Epidemiology of Sport-Related Concussion: The Intersection of Sex and Gender

Abigail Bretzin, PhD, ATC
Penn Injury Science Center
Department of Biostatistics, Epidemiology and Informatics
University of Pennsylvania

Carrie Esopenko, PhD
Department of Rehabilitation and Movement Sciences
Graduate Program in Kinesiology and Applied Physiology
School of Graduate Studies, New Jersey Medical School
Conflict of Interest Statement

• Both presenters have no conflicts of interest.

Abigail Bretzin, PhD, ATC
Carrie Esopenko, PhD
Learning Objectives

1. Describe the epidemiology of sport-related concussion in high school and collegiate settings.

2. Compare differences in concussion incidence between male and female athletes.

3. Examine differences in concussion outcomes and recovery between male and female athletes.

4. Differentiate between sex and gender related effects in concussion incidence, outcomes, and recovery.
What is a concussion?
What is a Concussion?

Concussion as a 'trauma induced alteration in mental status that may or may not involve loss of consciousness.'

LAST ESTIMATE: 42 definitions of concussion
A Concussion is…

- A mild traumatic brain injury.
  - It’s NOT: graded.
  - It’s NOT: Chronic Traumatic Encephalopathy (CTE).

- A complex pathophysiological process affecting the brain, induced by biomechanical forces resulting from a direct blow to the head, face or neck, or indirect impact to the body (McCrory et al 2017)…. which results in an alteration in mental status that may or may not involve loss of consciousness (Broglio et al., 2014).
A Concussion is...

- Usually involves a rapid onset of symptoms, but symptoms can be delayed
- Injury is typically transient
- Thought of as a functional, rather than structural, injury to the brain
- Brain imaging is usually unremarkable

**The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc.) or other comorbidities (e.g., psychological factors/coexisting medical conditions; McCrory et al., 2017).**
Signs and Symptoms of SRC

**Physical:**
- Headache
- Nausea
- Dizziness
- Impaired balance/postural control
- Impaired gait

**Cognitive:**
- Foggy
- Difficulty concentrating
- Impaired memory/forgetfulness
- Confusion

**Emotion:**
- Irritability
- Sadness
- Anxiety/nervousness
- Lability of Mood
- Personality changes

**Sleep:**
- Drowsy
- Sleeping more than usual
- Sleeping less than usual
- Trouble falling asleep

---

**SCAT5**

Sport Concussion Assessment Tool - 5th Edition

Please check: □ Baseline □ Post-Injury

<table>
<thead>
<tr>
<th>Symptom</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>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 &quot;in a fog&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&quot;Don't feel right&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fatigue or low energy</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Confusion</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>More emotional</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sadness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nervous or Anxious</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Total number of symptoms: 22
Symptom severity score: 132
Do your symptoms get worse with physical activity? Y N
Do your symptoms get worse with mental activity? Y N
If 100% is feeling perfectly normal, what percent of normal do you feel?
Learning Objective 1:
Describe the epidemiology of sport-related concussion in high school and collegiate settings.
Trends in Emergency Department Visits for Contact Sports–Related Traumatic Brain Injuries Among Children — United States, 2001–2018

Data Widerstrom, PhD2, Lindsey S. Womack, PhD3, Karen E. Thomas, MPH1, Kelly Surraione, MPH1

During 2010–2016, there were an average of 283,000 U.S. emergency department (ED) visits each year among children for sports and recreation–related traumatic brain injuries (SR–TBIs). Approximately 45% of these SR–TBIs were associated with contact sports. Although most children with an SR–TBI are asymptomatic within 4 weeks, there is growing concern about long-term effects on a child’s developing brain. This has led to calls to reduce the risk for traumatic brain injuries (TBIs) among child athletes, resulting in the introduction of state policies and the institution of safety rules (e.g., age and contact restrictions) for some sports programs. To assess changes in the incidence of ED–related SR–TBI among children, CDC analyzed data from the National Electronic Injury Surveillance System–All Injury Program (NEISS–AIP) for the period 2001–2018. After more than a decade of increasing rates, the rate of contact sports–related TBI ED visits declined 32% from 2012 to 2018. This reduction was primarily the result of a decline in football–related SR–TBI ED visits during 2013–2018. Decreased participation in tackle football (3) and implementation of contact limitations (6) were likely contributing factors to this decline. Public health professionals should continue to expand efforts to address SR–TBIs in football, which is the sport with the highest incidence of TBIs and identify effective prevention strategies for all sports to reduce TBIs among children.

NEISS–AIP is operated by the U.S. Consumer Product Safety Commission and each year houses data on approximately 500,000 initial injury–related visits for patients treated in hospital EDs. Data are drawn from a nationally representative probability sample (7). Data are weighted by the inverse probability of selection to provide national estimates.

SR–TBIs included TBIs among children aged ≤17 years that occurred during organized and unorganized SR activities. Children were classified as having a TBI if the primary body part injured was the head and the principal diagnosis was concussion or internal organ injury. Each case was initially classified into one of 39 mutually exclusive sports and recreation–related groups on the basis of an algorithm that considered both the consumer products involved (e.g., bicycles, swing sets, and inline skating equipment) and the narrative descriptions of the incident obtained from the medical record. SR–TBI activities were collapsed into categories (i.e., contact sports, limited contact sports, noncontact sport, or recreation) based on previous studies (8). Cases were excluded if the injury was violence–related or if the person was dead on arrival or died in the ED.

