Concussions, CTE, and Sport Participation: Where are we heading?

Innovations in Translating Injury Research into Effective Prevention
Center for Injury Epidemiology and Prevention at Columbia

Andrew Lincoln, ScD, MS
Disclosures

I have no relevant financial relationships to be discussed, directly or indirectly, referred to or illustrated with or without recognition within the presentation.
Greetings from the MedStar Sports Medicine Research Center

- Lisa Hepburn, PhD
- Kezia Alexander, MPH
- Reginald Dunn, MS
- Tom Goglia, MBA

June 5, 2018

Knowledge and Compassion Focused on You
Agenda

• Definitions: Concussion & CTE
• Current state of understanding
• Primary prevention approaches
• Disconnect between science & media
• Effects on sport participation, legislation & rule changes
• New directions
Concussion:

• A concussion is a type of traumatic brain injury—or TBI—caused by a bump, blow, or jolt to the head or by a hit to the body that causes the head and brain to move rapidly back and forth. This sudden movement can cause the brain to bounce around or twist in the skull, creating chemical changes in the brain and sometimes stretching and damaging brain cells.

• [https://youtu.be/Sno_0Jd8GuA](https://youtu.be/Sno_0Jd8GuA)
A unique injury and public health issue

NFL Commissioner Roger Goodell testifies with others before the House Judiciary Committee about brain injuries resulting from football.

Chip Somodevilla/Getty Images

June 5, 2018

Knowledge and Compassion **Focused on You**
Biomechanical measures associated with injury were not found to be correlated with number of symptoms, Sport Concussion Assessment Tool 3 Symptom Severity Score, or time to symptom resolution... While concussive impacts did not stand out relative to impacts that did not result in injury, concussive impacts were among the most severe for each individual player. This suggests tolerance to head acceleration might be individual-specific, meaning similar biomechanical inputs can produce different injury presentations between individuals.
Benefits of Strict Rest After Acute Concussion: A Randomized Controlled Trial

Danny George Thomas, MD, MPH\textsuperscript{a}, Jennifer N. Apps, PhD\textsuperscript{b}, Raymond G. Hoffmann, PhD\textsuperscript{a}, Michael McCrea, PhD\textsuperscript{c}, Thomas Hammeke, PhD\textsuperscript{b}

**CONCLUSIONS:** Recommending strict rest for adolescents immediately after concussion offered no added benefit over the usual care. Adolescents’ symptom reporting was influenced by recommending strict rest.
Proportion of patients reporting symptom resolution (PCSS ≤7) over time.
Mean PCSS with 95% confidence interval over time.
Current State of Knowledge on Sport-Related Concussion

Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016

What do we know about concussion regarding return-to-sport?

<table>
<thead>
<tr>
<th>Stage</th>
<th>Aim</th>
<th>Activity</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Symptom-limited activity</td>
<td>Daily activities that do not provoke symptoms</td>
<td>Gradual reintroduction of work/school activities</td>
</tr>
<tr>
<td>2</td>
<td>Light aerobic exercise</td>
<td>Walking or stationary cycling at slow to medium pace. No resistance training</td>
<td>Increase heart rate</td>
</tr>
<tr>
<td>3</td>
<td>Sport-specific exercise</td>
<td>Running or skating drills. No head impact activities</td>
<td>Add movement</td>
</tr>
<tr>
<td>4</td>
<td>Non-contact training drills</td>
<td>Harder training drills, eg, passing drills. May start progressive resistance training</td>
<td>Exercise, coordination and increased thinking</td>
</tr>
<tr>
<td>5</td>
<td>Full contact practice</td>
<td>Following medical clearance, participate in normal training activities</td>
<td>Restore confidence and assess functional skills by coaching staff</td>
</tr>
<tr>
<td>6</td>
<td>Return to sport</td>
<td>Normal game play</td>
<td></td>
</tr>
</tbody>
</table>
What do we know about concussion regarding return-to-school?

