A Multidimensional Approach to Studying Predictors of Recovery from Sport-Related Concussion:

What is the relevance of age in recovery?

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Departments of Neurosurgery & Neurology
Medical College of Wisconsin
What’s All The Fuss About?

- Up to 3.8 million concussions due to sport and recreation per year
- Among most frequent injuries in contact and collision sports
- More than just “bell rung”
- Serious acute effects that effect function
- Urgency to “get back out there”
- Concern about lasting effects
- Clinical challenges...
Not Just the Big Boys
How Long Does it Take to Recover?

80-90% Achieve Complete Recovery in 7-10 Days

75% of repeat concussions within first 7 days
• 92% of repeat concussions within first 10 days

McCrea et al., JAMA 2003; 290:2556-2563
Integrated Recovery Model

PRE-INJURY:
Normal Cerebral Function

CONCUSSIVE EVENT

ACUTE
IMPAIRED:
Elevated symptoms, functional impairment, physiological dysfunction

Window of Cerebral Vulnerability

Clinical Recovery

ACUTE

POST-ACUTE
COMPENSATORY:
Full clinical recovery, but persistent physiological dysfunction

Physiological Recovery
(Common Time Point for Return to Play)

FULL
COMPLETE:
Full clinical recovery, normal physiological function

Full Clinical & Physiological Recovery

Science Driving Evidence-based Management

Prevention-based Return to Activity
How Far We’ve Come…

Consensus Statement on Concussion in Sport: The 4th International Conference on Concussion in Sport, Zurich, November 2012

Paul McCrory, MBBS, PhD†; Willem H. Meeuwisse, MD, PhD†; Mark Aubry, MD†; Robert C. Cantu, MD†; Jiří Dvořák, MDII; Ruben J. Echemendia, PhD‡; Lars Engbretsen, MD, PhD†; Karen Johnston, MD, PhD‡; Jeffrey S. Kutcher, MD††; Martin Raftery, MBBS‡‡; Allen Sills, MD §§; Brian W. Benson, MD, PhD; Gavin A. Davis, MBBS‡‡; Richard Ellenbogen, MD††; Kevin M. Guskiewicz, PhD****; Stanley A. Herring, MD†††; Grant L. Iversen, PhD****; Barry D. Jordan, MD§§§; James Kissick, MD§§§§; Michael McCrea, PhD§§§§; Andrew S. McIntosh, PhD##; David Maddocks, LLB, PhD###; Michael Makdissi, MBBS, PhD#####; Laura Purcell, MDDDD; Margot Putukian, MD$$$$; Kathryn Schneider, PhD$$$$$; Charles H. Tator, MD, PhD$$$$$; Michael Turner, MD$$$$$

National Athletic Trainers’ Association Position Statement: Management of Sport Concussion

Steven P. Broglio, PhD, ATC*; Robert C. Cantu, MD†; Gerard A. Gioia, PhD‡; Kevin M. Guskiewicz, PhD, ATC, FNATA, FACSM§; Jeffrey Kutcher, MD†; Michael Palm, MBA, ATC¶; Tamara C. Valovich McLeod, PhD, ATC, FNATA¶

Wisconsin State Legislature

Concussion guidelines

Diagnosis and Management of Sport-Related Concussion Guidelines

Recommendations and Guidelines for Minimizing Head Impact Exposure and Concussion Risk in Football

National Federation of State High School Associations (NFHS) Report from the July 2014 NFHS Concussion Summit Task Force
Multimodal Assessment of Sport Concussion

**SCAT3™**
Sport Concussion Assessment Tool – 3rd Edition
For use by medical professionals only.

**SYMPTOM EVALUATION**

**How do you feel?**
“You should score yourself on the following symptoms, based on how you feel now”.

<table>
<thead>
<tr>
<th></th>
<th>none</th>
<th>mild</th>
<th>moderate</th>
<th>severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>“Pressure in head”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Neck Pain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nausea or vomiting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Balance problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling like “in a fog”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**Cognitive assessment**
Standardized Assessment of Concussion (SAC)

<table>
<thead>
<tr>
<th>Orientation (1 point for each correct answer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What month is it?</td>
</tr>
<tr>
<td>What is the date today?</td>
</tr>
<tr>
<td>What is the day of the week?</td>
</tr>
<tr>
<td>What year is it?</td>
</tr>
<tr>
<td>What time is it right now? (within 1 hour)</td>
</tr>
</tbody>
</table>

Orientation score of 5

**Immediate memory**

**Balance examination**
Do one or both of the following tests.

Footwear (shoes, barefoot, braces, tape, etc.)