By sex (Figure 3), from 2001 to 2012, the rate among males increased by approximately 200%, from 105.5 to 400.9 and among females, increased approximately 25% from 32.3 in 2001 to 41.0 in 2012. From 2012 to 2018, the rate among males declined 31%, to 277.3. From 2014 to 2018, the rate among females declined 38%, to 76.1.
Epidemiology

• Overall SRC rate: 4.47 per 10,000 athlete exposures (AEs)
  – One AE = participation in one competition or practice event

• SRC accounted for 6.2% of all injuries
Epidemiology

- Overall SRC rate: 4.17 per 10,000 athlete exposures (AEs)
  - One AE = participation in one competition or practice event
Epidemiology

- Overall SRC rate: 4.17 per 10,000 athlete exposures (AEs)
  - One AE = participation in one competition or practice event

Concussion Frequencies

<table>
<thead>
<tr>
<th>Season</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preseason</td>
<td>14.20%</td>
</tr>
<tr>
<td>Regular Season</td>
<td>81.60%</td>
</tr>
<tr>
<td>Postseason</td>
<td>3.30%</td>
</tr>
</tbody>
</table>
Epidemiology

- Overall SRC rate: 4.17 per 10,000 athlete exposures (AEs)
  - One AE = participation in one competition or practice event

- Highest rates
  - Boys’ Football: 10.40 per 10,000 AEs
  - Girls’ Soccer: 8.19 per 10,000 AEs
  - Boys’ Ice Hockey: 7.69 per 10,000 AEs
Epidemiology

- Are there differences in SRC incidence within timing of practice or competition?

- Clinical Incidence:

\[
\frac{\text{# of injured athletes}}{\text{# total participants in season}} \times 100
\]

- Relative Risk Ratio:

\[
\frac{\text{Clinical incidence middle}}{\text{Clinical incidence beginning}}
\]
Epidemiology

- SRC was 2x greater in competition vs. practice

- Competition SRC
  - 4.9x more likely in the middle compared to beginning
  - 1.4x more likely in middle compared to end

- Practice
  - 5x more likely in the middle compared to beginning
  - 1.8x more likely for SRC in middle compared to end
Learning Objective 1:
Describe the epidemiology of sport-related concussion in high school and collegiate settings.

Summary:
• Concussion is a common injury among high school and college athletes.

• Sport injury surveillance studies are important tools to investigate the risk and associated outcomes of concussions.
Learning Objective 2:
Compare differences in concussion incidence between male and female athletes.
Epidemiology: Males vs Females

- Concussion rates vary across sport and age
- Females have increased risk in gender-comparable sports
  - High school
  - College
Epidemiology:
Males vs Females

- Relative risk greater in females:
  - Softball baseball 1.95 (1.45, 2.65)
  - Soccer 1.54 (1.31, 1.83)
  - Basketball 1.4 (1.17, 1.67)
Epidemiology: Males vs Females
Epidemiology:
Males vs Females

Figure 2. Mean annual rates of concussion per 1000 athlete exposures in the Ivy League in 11 sports for which exposure data are collected: 2016-2017 and 2017-2018 athletic seasons. Exposure data are collected for varsity and club rugby at some but not all campuses; thus rugby is not included in the analysis.
Epidemiology

- Are there differences in SRC between males in females participating in comparable sports?

- Clinical Incidence:

\[
\frac{\text{# of injured athletes}}{\text{# total participants in season}} \times 100
\]

- Relative Risk Ratio:

\[
\frac{\text{Clinical incidence of female}}{\text{Clinical incidence of male}}
\]
Epidemiology

- Are there differences in SRC between males in females participating in comparable sports?

**Sex Comparable Sports**

- Baseball/Softball
- Basketball
- Swimming and Diving
- Soccer
- Lacrosse

**Females Lower Risk**

**Females Greater Risk**
Learning Objective 2:
Compare differences in concussion incidence between male and female athletes.

Summary
• Overall, male athletes have a higher risk of concussion.

• However, when accounting for sex comparable sports, females are at an increased risk.
Learning Objective 3:
Examine differences in concussion outcomes and recovery between male and female athletes.
Sex Differences: Concussion Outcomes and Recovery
Sex differences in outcome following sports-related concussion

DONNA K. BROSHIEK, Ph.D., TANYA KAUSHIK, Psy.D., JASON R. FREEMAN, Ph.D., DAVID ERLANGER, Ph.D., FRANK WEBBE, Ph.D., AND JEFFREY T. BARTH, Ph.D.

Fig. 1. Bar graph demonstrating mean RCI scores on CRIs together with 95% CIs on follow up. Shaded bars represent men; white bars represent women. *p < 0.05.

Fig. 4. Bar graph exhibiting mean RCI scores on CRIs together with 95% CIs on follow up. *Scores in females (white bars) were lower than those in males without helmets (light gray bars), p < 0.01; scores in females were lower than those in males with helmets (dark gray bars), p < 0.15. **Scores in females were lower than those in males without helmets, p < 0.15; scores in females were lower than those in males with helmets, p < 0.05. ***Scores in females were lower than those in males without helmets, p < 0.05.

Fig. 5. Bar graph demonstrating the mean number of symptoms as well as CIs reported on follow up by males with helmets (dark gray bars), males without helmets (light gray bars), and females (white bars). Females had more symptoms than males without helmets, p = 0.01; females had more symptoms than males with helmets, p = 0.05.
Sex Differences in Vestibular/Ocular and Neurocognitive outcomes following Sport-related Concussion

Alicia M. Sufrinko, PhD\(^a\), Anne Mucha, DPT\(^b\), Tracey Covassin, PhD, ATC; PhD\(^c\), Greg Marchetti, PhD\(^d\), R.J. Elbin, PhD\(^e\), Michael W. Collins, PhD\(^f\), and Anthony P. Kontos, PhD\(^a\)