### Table 2: Graduated return-to-school strategy

<table>
<thead>
<tr>
<th>Stage</th>
<th>Aim</th>
<th>Activity</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Daily activities at home that do not give the child symptoms</td>
<td>Typical activities of the child during the day as long as they do not increase symptoms (e.g., reading, texting, screen time). Start with 5–15 min at a time and gradually build up</td>
<td>Gradual return to typical activities</td>
</tr>
<tr>
<td>2</td>
<td>School activities</td>
<td>Homework, reading or other cognitive activities outside of the classroom</td>
<td>Increase tolerance to cognitive work</td>
</tr>
<tr>
<td>3</td>
<td>Return to school part-time</td>
<td>Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day</td>
<td>Increase academic activities</td>
</tr>
<tr>
<td>4</td>
<td>Return to school full time</td>
<td>Gradually progress school activities until a full day can be tolerated</td>
<td>Return to full academic activities and catch up on missed work</td>
</tr>
</tbody>
</table>

- Changes in practice:
  - Dangers of isolation
  - Potential benefits of early (sub-threshold) exercise
What’s effective for primary prevention?

<table>
<thead>
<tr>
<th>Intervention (Rules, Equipment, Training)</th>
<th>Strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prohibiting body checking in youth (&lt;13yo) ice hockey</td>
<td>Consistent protective effect in reducing the risk of SRC</td>
</tr>
<tr>
<td>Mandatory helmet use in skiing/snowboarding.</td>
<td>Sufficient evidence for reduction of overall head injury</td>
</tr>
<tr>
<td>Mouth guard use</td>
<td>Mixed evidence; trend towards a protective effect in collision sports</td>
</tr>
</tbody>
</table>
What’s not effective for primary prevention?

<table>
<thead>
<tr>
<th>Intervention (Training, Officiating)</th>
<th>Strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limiting contact in youth football practices</td>
<td>Reduces the frequency of head contact, but not in SRC risk</td>
</tr>
<tr>
<td>1. Fair play rules in youth ice hockey</td>
<td>No reduction in SRC risk</td>
</tr>
<tr>
<td>2. Tackle training without helmets/shoulder pads in youth football</td>
<td></td>
</tr>
<tr>
<td>3. Tackle technique training in professional rugby</td>
<td></td>
</tr>
<tr>
<td>Stricter rule enforcement of red cards for high elbows in heading duels in professional soccer</td>
<td>Effect not yet demonstrated</td>
</tr>
</tbody>
</table>
Current areas of concussion research focus (Injury prevention)

- Implementation and evaluation of the effectiveness of rule changes
- Risk factors for concussion (host)
- Genetic studies—apolipoprotein E, glial cell-derived neurotrophic factor, catechol-O-methyltransferase (host)
- Energy absorbing artificial turf (environment)
- Energy absorbing helmet technology (host-protective equipment)
- The role of tackling technique in reducing concussion risk (energy transfer)
HEADS UP FOOTBALL: SAFETY IN ACTION

Starting as three pilot programs in 2012, Heads Up Football is now used by more than 7,000 youth and high school programs, setting the highest standards in the sport and giving the football community one voice when it comes to safety.

Enroll Today

- High School and Middle School
- Youth Organizations

June 5, 2018

Knowledge and Compassion Focused on You
Comprehensive Coach Education and Practice Contact Restriction Guidelines Result in Lower Injury Rates in Youth American Football

Zachary Y. Kerr,* PhD, MPH, Susan Yeargin,† PhD, ATC,
Tamara C. Valovich McLeod,‡ PhD, ATC, FNATA, Vincent C. Nittoli,§ MS, ATC,
James Mensch,‖ PhD, ATC, Thomas Dodge,‖‖ PhD, ATC, Ross Hayden,* MA,
and Thomas P. Dompier,*§ PhD, ATC

Investigation performed at Datalys Center for Sports Injury Research and Prevention,
Indianapolis, Indiana, USA

Purpose: To compare injury rates among youth football players aged 5 to 15 years by whether their leagues implemented HUF and/or were PW-affiliated.

Study Design: Cohort study; Level of evidence, 2.

