An Update on the Physiology of Mild Traumatic Brain Injury

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Grand Rounds
Psychiatry 2017
Disclosures

The Buffalo Sabres Foundation
Robert Rich Family Foundation
PUCCS Foundation
NFL Charities
Ralph and Mary Wilson Fund
NIH (1 R01 NS094444-01A1)
Change in Perspective of Concussion (and mTBI)

• Concussion has generally been perceived of as a problem of cognition
  – Hence the emphasis on neuropsychological testing (e.g. ImPACT)
  – And an emphasis on symptoms (self report)
  – Until recently the Treatment as Usual (TAU) has been rest and isolation
Purpose

• To present information on concussion as a problem with physiology (with psychosocial implications)
  – Concussion is perceived as a “medical” condition with psychological and social factors
  – Physical signs are emphasized (in addition to symptoms)
  – Physiologic research translates to assessment, diagnosis and treatment
  – Treatment is proactive and evidence based
Consensus guidelines for return to play

• Based largely on the observation of exercise intolerance
• We developed the Buffalo Concussion Treadmill Test to systematically assess exercise intolerance
• Exercise intolerance is a problem of ANS disruption
Animal research described the Metabolic Cascade and Physiologic Changes.
Concussion produces alterations in the ANS

- Dysregulation of CBF
  - Decreased at rest
  - Increased during exercise
- Higher resting HR at rest
- Decreased HRV at rest
- Decreased HR during exercise
  - Sympathetic at rest (Difficulty attaining a parasympathetic state)
  - Parasympathetic influence during exercise
Cardiovascular Dysfunction during Exercise in Adolescents
5 days after SRC (Acute) and at 14 days (Recovered), (N=27)

For both HR and RPE, time and group were significant (p<0.05) and a group-time interaction effect was significant for RPE (p<0.05)
UB Data on ANS function in College athletes within 1 week of SRC
10 concussed v. 10 HC after Cold Water Immersion- Blair Johnson PhD
Patients with Concussion

- At rest, higher than normal HR, decreased HRV, decreased CBF, evidence of orthostatic imbalance
- Unable to achieve a true sympathetic response during exercise (e.g. inadequate HR, reduced cardiac output, poor regulation of CBF)
- Unable to achieve a true parasympathetic response during rest (increased HRV)
Autonomic Nervous System

SYMPATHETIC

- Dilates Pupils
- Inhibits Salivation
- Bronchial Dilation
- Inhibits Digestion
- Stimulates Glucose Release by Liver
- Stimulates Epinephrine & Norepinephrine Release
- Relaxes Bladder
- Contracts Rectum
- Orgasm
- Ejaculation

PARASYMPATHETIC

- Pupils
- Stimulates Salivation
- Bronchial Constriction
- Stimulates Digestion
- Stimulates Gallbladder
- Contracts Bladder
- Relaxes Rectum
- Vaginal Lubrication
- Erection

Flight or Fight
Rest and Digest
Sympathetic

**Fight or flight**

- Quick response system (not intended for long periods)
- Characterized by increased HR and decreased HRV
- Pupil dilation

**Experienced by the individual**

- Disconcerting
- Anxious (over time anxiety morphs into depression)
- Light and sound sensitivity
- Dizziness
- *Exercise intolerance*
Parasympathetic

**Rest and Digest**
- Increased blood flow to internal organs
- Contraction of ciliary muscles facilitating accommodation
- Modulation of vital functions to achieve homeostasis

**How patient feels**
- Difficulty achieving a restful state
- Difficulty going to and staying asleep
- Nausea
- Irritable bowel
- Loss of appetite
- Difficulty with close vision
Other conditions that have ANS dysfunction:

- Parkinson’s disease
- Multiple system atrophy
- Postural orthostatic tachycardia syndrome
- Multiple Sclerosis
- Jet Lag and Space flight
CBF Regulation