Adolescent male and female athletes 9-18 yrs of age

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Male mean ± SD (range)</th>
<th>Female mean ± SD (range)</th>
<th>(p^*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>13.6 ± 2.8 (9-18)</td>
<td>14.3 ± 2.1 (10-18)</td>
<td>.25</td>
</tr>
<tr>
<td>Days Since Injury</td>
<td>4.5 ± 3.3 (1-16)</td>
<td>6.0 ± 4.7 (1-21)</td>
<td>.12</td>
</tr>
<tr>
<td>Number (%) with previous concussions</td>
<td>8 (22)</td>
<td>6 (21)</td>
<td>.94</td>
</tr>
<tr>
<td>Number (%) with Learning Disability</td>
<td>1 (3)</td>
<td>1 (4)</td>
<td>.86</td>
</tr>
<tr>
<td>Number (%) with LOC</td>
<td>4 (13)</td>
<td>3 (11)</td>
<td>.80</td>
</tr>
<tr>
<td>Number (%) with Post-traumatic amnesia</td>
<td>6 (17)</td>
<td>1 (4)</td>
<td>.09</td>
</tr>
<tr>
<td>Number (%) with Confusion/Disorientation</td>
<td>9 (25)</td>
<td>7 (25)</td>
<td>.99</td>
</tr>
<tr>
<td>Verbal Memory</td>
<td>79.3 ± 15.7 (42-100)</td>
<td>77.6 ± 17.3 (32-100)</td>
<td>.80</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>67.6 ± 16.1 (35-94)</td>
<td>65.6 ± 18.1 (19-96)</td>
<td>.61</td>
</tr>
<tr>
<td>Motor Processing</td>
<td>31.5±9.4 (18.7-52.1)</td>
<td>31.6±10.4 (10.5-48.0)</td>
<td>.77</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>.70±.12 (.45-1.03)</td>
<td>.74±.24 (.47-1.49)</td>
<td>.74</td>
</tr>
<tr>
<td><strong>PCSS</strong></td>
<td>20.8±17.0 (0-63)</td>
<td>37.7±26.2 (0-99)</td>
<td><strong>.01</strong></td>
</tr>
<tr>
<td>BESS</td>
<td>12.5±8.2 (2-50)</td>
<td>13.6±10.2 (6-60)</td>
<td>.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VOMS Item</th>
<th>Male mean ± SD (range)</th>
<th>Female mean ± SD (range)</th>
<th>Group Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Pursuits</td>
<td>1.4 ± 2.7 (0-10)</td>
<td>3.1 ± 6.5 (0-31)</td>
<td>(p = .44)</td>
</tr>
<tr>
<td>Horizontal Saccades</td>
<td>1.9 ± 3.1 (0-11)</td>
<td>3.3 ± 6.4 (0-29)</td>
<td>(p = .67)</td>
</tr>
<tr>
<td>Vertical Saccades</td>
<td>1.6 ± 3.2 (0-11)</td>
<td>2.86 ± 5.9 (0-29)</td>
<td>(p = .46)</td>
</tr>
<tr>
<td>Convergence (Symptoms)</td>
<td>1.8 ± 3.0 (0-11)</td>
<td>2.8 ± 4.0 (0-20)</td>
<td>(p = .80)</td>
</tr>
<tr>
<td>Horizontal Vestibular Ocular Reflex</td>
<td><strong>178 ± 2.5 (0-11)</strong></td>
<td><strong>61 ± 6.4 (0-22)</strong></td>
<td><strong>(p = .01)</strong></td>
</tr>
<tr>
<td>Visual Motion Sensitivity</td>
<td>1.9 ± 3.2 (0-12)</td>
<td>4.6 ± 7.5 (0-35)</td>
<td>(p = .18)</td>
</tr>
<tr>
<td>Next Point of Convergence Distance (cm)</td>
<td>4.5 ± 4.5 (0-21)</td>
<td>7.5 ± 10.4 (0-41)</td>
<td>(p = .72)</td>
</tr>
</tbody>
</table>

\* Mann-Whitney U non-parametric

Sex was predictive of horizontal VOR Scores following SRC even when adjusting for TSS
Large, well-powered, study: 9314 youth soccer players, concussion history in 613 boys, 609 girls

Post-Concussion:
- Dose response relationship between number of concussions and symptoms
- Found no differences in cognitive performance and symptom reporting between boys and girls
- Predictors of symptoms: treatment for a psychiatric problem, headaches, or migraines, older age, being a girl, learning disability, substance use, ADHD, prior concussions

Premorbid Factors:
- Sex differences in baseline cognitive performance and symptoms:
  - Girls performed better on the verbal memory composite and the visual motor speed composite and slightly faster on the reaction time composite.
  - Boys performed better on the visual memory composite
  - Girls also endorsed more symptoms than boys.
Sex Differences:
Risk For Persistent Symptoms
A number of preinjury factors increase the risk of symptoms post-injury and also complicate our understanding of the relationships between predictors and clinical outcome.

- Girls and young women report more symptoms preinjury compared to males
- Other pre-injury predictors: Learning problems, ADHD, premorbid mental illness, substance misuse, treatment for migraine or headaches, multiple concussions

Past research is mixed, but suggests that overall females take longer to recover and are more likely to have symptoms persisting > 1 month.
3063 patients (median age = 12; 39% female)

Goal of the study: develop clinical risk score to predict risk of persistent symptoms

One of the largest predictors of risk was female sex (OR = 2.3)
Factors Affecting Recovery Trajectories in Pediatric Female Concussion

Natasha Desai, MD, CAQSM,* Douglas J. Wiebe, PhD,† Daniel J. Corwin, MD,‡ Julia E. Lockyer, MS,§ Matthew F. Grady, MD, CAQSM,§‖ and Christina L. Master, MD, CAQSM§‖

Greater number of females reported symptoms across all categories compared to males
Sample of pediatric patients, 7-18 years of age, females took longer to recover on 5 markers of recovery:

1) Return to school without accommodations
2) Return to noncontact exercise
3) Return to full sport participation
4) Recovery of neurocognitive function on computerized testing
5) Clinical recovery of vision and vestibular function
Sex Differences: Recovery Time
Sex Differences in Time to Return-to-Play Progression After Sport-Related Concussion

Retrospective Chart Review of 570 athletes (37% female) 11-20 years of age

Female athletes took significantly longer (average 6 days) to start an RTP progression after an initial SRC compared with age-matched male athletes
• Average time lost from sport
  – Males: 12.0 ± 12.1 days
  – Females: 13.8 ± 12.9 days

• Average missed school days
  – Males: 1.0 ± 2.7 days
  – Females: 1.1 ± 2.5 days

Importantly, these studies group high school athletes together! And report average days to return......
Figure 1. Kaplan-Meier survival curves for time to authorized return to unrestricted activity following sport-related concussion (SRC) by academic year. IRQ, Interquartile Range.
## SRC Recovery