Methods: Athletic trainers (ATs) evaluated and tracked injuries at each practice and game during the 2014 youth football season. Players were drawn from 10 leagues across 4 states. The non-Heads Up Football (NHUF) group consisted of 704 players (none of whom were PW-affiliated) from 29 teams within 4 leagues. The HUF+PW group consisted of 741 players from 27 teams within 2 leagues. The HUF-only group consisted of 663 players from 44 teams within 4 leagues. Injury rates and injury rate ratios (IRRs) were reported with 95% CIs.
TABLE 2
Injury Rates in Youth Football Teams, by Implementation of Heads Up Football, Affiliation With Pop Warner Football, and Event Type

<table>
<thead>
<tr>
<th></th>
<th>HUF+PW</th>
<th>HUF-only</th>
<th>NHUF</th>
<th>Rate</th>
<th>Rate</th>
<th>Rate</th>
<th>Rate</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Rate</td>
<td>n</td>
<td>Rate</td>
<td>n</td>
<td>Rate</td>
<td>HUF+PW vs NHUF</td>
<td>HUF-only vs NHUF</td>
</tr>
<tr>
<td>Practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All injuries</td>
<td>20</td>
<td>0.97</td>
<td>42</td>
<td>2.73</td>
<td>148</td>
<td>7.32</td>
<td>0.13 (0.08-0.21)*</td>
<td>0.37 (0.26-0.53)*</td>
</tr>
<tr>
<td>Time-loss injuries</td>
<td>14</td>
<td>0.68</td>
<td>29</td>
<td>1.89</td>
<td>56</td>
<td>2.77</td>
<td>0.25 (0.14-0.44)*</td>
<td>0.68 (0.43-1.07)</td>
</tr>
<tr>
<td>Concussions</td>
<td>4</td>
<td>0.19</td>
<td>10</td>
<td>0.65</td>
<td>12</td>
<td>0.58</td>
<td>0.33 (0.11-1.02)</td>
<td>1.10 (0.47-2.54)</td>
</tr>
<tr>
<td>Game</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All injuries</td>
<td>15</td>
<td>3.42</td>
<td>55</td>
<td>13.76</td>
<td>90</td>
<td>13.48</td>
<td>0.25 (0.15-0.44)*</td>
<td>1.02 (0.73-1.43)</td>
</tr>
<tr>
<td>Time-loss injuries</td>
<td>10</td>
<td>2.28</td>
<td>24</td>
<td>6.01</td>
<td>35</td>
<td>5.24</td>
<td>0.43 (0.22-0.88)*</td>
<td>1.15 (0.68-1.93)</td>
</tr>
<tr>
<td>Concussions</td>
<td>3</td>
<td>0.68</td>
<td>6</td>
<td>1.50</td>
<td>10</td>
<td>1.46</td>
<td>0.46 (0.13-1.66)</td>
<td>1.39 (0.60-3.22)</td>
</tr>
</tbody>
</table>


Players in the non–Heads Up Football group were also not affiliated with Pop Warner Football.

Rate per 1000 athlete-exposures, defined as 1 athlete’s participation in 1 practice or 1 competition.

Time-loss injuries are those injuries that restrict participation for at least 24 hours.

Significant differences between groups analyzed.
Youth leagues that employed Heads Up Football saw...

63% ↓ Lower injury rates in practice

Peer-reviewed and published in The Orthopaedic Journal of Sports Medicine, July 2015

Youth leagues that employed Heads Up Football and Pop Warners practice restriction guidelines saw...

87% ↓ Lower injury rate during practice

*USA Football commissioned research is publicized only when it has been peer-reviewed and published.
An integral part of the Heads Up Football (HUF) educational program is the Player Safety Coach (PSC), who is responsible for teaching other coaches within a youth football league about safer blocking/tackling and injury prevention…

Nearly half of coaches (44.8%) did not attend the PSC clinic; 25.9% reported not seeing their league's PSC on the field on a regular basis. The lack of PSC on-site presence was significantly associated with worse implementation for "concussion recognition and response," "heat preparedness and hydration," and "sudden cardiac event preparedness."

PSC clinic attendance was not associated with implementation. Opportunities exist for improvement in the HUF educational program as there appears to be inconsistent implementation. Further research is warranted to understand how to optimize the role of the PSC in the youth sports context.
CTE is a neurodegenerative disease that is associated with changes and deficits in cognition, behavior, mood, and motor skills. It is believed to be caused in part by exposure to repetitive head impacts, including concussions as well as subconcussive trauma (i.e., head impacts that do not cause symptoms of concussion). (CDC Heads Up)
Junior Seau (1969-2012)
Sports-related concussions – media, science and policy

