (mmHg)</td>
<td>Stand Pressure (4-7sec)</td>
<td>62.8</td>
<td>50.5</td>
</tr>
<tr>
<td>Heart Rate (bpm)</td>
<td>Squat Heart Rate (4-7sec)</td>
<td>63.8</td>
<td>109.4</td>
</tr>
<tr>
<td></td>
<td>Stand Heart Rate (4-7sec)</td>
<td>125.1</td>
<td>137.2</td>
</tr>
<tr>
<td>Respiration Rate (bpm)</td>
<td>Respiration Rate (5 minutes)</td>
<td>19.4</td>
<td>31.2</td>
</tr>
<tr>
<td>PETCO₂ (mmHg)</td>
<td>% CO₂ Conversion</td>
<td>27.1</td>
<td>22.0</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>Fourier Transformation</td>
<td>90.3</td>
<td>129.1</td>
</tr>
<tr>
<td>HRSD (bpm)</td>
<td>Fourier Transformation</td>
<td>28.1</td>
<td>23.1</td>
</tr>
<tr>
<td>Total Power (ms²)</td>
<td>Fourier Transformation</td>
<td>30019</td>
<td>12343</td>
</tr>
<tr>
<td>LF Power (ms²)</td>
<td>Fourier Transformation</td>
<td>57.4</td>
<td>70.6</td>
</tr>
<tr>
<td>HF Power (ms²)</td>
<td>Fourier Transformation</td>
<td>10.2</td>
<td>14.1</td>
</tr>
<tr>
<td>LF/HF Ratio</td>
<td>Fourier Transformation</td>
<td>5.6</td>
<td>5.0</td>
</tr>
</tbody>
</table>

**Figure 1:** Example of a participant performing a squat-stand baroreflex test (n = 1) **Top** – Averaged squat-stand baroreflex cycle of mean arterial pressure (MAP) pre-exercise (black) and post-exercise (red). **Bottom** – Averaged squat-stand baroreflex cycle of heart rate (HR), pre-exercise (black) and post-exercise (red). **Right** – Calculations of MAP, HR, respiration rate, Pressure End Tidal CO₂ (PETCO₂), and select HRV variables during the pre- and post-exercise baroreflex (squat-stand [SS]) tests.

**Figure 2.** A (top) – Model of healthy blood vessel reactivity where a full range of constriction to dilation is present (demonstrated by long and short arrows), and gives rise to a healthy range of variance, as shown by the column of starting and ending reactivity points. B (bottom) – Model of altered reactivity, where the possibility of full constriction to full dilation is lost (demonstrated by no long arrows), and negatively shows healthy variance, as shown by the column of starting and ending reactivity points. Altered reactivity is being driven by altered biochemical and second messenger influences. Comparisons of model A to model B can be used for rest versus exercise, healthy versus or diseased states. **Legend** - Inner circle = maximal constriction of vessel, middle circle = average vessel circumference, outer circle = maximal dilation of vessel.
DISCUSSION

- Exercise likely changed the capacity for cerebrovascular flow-pressure regulation. This is evidence by the following factors:
  - LF/HF ratio indicates a shift towards a sympathetic states
  - There was a bias towards high flow-pressure (high HR and MAP) challenged the ability to quickly transition from vasodilation to vasoconstriction. I.e. blood pressure peaks and troughs post-exercise appear later after squatting and standing. This is evidence in Figure 1, and modeled in Figure 2.
  - Elevated PETCO$_2$ levels during exercise further bias flow-pressure, even though the participant was hypocapnic.

- These results align with previous cerebrovascular physiology projects that study the effect of exercise on flow-pressure regulation (3). Elevated CO$_2$ and MAP values during exercise contribute to uncoupling of blood flow from blood pressure. A model of this can be seen in Figure 2.

- Previous research has demonstrated a reduction in blood pressure alleviation during a resting-state 10SS postural baroreflex in the acute phase of concussion recover in elite athletes (6). The presence of this finding is unknown in the general population.

- The current project demonstrates that the introduction of exercise must be done with caution, as flow-pressure regulation during exercise may be further altered by the physiologic processes underpinning concussion recovery (1-2,5).

- Using a pre-exercise postural baroreflex after sustaining a concussion may be an easy way to assess if symptom exacerbation will occur.

- Using a post-exercise postural baroreflex after sustaining a concussion may be applicable to the general population for assessing return-to-work status in labour-intensive occupations.

REFERENCES