### Table 3. Proportions of Student-Athletes Not Authorized to Return to Unrestricted Participation following Sport-Related Concussion (SRC) by Sport

<table>
<thead>
<tr>
<th>Sport</th>
<th>Sex</th>
<th>SRC 7 days</th>
<th>SRC 14 days</th>
<th>SRC 21 days</th>
<th>SRC 28 days</th>
<th>SRC 35 days</th>
<th>SRC 42 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseball</td>
<td>Male</td>
<td>210</td>
<td>71.0</td>
<td>19.1</td>
<td>5.7</td>
<td>1.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Softball</td>
<td>Female</td>
<td>403</td>
<td>69.7</td>
<td>28.3</td>
<td>11.2</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Basketball</td>
<td>Male</td>
<td>636</td>
<td>71.4</td>
<td>28.1</td>
<td>11.0</td>
<td>5.1</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1,249</td>
<td>74.5</td>
<td>34.5</td>
<td>18.0</td>
<td>9.2</td>
<td>5.1</td>
</tr>
<tr>
<td>Competitive Cheer</td>
<td>Female</td>
<td>429</td>
<td>77.4</td>
<td>43.5</td>
<td>24.3</td>
<td>15.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Sideline Cheer</td>
<td>Female</td>
<td>123</td>
<td>75.6</td>
<td>39.0</td>
<td>15.5</td>
<td>9.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Football</td>
<td>Male</td>
<td>5,285</td>
<td>70.5</td>
<td>27.1</td>
<td>11.6</td>
<td>5.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>Female</td>
<td>30</td>
<td>83.3</td>
<td>50.0</td>
<td>33.3</td>
<td>26.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Ice Hockey</td>
<td>Male</td>
<td>408</td>
<td>75.4</td>
<td>35.5</td>
<td>18.2</td>
<td>7.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>Male</td>
<td>259</td>
<td>74.5</td>
<td>31.3</td>
<td>10.8</td>
<td>5.8</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>148</td>
<td>76.4</td>
<td>30.4</td>
<td>13.5</td>
<td>6.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Soccer</td>
<td>Male</td>
<td>687</td>
<td>64.3</td>
<td>20.2</td>
<td>6.8</td>
<td>4.2</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1,065</td>
<td>72.2</td>
<td>30.0</td>
<td>11.2</td>
<td>4.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Swimming and Diving</td>
<td>Male</td>
<td>50</td>
<td>60.0</td>
<td>30.0</td>
<td>20.0</td>
<td>12.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Track and Field</td>
<td>Male</td>
<td>27</td>
<td>66.7</td>
<td>37.0</td>
<td>14.8</td>
<td>11.1</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>51</td>
<td>76.5</td>
<td>35.3</td>
<td>15.7</td>
<td>5.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Volleyball</td>
<td>Female</td>
<td>640</td>
<td>68.3</td>
<td>27.5</td>
<td>8.8</td>
<td>4.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Wrestling</td>
<td>Male</td>
<td>720</td>
<td>78.9</td>
<td>39.2</td>
<td>21.3</td>
<td>12.1</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>18</td>
<td>88.9</td>
<td>44.4</td>
<td>27.8</td>
<td>11.1</td>
<td>5.6</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>8,282</td>
<td>71.1</td>
<td>28.0</td>
<td>12.2</td>
<td>6.0</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>4,247</td>
<td>73.1</td>
<td>32.7</td>
<td>14.8</td>
<td>7.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>12,529</td>
<td>71.8</td>
<td>29.6</td>
<td>13.1</td>
<td>6.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>
### Table 4. Time Loss for Practice and Game Concussions by Male and Female Sports

<table>
<thead>
<tr>
<th>National Collegiate Athletic Association Sport</th>
<th>Practice Concussions, No.</th>
<th>Days ± SD (P Value)</th>
<th>Competition Concussions, No.</th>
<th>Days ± SD (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men's baseball</td>
<td>18</td>
<td>7.56 ± 5.74</td>
<td>53</td>
<td>8.04 ± 6.88</td>
</tr>
<tr>
<td>Women's softball</td>
<td>30</td>
<td>7.97 ± 6.94 (.828)</td>
<td>54</td>
<td>8.19 ± 6.96 (.912)</td>
</tr>
<tr>
<td>Men's basketball</td>
<td>130</td>
<td>6.02 ± 6.50</td>
<td>70</td>
<td>5.57 ± 3.39</td>
</tr>
<tr>
<td>Women's basketball</td>
<td>144</td>
<td>7.78 ± 8.10 (.048)</td>
<td>119</td>
<td>7.40 ± 7.10 (.01)a</td>
</tr>
<tr>
<td>Men's ice hockey</td>
<td>74</td>
<td>8.93 ± 7.34</td>
<td>32</td>
<td>8.75 ± 7.75</td>
</tr>
<tr>
<td>Women's ice hockey</td>
<td>25</td>
<td>6.67 ± 4.97 (.190)</td>
<td>48</td>
<td>9.96 ± 7.45 (.897)</td>
</tr>
<tr>
<td>Men's lacrosse</td>
<td>40</td>
<td>8.70 ± 7.99</td>
<td>74</td>
<td>8.93 ± 7.34</td>
</tr>
<tr>
<td>Women's lacrosse</td>
<td>34</td>
<td>6.65 ± 3.89 (.156)</td>
<td>50</td>
<td>6.16 ± 5.89 (.022)</td>
</tr>
<tr>
<td>Men's soccer</td>
<td>70</td>
<td>6.14 ± 6.15</td>
<td>147</td>
<td>8.27 ± 8.07</td>
</tr>
<tr>
<td>Women's soccer</td>
<td>94</td>
<td>9.33 ± 8.54 (.006)a</td>
<td>257</td>
<td>7.95 ± 6.21 (.67)</td>
</tr>
</tbody>
</table>