Rebekah Mannix, William P. Meehan III & Alvaro Pascual-Leone


---

**Evidence**
- Dose-dependent elevation of tau species in blood and tissue acutely after injury
- Increased symptoms
- Reduced neurocognitive performance in athletes with history of multiple concussions
- Fibrillary insoluble proteins (visualized by PET) in former players suspected of CTE
- Pattern consistent with autopsy results
- Progressive neuropsychiatric symptoms in athletes exposed to multiple head traumas
- Characteristic global and histopathological changes, including tauopathy

**Source(s)**
- Clinical case series, animal models
- Clinical case series
- Clinical case series
- Clinical case series
- Clinical case series, animal models

**Injury**
- Hours
- Days
- Weeks
- Years

**Gaps in knowledge**
- Lack of correlation between high tau levels and clinical outcomes
- No prospective, longitudinal studies to document CTE progression over time
- No correlation with tau pathology
- No prospective, longitudinal studies to document CTE progression over time
- Limited correlation between CTE and tau pathology
- No correlation of CTE with tau pathology
- No prospective, longitudinal studies on CTE progression over time in vivo
- Limited correlation between pathology and symptoms
- Case series not useful to generate risk estimates for subpopulations and larger populations

---

Knowledge and Compassion Focused on You
From concussion to CTE — sequence of events and knowledge gaps

Data from clinical case series and animal models suggest that athletes who sustain concussions could develop a form of tauopathy, chronic traumatic encephalopathy (CTE), which leads to the deposition of fibrillary insoluble proteins and progressive deterioration of brain function. A definitive causal link between concussion and CTE has yet to be established, however.

Robert Stern: "repetitive head impact exposure is a necessary variable for getting the disease, but it's obviously not sufficient, because not everyone who hits their head is going to get this brain disease. That's pretty much all we know. ... I'm the one person who says over and over again we have no idea what's going on yet. People should not overreact and be fearful that they're going to develop CTE, especially our youth athletes."
On the other hand...
A neuropathologist has examined the brains of 111 N.F.L. players — and 110 were found to have C.T.E., the degenerative disease linked to repeated blows to the head.

By Joe Ward, Josh Williams and Sam Manchester
July 25, 2017
How did an athlete with treatable depression come to believe that he had an untreatable condition and commit suicide?
The Disconnect

• Create a "sensationalized state of fear" about CTE
• Ignore and/or severely criticize research findings that don't fit the football = dementia narrative
• Label anyone who dares to challenge that narrative or call for further study a 'CTE denier' or a 'shill' trying to advance their own vested interests
• Confuse the public and conflate the issues
Prescribed Repair: A three-pronged approach

1. Acknowledge our own biases:
   1. 'belief bias,' causing us to stubbornly adhere to the most intuitively attractive conclusions and own beliefs
   2. 'illusion of validity' bias, which falsely equates research quantity and quality
   3. 'bias blind spot': the tendency to see oneself as less biased than others

2. More education of the media (translational efforts)
3. Promote cordial discourse among researchers
STATE OF PLAY 2017
TRENDS AND DEVELOPMENTS

TOTAL SPORT PARTICIPATION RATES
Percentage of children ages 6 to 12 who played at least one day during the year

TEAM SPORT
INDIVIDUAL SPORT
TEAM SPORT ON A REGULAR (CORE) BASIS

THE STATE OF PLAY IN THE U.S.
SCOREBOARD
ACTIVE TO A HEALTHY LEVEL
Percentage of kids who regularly participated in high-calorie-burning sports

June 5, 2018
Knowledge and Compassion Focused on You
**Five findings in East Baltimore:**

- Fear of injury is limiting sports participation. A 2017 Harris Poll conducted on behalf of the American Osteopathic Association found that 16 percent of parents are now concerned enough about concussion risks that they won’t let their child play any sport. Our survey of youth in East Baltimore found that they

---

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I don’t have time to play due to schoolwork</td>
<td>32%</td>
</tr>
<tr>
<td>I don’t want to get hurt</td>
<td>20%</td>
</tr>
<tr>
<td>I don’t have time to play due to family responsibilities</td>
<td>16%</td>
</tr>
<tr>
<td>Sports are too expensive</td>
<td>12%</td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>6%</td>
</tr>
<tr>
<td>I’m not good enough to play</td>
<td>4%</td>
</tr>
<tr>
<td>I don’t have a way to get to practices or games</td>
<td>3%</td>
</tr>
<tr>
<td>My friends don’t play</td>
<td>2%</td>
</tr>
<tr>
<td>Sports are too serious</td>
<td>2%</td>
</tr>
<tr>
<td>Too many bad coaches</td>
<td>2%</td>
</tr>
<tr>
<td>I don’t have time to play due to a job</td>
<td>2%</td>
</tr>
<tr>
<td>The fields, gyms, and/or courts are bad quality</td>
<td>2%</td>
</tr>
<tr>
<td>I don’t feel safe at the fields, gyms, or courts</td>
<td>2%</td>
</tr>
</tbody>
</table>