**Modified Balance Error Scoring System (BESS) testing**
Which foot was tested (i.e. which is the non-dominant foot) Left Right
Testing surface (hard floor, field, etc.)

**Condition**
Double leg stance: Errors
Single leg stance (non-dominant foot): Errors
Tandem stance (non-dominant foot at back): Errors
Current Questions in SRC: 

**Acute Effects & Recovery**

**Clinical Recovery:**
Why do individuals vary in recovery?

**Physiological Recovery:**
How long does it take for the brain to recover?

**Individual Variability:**
Who is at risk for prolonged clinical and physiological recovery?

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Giza & Hovda, 2010
What about Youth Athletes?

Which symptom assessments and approaches are uniquely appropriate for paediatric concussion?

G A Gioia,¹ J C Schneider,¹ C G Vaughan,¹ P K Isquith²

Pediatric Sport-Related Concussion: A Review of the Clinical Management of an Oft-Neglected Population

Michael W. Kirkwood, PhD,*³, Keith Owen Yeates, PhD,*³, Pamela E. Wilson, MD, MS³

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Psychometric and Measurement Properties of Concussion Assessment Tools in Youth Sports

Tamara C. Valovich McLeod;⁴ William B. Barr; Michael McCrea;⁵ Kevin M. Guskiewicz⁶

⁴Arizona School of Health Sciences, A.T. Still University, Mesa, AZ; ⁵New York University School of Medicine, New York, NY; ⁶Waukesha Memorial Hospital, Waukesha, WI, and Medical College of Wisconsin, Milwaukee, WI; ⁷University of North Carolina at Chapel Hill, Chapel Hill, NC
The human brain undergoes dramatic changes in both its structural architecture and functional organization that reflect a dynamic interplay of simultaneously occurring progressive and regressive events. Although the total brain size is about 50% of adult size by age 6 years, the brain continues to undergo dynamic changes throughout adolescence and well into young adulthood [61]. Figure 1 illustrates some of these developmental changes, including proliferation and migration of cells mostly during fetal development [62,63], regional changes in synaptic density during postnatal development [11,12,64], and protracted development of myelination well into adulthood [65]. Current non-invasive neuroimaging methods do not have the resolution to delineate which of these processes underlies observed developmental changes beyond gray and white matter subcomponents.
NCAA, PrSL, CPI Combined Dataset: High School vs. College Recovery

405 High School, 216 Collegiate concussed athletes

Symptoms (GSC)

Cognitive Performance (SAC)

Concussed vs. Control Group Effect Sizes (Cohen’s $d$) at 24-hours
165 concussed athletes, 166 controls

Symptom Recovery and Clinical Management

Pfaller, Nelson, Apps, Walter, & McCrea (*under review*).
## Changes in Clinical Management

<table>
<thead>
<tr>
<th>Duration of symptom-free waiting period (SFWP)</th>
<th>1999-2004 sample*</th>
<th>2012-2014 sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days lost from sports participation</td>
<td>3.21</td>
<td>5.95</td>
</tr>
<tr>
<td>Symptom-Free Waiting Period</td>
<td>7.41</td>
<td>12.31</td>
</tr>
<tr>
<td>None</td>
<td>39.7%</td>
<td>1.4%</td>
</tr>
<tr>
<td>$\leq$ 1 day</td>
<td>14.8%</td>
<td>7.0%</td>
</tr>
<tr>
<td>$&gt; 1$ day, $\leq 7$ days</td>
<td>30.9%</td>
<td>67.8%</td>
</tr>
<tr>
<td>$&gt; 7$ days</td>
<td>14.6%</td>
<td>23.8%</td>
</tr>
</tbody>
</table>

Hypothesized Modifiers of Recovery/Clinical Management

• Injury Severity (symptoms, prolonged loss of consciousness or amnesia)
• Convulsions
• Repeated injuries close in time
• Younger Age
• Migraine history, psychiatric history, ADHD
• Etc....
Predictors of Recovery

Early symptom burden predicts recovery after sport-related concussion

In incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes.

Symptom severity predicts prolonged recovery after sport-related concussion, but age and amnesia do not.