*Greater time loss for females compared with males.*

---

Note: The table above represents the time loss in days for practice and competition concussions by male and female sports from the National Collegiate Athletic Association. The table shows the number of concussions, days lost, and the associated p-values. The data indicates that women have a greater time loss for both practice and competition concussions compared to men, with statistically significant differences highlighted (e.g., p < 0.05). This suggests that female athletes may experience longer recovery times following concussions, which could have implications for training, competition scheduling, and overall athlete welfare. Further research is needed to explore the underlying factors contributing to these differences and to develop effective strategies to mitigate any adverse effects on female athletes.
• NCAA ISP
  – 1670 concussions

• No difference in total # of symptoms and symptom resolution time within sex comparable sport

• Differences in symptom presentation between males and females
The Ivy League–Big Ten Epidemiology of Concussion Study

A Report on Methods and First Findings

Margot Putukian,* MD, Bernadette A. D’Alonzo,1 MPH, Carolyn S. and Douglas J. Wiebe,2 PhD

Investigation performed at University of Pennsylvania, Philadelphia

Background: Little is known about the nature of concussion injury among university students in terms of incidence and rates across sports, the mechanisms of injury, the type of activity during co-activities, return to sport, and symptom resolution.

Purpose: To describe methods of the Ivy League–Big Ten Epidemiology of Concussion Study and to report first findings regarding incidence and rates of concussion injury among university student athletes.

Methods: A prospective cohort study was conducted with data collected through the 2013-2014 academic year. Surveillance was conducted across participating institutions to identify and report all cases of concussion injury among university student athletes.

Results: A total of 1232 cases of SIC (649 women, 583 men) among athletes for injury, were enrolled during the 2013-2014 season. The highest number of injuries occurred in women’s soccer (n = 303, 19.3%), followed by women’s track and field (n = 103, 6.6%), and men’s track and field (n = 3, 3.6%). The highest number of injuries occurred in the sports of wrestling (n = 26, 4.6%), followed by men’s soccer (n = 22, 3.9%). The highest number of concussions occurred in the sport of wrestling (n = 26, 4.6%) and football (n = 12, 2.1%). Rates of concussion were generally higher in higher levels of sport participation, ranging from 1.95 to 10.00 per 1000 AEs.

Conclusions: Multivariate logistic regression analysis of the data from this study did not reveal any difference in the risk of concussion injury between men and women, or between male and female athletes. Women and men did not differ in days to return to play (median, 8 vs 9 days, respectively). Women and men did not differ in days to return to academic activities, or to return to playing on the same team (median, 6 vs 7 days, respectively). The findings from this study extend the understanding of concussion injury among university student athletes and provide valuable insights into the mechanisms of injury and the factors that influence symptom resolution.

Keywords: concussion; sport-related concussion; epidemiology; surveillance

The Big Ten–Ivy League Traumatic Brain Injury Research Collaboration is a multiyear, multi-institutional research effort whose mission is to better understand the mechanisms of head injury and sport-related concussion (SRC) and as well as the effect of these injuries on student-athletes and academics. Established in 2012, the 22-institution membership is composed of clinicians and scientists working in partnership to study the effects of traumatic brain injury in sports and, ultimately, to improve the health and wellness of student-athletes.

The position is the Study’s conclusion that the injury was instigated by the Big Ten presidents and the Ivy League presidents and that it was joined by a majority of the Big Ten presidents and the Ivy League presidents. Given the interdisciplinary nature of this study, this finding provides valuable insights into the mechanisms of injury in sports and, ultimately, to improve the health and wellness of student-athletes.
The Ivy League–Big Ten Epidemiology of Concussion Study

A Report on Methods and First Findings

Margot Putukian,* MD, Bernadette A. D’Alonzo,† MPH, Carolyn S. Campbe and Douglas J. Wiebe,‡ PhD
Investigation performed at University of Pennsylvania, Philadelphia, Pennsy

Background: Little is known about the nature of concussion injury among university student-athlete
dence and rates across sports, the mechanisms of injury, the type of activity during competition or p
to academics, return to sport, and symptom resolution.

Purpose: To describe methods of the Ivy League–Big Ten Epidemiology of Concussion Study an
Study Design: Descriptive epidemiology study.

Methods: A prospective cohort study was conducted with data entered through a surveillance at
2013-2014 athletic season. Surveillance continues to operate by detecting and collecting sport-
non-SIC cases in addition to outcomes among university student athletes.

Results: A total of 822 cases of SIC (649 women, 1004 men) among athletes from 27 sports, i
of injury, were enrolled during the 2013-2014 season from 2017-2018. Acute
hockey, followed by women’s rugby (n = 199, 6.2%), men’s ice hockey (n = 106, 5
women’s soccer (n = 103, 5.4%), wrestling (n = 43, 4.8%), and men’s soccer (n = 49,
5.5%). Women’s soccer (n = 103, 5.4%) and men’s soccer (n = 99, 4.9%) had the highest overall concussion rates among women’s lacrosse (1.55 concus
2.62% and 2.18% for men and women, respectively, 21 days, respectively). Women and men did not differ in days to return to academic

Conclusion: Multiple collaborative endeavors have produced robust data sets yielding r
stand the epidemiology of concussion among university student athletes participating in a var
of cases, these findings add to our understanding of SIC and are the first of many the
years from this large study that continues to its sixth year.

Keywords: concussion; sport-related concussion; epidemiology; surveillance system; symp

Alexander Bell–Ivy League Traumatic Brain Injury Research
Collaboration is a multiyear, multi-institutional research project, whose mission is to better understand the mecha
of concussions and sport-related concussions (SRC) as well as the effect of these injuries on student-athletes’
return to academics and athletics. Established in 2012, the 22-institution membership is composed of clinicians
and scientists working in partnership to study the effects of traumatic brain injury in sports and ultimately, to
improve the health and wellness of student-athletes.