**FIG. 8 | TRAINING REQUIREMENTS OF COACHES BY SCHOOLS**

- CPR: 63%
- First Aid: 63%
- Sports Skills and Tactics: 38%
- Coaching Philosophy: 38%
- No Requirements: 38%
- Concussion Mgmt: 25%
- Other: 12.5%
NY Assemblyman Michael Benedetto: “There are laws that you need to use a car seat, wear a bicycle helmet. It’s the same principle.”

Dr. Robert Cantu: “… health experts set age minimums for all sorts of activities like drinking, smoking and driving, and the science is never purely black and white.”
Rule Changes by Youth Sports NGBs

• Promotion of flag football as a safer alternative to tackle;
  – Participation rates have risen sharply.

• United States Soccer Federation rule changes:
  – In 2015, banned players age 10 and younger from heading the ball

• Pop Warner (youth football) rule changes:
  – In 2016, the organization eliminated kickoffs in its three youngest divisions (5-10 years old).
  – Reduced the amount of contact time in practice in all age groups, to 25 percent.
Youth Football Injuries

A Prospective Cohort

Andrew R. Peterson,*† MD, MSPH, Adam J. Kruse,† MS, Scott M. Meester,† BS, Tyler S. Olson,† BS, Benjamin N. Riedle,† MS, Tyler G. Slayman,‡ MD, Todd J. Domeyer,§ MD, Joseph E. Cavanaugh,† PhD, and M. Kyle Smoot,‖ MD

Investigation performed at University of Iowa, Iowa City, Iowa, USA

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Comparison of Injury Rates Between League Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>League Type</td>
<td>Response Variable</td>
</tr>
<tr>
<td>Flag vs tackle</td>
<td>Injury rate</td>
</tr>
<tr>
<td>Flag vs tackle</td>
<td>Severe injury rate</td>
</tr>
<tr>
<td>Flag vs tackle</td>
<td>Concussion rate</td>
</tr>
</tbody>
</table>

June 5, 2018

Knowledge and Compassion Focused on You
What’s on the horizon…

The 2017 Berlin Concussion in Sport Group Consensus Statement provides a global summary of best practice in concussion prevention, diagnosis and management, underpinned by systematic reviews and expert consensus.
PINK CONCUSSIONS

SESSION SPOTLIGHT
PINK CONCUSSIONS PANEL: THE FACES OF FEMALE BRAIN INJURY

Katherine Snedaker, LCSW
Executive Director
PINK Concussions

Wednesday June 13
7:30 AM - 8:45 AM

WASHINGTON, DC
JUNE 11 - 13, 2018

4th Federal Interagency Conference on Traumatic Brain Injury
THE NCAA-DOD GRAND ALLIANCE: A UNIQUE COLLABORATION

Brian Hainline, MD
NCAA Chief Medical Officer
Clinical Professor of Neurology
Indiana University School of Medicine
New York University School of Medicine
What is the natural history of concussion?
- Short-term and long-term.
- What functional domains are reliably impaired?
- Are specific functional domains more or less predictive of recovery trajectory?

Are all sports-related concussions the same?
- Most work has been in men.
- Most studies in American football.

What is the neurobiology of concussion?
- Are there critical biomechanical elements that predict concussion, prognosis, and recovery?
- Is concussion the right metric? What about repetitive head impact exposure?
- Is there disconnect between clinical and neurophysiological “return to play” point?
- Do these issues differ across sex and sport?

What role can neuroimaging biomarkers, fluid biomarkers, and genotype play in answering these questions?
FURTHER GAP ANALYSIS

- Does knowledge of concussion lead to behavioral safety changes?

- What are the perceived norms of concussion safety?