• Assessed using Transcranial Doppler (TCD)
• Tilt table raises feet 6” (6 degrees)
• Initially there is increased profusion but the ANS adjusts in seconds...in controls.
Imaging of CBF Regulation

- Had to build a table that could be tilted 6” while the subject was in the imager. Can’t included any metal. Head must remain motionless.
Implications for Assessment

**Physical Exam:**
- Neck
- Eyes
- Vestibular function
- Orthostasis
Physical Examination within first week after Concussion
(% with abnormal physical signs, n=54)

Visit #1

<table>
<thead>
<tr>
<th>Physical Exam Signs</th>
<th>Recovered</th>
<th>Not Recovered</th>
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<tbody>
<tr>
<td>Neck spasm</td>
<td>2</td>
<td>18</td>
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<tr>
<td>Neck tenderness</td>
<td>21</td>
<td>27</td>
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<tr>
<td>Neck ROM</td>
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<td>Smooth pursuits</td>
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<td>VOR</td>
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<td>29</td>
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<tr>
<td>VOR dizziness</td>
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<td>28</td>
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<tr>
<td>Tandem gait</td>
<td>54</td>
<td>33</td>
</tr>
<tr>
<td>Romberg</td>
<td>18</td>
<td>27</td>
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</tbody>
</table>

Recovered n=43. Not recovered n=11. Control n=30
Physical Exam

- Excellent for diagnosis
- Not predictive of recovery time
- Excellent for determination of recovery
Exercise (In)Tolerance

• Buffalo Concussion Treadmill Test
• Also have a protocol for an exercise bike
• Key outcome: Heart Rate when patient is unable to continue due to symptoms
Physiological Model improves differential diagnosis

- Physical exam derived from research on physiological changes
  - Exercise intolerance
  - Orthostatic imbalance
  - ANS disturbance

- Patients who are exercise tolerant may have related condition
  - Cervicogenic
  - Oculomotor
  - Vestibular
Differential Diagnosis of Post Concussion Disorders

- CVO (22) 55%
- PCS (22) 20%
- Resolved (19) 15%
- Anxiety (20) 5%
- Migraine (15) 5%
Physiological Approach improves Prognostication
RCT of Exercise versus Stretching

Days to Recovery

- **TAU (Rest)**
- **Stretching**
- **Aerobic Exercise**
ANS Recovery

• In case of concussion, ANS expect spontaneous recovery in 85% of cases.
• Exercise speeds recovery for those that would recover spontaneously.
• Exercise reduces the number of patients with protracted recovery.
A Complete Approach to Treatment

• Sub-Threshold exercise
  – Other interventions that address ANS imbalance

• Treating COV deficits
  – Vestibular
  – Oculomotor
  – Cervicogenic

COV issues recover faster if there is coincident ANS recovery
Exercise Script Must Be Individualized and Must Be Sub-Threshold

• 10% below threshold
• 20 minutes a day
• Don’t exercise on “bad” days
• Stop if you feel symptoms
Why (How) Does Exercise Do Its Magic?

• Most of what we know is from Animal studies:
  – Increases available BDNF, HGF, general endocrine function, wakefulness/sleep cycle, energy metabolism
  – Inhibits apoptosis
  – Promotes angiogenesis particularly in the hippocampus
  – Improves CBF in response to cognitive demands
  – Improves inflammatory response
  – Improves white matter integrity
When and How Much Exercise
Is Exercise the Only Answer?

• Anything that improves an individual’s control of the ANS should be beneficial:
  – Yoga; Meditation; Good sleep/wake cycle, bio-feedback
  – Especially useful for older patients or patients who do not want to exercise
What About Cognitive Interventions

- Absolutely Essential
  - For Patients With Pre-existing cognitive deficits
- For patients with prolonged recovery
  - Generally struggle with cognitive intolerance (fatigue)
  - Assisting with adjustment issues
Definition of Recovery

• Asymptomatic
• Negative physical exam
• Exercise tolerant (BCTT)
• Cognitive tolerant?
Questions