The median number of days to return to academics for women was 6 days, and for men, 5 days. The
proportion of athletes who returned to academics by lag day was calculated using only the

The study employed an ecologic analysis, assessing the effect of SRC and the health and wellness of student-athletes. The
Ivy League guidelines and has since been joined by many

The median number of days to return to academics for women was 6 days, and for men, 5 days. The
proportion of athletes who returned to academics by lag day was calculated using only the

The American Journal of Sports Medicine
DOI: 10.1177/0363546518798010

The Ivy League–Big Ten Epidemiology of Concussion Study

A Report on Methods and First Findings

Margot Putukian,* MD, Bernadette A. D’Alonzo,† MPH, Carolyn S. Campbe and Douglas J. Wiebe,‡ PhD
Investigation performed at University of Pennsylvania, Philadelphia, Pennsy

Background: Little is known about the nature of concussion injury among university student-athlete
dence and rates across sports, the mechanisms of injury, the type of activity during competition or p
to academics, return to sport, and symptom resolution.

Purpose: To describe methods of the Ivy League–Big Ten Epidemiology of Concussion Study an
Study Design: Descriptive epidemiology study.

Methods: A prospective cohort study was conducted with data entered through a surveillance at
2013-2014 athletic season. Surveillance continues to operate by detecting and collecting sport-
non-SIC cases in addition to outcomes among university student athletes.

Results: A total of 822 cases of SIC (649 women, 1004 men) among athletes from 27 sports, i
of injury, were enrolled during the 2013-2014 season from 2017-2018. Acute
hockey, followed by women’s rugby (n = 199, 6.2%), men’s ice hockey (n = 106, 5
women’s soccer (n = 103, 5.4%), wrestling (n = 43, 4.8%), and men’s soccer (n = 49,
5.5%). Women’s soccer (n = 103, 5.4%) and men’s soccer (n = 99, 4.9%) had the highest overall concussion rates among women’s lacrosse (1.55 concus
2.62% and 2.18% for men and women, respectively, 21 days, respectively). Women and men did not differ in days to return to academic

Conclusion: Multiple collaborative endeavors have produced robust data sets yielding r
stand the epidemiology of concussion among university student athletes participating in a var
of cases, these findings add to our understanding of SIC and are the first of many the
years from this large study that continues to its sixth year.

Keywords: concussion; sport-related concussion; epidemiology; surveillance system; symp

Alexander Bell–Ivy League Traumatic Brain Injury Research
Collaboration is a multiyear, multi-institutional research project, whose mission is to better understand the mecha
of concussions and sport-related concussions (SRC) as well as the effect of these injuries on student-athletes’
return to academics and athletics. Established in 2012, the 22-institution membership is composed of clinicians
and scientists working in partnership to study the effects of traumatic brain injury in sports and ultimately, to
improve the health and wellness of student-athletes.

The median number of days to return to academics for women was 6 days, and for men, 5 days. The
proportion of athletes who returned to academics by lag day was calculated using only the

The study employed an ecologic analysis, assessing the effect of SRC and the health and wellness of student-athletes. The
Ivy League guidelines and has since been joined by many

The median number of days to return to academics for women was 6 days, and for men, 5 days. The
proportion of athletes who returned to academics by lag day was calculated using only the

The American Journal of Sports Medicine
DOI: 10.1177/0363546518798010

The Ivy League–Big Ten Epidemiology of Concussion Study

A Report on Methods and First Findings

Margot Putukian,* MD, Bernadette A. D’Alonzo,† MPH, Carolyn S. Campbe and Douglas J. Wiebe,‡ PhD
Investigation performed at University of Pennsylvania, Philadelphia, Pennsy

Background: Little is known about the nature of concussion injury among university student-athlete
dence and rates across sports, the mechanisms of injury, the type of activity during competition or p
to academics, return to sport, and symptom resolution.

Purpose: To describe methods of the Ivy League–Big Ten Epidemiology of Concussion Study an
Study Design: Descriptive epidemiology study.

Methods: A prospective cohort study was conducted with data entered through a surveillance at
2013-2014 athletic season. Surveillance continues to operate by detecting and collecting sport-
non-SIC cases in addition to outcomes among university student athletes.

Results: A total of 822 cases of SIC (649 women, 1004 men) among athletes from 27 sports, i
of injury, were enrolled during the 2013-2014 season from 2017-2018. Acute
hockey, followed by women’s rugby (n = 199, 6.2%), men’s ice hockey (n = 106, 5
women’s soccer (n = 103, 5.4%), wrestling (n = 43, 4.8%), and men’s soccer (n = 49,
5.5%). Women’s soccer (n = 103, 5.4%) and men’s soccer (n = 99, 4.9%) had the highest overall concussion rates among women’s lacrosse (1.55 concus
2.62% and 2.18% for men and women, respectively, 21 days, respectively). Women and men did not differ in days to return to academic

Conclusion: Multiple collaborative endeavors have produced robust data sets yielding r
stand the epidemiology of concussion among university student athletes participating in a var
of cases, these findings add to our understanding of SIC and are the first of many the
years from this large study that continues to its sixth year.

Keywords: concussion; sport-related concussion; epidemiology; surveillance system; symp

Alexander Bell–Ivy League Traumatic Brain Injury Research
Collaboration is a multiyear, multi-institutional research project, whose mission is to better understand the mecha
of concussions and sport-related concussions (SRC) as well as the effect of these injuries on student-athletes’
return to academics and athletics. Established in 2012, the 22-institution membership is composed of clinicians
and scientists working in partnership to study the effects of traumatic brain injury in sports and ultimately, to
improve the health and wellness of student-athletes.
The Ivy League—Big Ten Epidemiology of Concussion Study

A Report on Methods and First Findings

Margot Putukian,* MD, Bernadette A. D’Alonzo,1 MPH, Carolyn S. Campbell,2 and Douglas J. Weibe,3,4 PhD
Investigation performed at University of Pennsylvania, Philadelphia, Pennsylvania

Background: Little is known about the nature of concussion injury among university student-athletes, the incidence and rates across sports, the mechanisms of injury, the type of activity during competition or prior to academics, return to sport, and symptom resolution.

Purpose: To describe methods of the Ivy League-Big Ten Epidemiology of Concussion Study and its first findings.

Study Design: Descriptive epidemiology study.