- What is the evidence that perceived norms and the culture of concussion safety can be shifter through intervention?
NCAA-DoD CARE Consortium:
Sponsored by U.S. Dept. of Defense (DoD) & NCAA
Principal Investigators: S. Broglio, PhD, Thomas McAllister, MD, Michael McCrea, PhD

Executive Committee
Fudge & Rauch (DoD), Hack & Hainline (NCAA), Koroschetz (NIH)

Concussion Research Initiative

Scientific Advisory Panel
Nelson, Jordan, Kelly, Marshall, Saykin, Smith, Tabakove, Wallace, Xu

Consortium Operating Committee
Anderson, Broglio (co-Chair), Clugston, Duma, Giza, Guskiewicz, McAllister (co-Chair), McCrea (co-Chair), McGinty, Putukian

Administration and Operations Core
Indiana U School of Medicine
McAllister (coPI)

Advanced Research Coordinating Center:
Medical College of Wisconsin
McCrea (coPI)

U Oklahoma (BIG12)
Anderson

U Delaware (Colonial)
Buckley & Kaminski

Humboldt State U (California)
Ortega

US Coast Guard Academy (New England)
O’Donnell

US Air Force Academy (Mountain West)
McGinty & Campbell

US Military Academy (Patriot)
Svensda

UCLA (PAC12)
Giza & DiFiori

U Washington (PAC12)
Chrisman

U Wisconsin (BIG10)
Brooks

U North Carolina (ACC)
Guskiewicz & McNeal

Virginia Tech (ACC)
Duma & Rowson

Wake Forest U (ACC)
Miles

U Miami (ACC)
Feigenbaum

U North Georgia (Peach Belt)
Miles

Winston-Salem State U (Central)
Lindner

Wilmington College (Ohio)
Dykhuizen

Princeton U (Ivy)
Putukian

U Pennsylvania (Ivy)
Master

Temple U (American)
Langford & Tierney

Temple U (American)
Langford & Tierney

Bloomsburg U (Pennsylvania)
Hazzard

California Lutheran U (Southern Cal)
Kelly

U Chicago (University)
Benjamin

Azusa Pacific U (Pacific West)
Hoy

U Pittsburgh (ACC)
Kontos & Collins

U Georgia (SEC)
Schmidt

U Florida (SEC)
Clugston

U Rochester (University)
Barranan

U North Carolina (ACC)
Guskiewicz & McNeal

Virginia Tech (ACC)
Duma & Rowson

Wake Forest U (ACC)
Miles

U Miami (ACC)
Feigenbaum

U North Georgia (Peach Belt)
Miles

Winston-Salem State U (Central)
Lindner

ECU

ECU
Aims of the CARE Consortium

- **AIM 1:** Create a national multi-site consortium for concussion research
- **AIM 2:** Conduct a prospective, longitudinal, multi-site, multi-sport study of the natural history of concussion in males and females
- **AIM 3:** Conduct advanced studies that integrate biomechanical, clinical, neuroimaging, neurobiological and genetic markers of injury to advance our understanding of neurobiology of concussion

To conduct the largest, most comprehensive study of the natural history of concussion in NCAA Student Athletes and Military Service Academy Cadets.
Integrated Recovery Model

**PRE-INJURY:** Normal Cerebral Function

**CONCUSSIVE EVENT**

**ACUTE**

**IMPAIRED:** Elevated symptoms, functional impairment, physiological dysfunction

**POST-ACUTE**

**COMPENSATORY:** Full clinical recovery, but persistent physiological dysfunction

**FULL**

**COMPLETE:** Full clinical recovery, normal physiological function

**Window of Cerebral Vulnerability**

**Clinical Recovery**

(Comon Time Point for Return to Play)

**Prevention-based Return to Activity**

**Science Informing Clinical Management**

Knowledge and Compassion Focused on You
Future Directions:
Multi-Dimensional Model of Recovery & Outcome

Understanding How Individual Factors Predict Recovery, Outcome and Risk after SRC

Knowledge and Compassion Focused on You
Conclusions

• Challenging areas for research
• Need for big data & collaboration
• Longitudinal studies
• Evaluations of primary prevention interventions
• Coordination across populations (age, sport, sex, level of play)
• Science-media collaboration
Thank you!

Andrew Lincoln, ScD, MS
Director, MedStar Sports Medicine Research Center
Associate Professor, Department of Rehabilitation Medicine
Georgetown University Medical Center
410-261-8217
andrew.e.lincoln@medstar.net