Methods: A prospective cohort study was conducted with data scored through a surveillance system 2013-2014 athletic season. Surveillance continues to operate by detecting and collecting sport-related and non-SRC cases in addition to outcomes among university student-athletes.

Results: A total of 192 cases of SRC (649 women, 1004 men) among athletes from 37 sports, including football, were evaluated during the 5 athletic seasons from 2013-2014 through 2017-2018. American football (n = 191, 99.5%), rugby (n = 106, 5.5%), men’s ice hockey (n = 46, 25.8%), wrestling (n = 93, 4.8%), and men’s soccer (n = 67, 3.5%) were most common. The highest overall concussion rates occurred in women’s lacrosse (7.84 per 1000 AES) and football (1.75 per 1000 AES). Rates of concussion were generally higher during football competition (2.44 per 1000 AES) and second highest during football competition (4.49 per 1000 AES) and second highest during football competition (4.49 per 1000 AES). The median number of concussions per athlete was 1. Time to symptom resolution was longer for athletes with a history of concussion symptoms, 2.5 to 7.5 days. The number of concussions per sport was comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports with rates comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports with rates comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports.

Conclusions: This prospective cohort study has yielded new data on the epidemiology of concussion among university student-athletes participating in a variety of sports. The number of concussions per sport was comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports with rates comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports with rates comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports with rates comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports with rates comparable to sex and did not differ significantly (p = 0.01) but did not differ across the 4 sports.

Keywords: concussion; sport-related concussion; epidemiology; surveillance system; symptoms

The Ivy League—Big Ten Traumatic Brain Injury Research Collaboration is a 3-year, multi-institutional research effort whose mission is to better understand the mechanisms of head injury and sport-related concussion (SRC) as well as the effect of these injuries on student-athletes’ return to academics and athletics. Established in 2013, the 23-institution membership is composed of clinicians and scientists working in partnership to study the effects of traumatic brain injury in sports and, ultimately, to improve the health and wellness of student-athletes.

The premier study to be performed is the Ivy League—Big Ten Study. The study entails epidemiologic analyses, clinical outcomes, and comparisons of SRC and concussion in women and men. The study is designed to provide valuable opportunities to explore and enhance the care and management of conditions in sports and across many sports. Beyond this, the study intends to be applied to its

---

The American Journal of Sports Medicine
DOI: 10.1177/0363546518802103
Learning Objective 3:
Examine differences in concussion outcomes and recovery between male and female athletes.

Summary

• Consistent across most studies, female athletes experience greater severity of symptoms post-injury. The data for sex differences in cognitive functioning is more mixed.

• However, premorbid differences in symptom reporting and cognitive function need to be accounted for.

• Conflicting evidence exists regarding sex differences in recovery outcomes (RTP, RTL). Recent work suggests within sport differences need to be accounted for.
Learning Objective 4:
Differentiate between sex and gender related effects in concussion incidence, outcomes, and recovery.
Differentiating Sex and Gender

- **Sex** refers to the biological determination based on chromosomes, hormones, and anatomical attributes
  - Biological mechanisms that increase risk of concussion
  - Gonadal/Sex hormones and risk of protracted recovery

- **Gender** refers to the behavior and identity expressed with regard to a set of social, cultural, and environmental norms
  - Reporting behaviors
  - Differences in rules
  - Access to sports medicine personal
Sex based mechanisms that increase risk and impact recovery from concussion
Sex Differences in Anthropometrics and Heading Kinematics Among Division I Soccer Athletes: A Pilot Study

Abigail C. Bretzin, MS, ATC,* † Jamie L. Mansell, PhD, LAT, ATC, ‡ Ryan T. Tierney, PhD, ATC, ‡ and Jane K. McDevitt, PhD, LAT, ATC, CSCS§

Table 2. Means (M) and standard deviations (SD) for muscle group strength

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>P Value</td>
</tr>
<tr>
<td>Flex</td>
<td>34.66</td>
<td>±8.60</td>
<td>23.12</td>
<td>±5.38</td>
<td>27.56</td>
<td>±8.70</td>
<td>0.012*</td>
</tr>
<tr>
<td>Ext</td>
<td>37.40</td>
<td>±8.94</td>
<td>30.20</td>
<td>±7.53</td>
<td>32.97</td>
<td>±8.54</td>
<td>0.147</td>
</tr>
<tr>
<td>RLF</td>
<td>25.53</td>
<td>±5.39</td>
<td>20.54</td>
<td>±5.76</td>
<td>22.46</td>
<td>±5.95</td>
<td>0.149</td>
</tr>
<tr>
<td>LLF</td>
<td>32.26</td>
<td>±4.68</td>
<td>21.66</td>
<td>±4.30</td>
<td>25.74</td>
<td>±6.85</td>
<td>0.002*</td>
</tr>
<tr>
<td>RR</td>
<td>22.06</td>
<td>±6.43</td>
<td>17.66</td>
<td>±3.54</td>
<td>19.35</td>
<td>±5.10</td>
<td>0.136</td>
</tr>
<tr>
<td>LR</td>
<td>25.26</td>
<td>±5.66</td>
<td>20.16</td>
<td>±3.77</td>
<td>22.12</td>
<td>±5.06</td>
<td>0.075</td>
</tr>
</tbody>
</table>

Ext, extension; Flex, flexion; LLF, left lateral flexion; LR, left rotation; RLF, right lateral flexion; RR, right rotation. All muscle groups were measured using the handheld dynamometer (in kilograms). *Denotes significance (P < 0.05).
Sex Differences in Anthropometrics and Heading Kinematics Among Division I Soccer Athletes: A Pilot Study

Abigail C. Bretzin, MS, ATC, Jami L. Mansell, PhD, LAT, ATC, Ryan T. Tierney, PhD, ATC, and Jane K. McDevitt, PhD, LAT, ATC, CSCS

Table 5. Pearson correlations for strength and kinematics

<table>
<thead>
<tr>
<th></th>
<th>LA 25 mph</th>
<th></th>
<th>LA 40 mph</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pearson Correlation</td>
<td>P Value</td>
<td>Pearson Correlation</td>
<td>P Value</td>
</tr>
<tr>
<td>Flexor</td>
<td>-0.677</td>
<td>0.011*</td>
<td>-0.609</td>
<td>0.027*</td>
</tr>
<tr>
<td>Extensor</td>
<td>-0.238</td>
<td>0.433</td>
<td>-0.467</td>
<td>0.100</td>
</tr>
<tr>
<td>R lat. flexor</td>
<td>-0.389</td>
<td>0.189</td>
<td>-0.558</td>
<td>0.048*</td>
</tr>
<tr>
<td>L lat. flexor</td>
<td>-0.598</td>
<td>0.031*</td>
<td>-0.600</td>
<td>0.030*</td>
</tr>
<tr>
<td>R rotator</td>
<td>-0.508</td>
<td>0.076</td>
<td>-0.548</td>
<td>0.053</td>
</tr>
<tr>
<td>L rotator</td>
<td>-0.588</td>
<td>0.034*</td>
<td>-0.564</td>
<td>0.044*</td>
</tr>
</tbody>
</table>

LA, linear acceleration; R lat. flexor, right lateral flexor; L lat. flexor, left lateral flexors.
*Denotes significance (P < 0.05).
Female athletes show greater peak linear and rotational head acceleration when heading a soccer ball relative to male athletes.
Found that odds of sustaining a concussion decreased by 5% for every one pound increase in neck strength.

Overall neck strength was lower in males with Hx of concussion ($p = 0.014$), while overall neck strength was marginally lower in females with Hx of concussion ($p = 0.052$).
Neck strength was positively associated with FA and negatively associated with RD across several WM regions in soccer players only.

Greater neck strength was related to more intact WMO in athletes with high exposure to RHI, particularly in regions prone to damage from brain trauma.

For soccer athletes, females tend to have a stronger relationship between neck strength and WMO.

For limited/non-contact athletes, there were weak or no relationship between neck strength and WMO for males and females.
Males larger axons, more complex cytoskeleton, larger cross-sectional area, greater number of microtubules and density

More injured axons in females compared to males post-injury

Greater intra-axonal calcium in females compared to males post-injury

Less axons able to transmit calcium in females compared to males post-injury
Sex differences in white matter alterations following repetitive subconcussive head impacts in collegiate ice hockey players

Sex Differences in Circulating T-Tau Trajectories After Sports-Concussion and Correlation With Outcome

Stefania Mondello 1*, Vivian A. Guedes 2, Chen Lai 2, Andreas Jeromin 3, Jeffrey J. Bazarian 4 and Jessica M. Gill 3

FIGURE 1 | Individual t-tau time course profiles in control and concussed athletes. The spline curves represent the time course of t-tau in non-concussed (A) and concussed (B) study participants. The 2 bold lines represent median values of t-tau in male (black) and female (red).
Difference between tau TRAJ group with regard to sex and RTP. Maximal decliner group was associated with female sex and RTP equal to or more than 10 days after concussion.

**TABLE 2 |** Bivariate trajectory group associations with demographic and clinical variables after concussions.

<table>
<thead>
<tr>
<th></th>
<th>Low Transient Decliners (n = 28)</th>
<th>Maximal decliners (n = 18)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 (28.6%)</td>
<td>12 (66.7%)</td>
<td>0.007</td>
</tr>
<tr>
<td>RTP</td>
<td>RTP (≥10 days), n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 (35.7%)</td>
<td>13 (72.2%)</td>
<td>0.011</td>
</tr>
</tbody>
</table>

**FIGURE 2 |** Trajectory groups for profiles over time and percent membership for each trajectory group for serum t-tau. The group-based trajectory analysis (TRAJ) procedure identified 2 groups. The “Low Transient Decliners” group (blue line) included 63% of the subjects. These were subjects with initially low concentrations of plasma t-tau, which further decreased over time. The “Maximal Decliners” group (red line) included the remaining 37% of the subjects, who showed a similar temporal pattern but with consistently higher levels of t-tau.
Women in the luteal phase (high progesterone) at injury showed lower overall health ratings (EuroQol) compared to women in the follicular phase or taking oral contraceptives 1-month post-injury.
23.5% of young women with concussion showed abnormal bleeding patterns compared to 3% of women with orthopedic injury.
The Effects of Sex Differences and Hormonal Contraception on Outcomes after Collegiate Sports-Related Concussion

Virginia Gallagher, Natalie Kramer, Kristin Abbott, John Alexander, Hans Breiter, Amy Herrold, Tony Lindley, Jeffrey Mjaanes, and James Reilly

Table 2. Injury and Outcome Information

<table>
<thead>
<tr>
<th></th>
<th>Males (n=40)</th>
<th>Females (n=50)</th>
<th>p</th>
<th>Non-hormonal contraceptive users (n=24)</th>
<th>Hormonal contraceptive users (n=25)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amnesia</td>
<td>8 (20%)</td>
<td>2 (4%)</td>
<td>0.016</td>
<td>0 (0%)</td>
<td>2 (8%)</td>
<td>ns</td>
</tr>
<tr>
<td>Loss of consciousness</td>
<td>1 (2%)</td>
<td>1 (2%)</td>
<td>ns</td>
<td>0 (0%)</td>
<td>1 (4%)</td>
<td>ns</td>
</tr>
<tr>
<td>RTP in same day</td>
<td>18 (47%)</td>
<td>22 (44%)</td>
<td>ns</td>
<td>11 (46%)</td>
<td>10 (40%)</td>
<td>ns</td>
</tr>
<tr>
<td>LOR (M[SD])</td>
<td>13(9)</td>
<td>22 (23)</td>
<td>0.031</td>
<td>24(30)</td>
<td>20(19)</td>
<td>ns</td>
</tr>
<tr>
<td>Peak Symptom Severity (M[SD])</td>
<td>26(21)</td>
<td>22(14)</td>
<td>ns</td>
<td>27(16)</td>
<td>18(10)</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Males had shorter length of recovery (LOR) than females, but had comparable symptom severity scores.

Among females, non-HC users demonstrated higher symptom severity than HC users.

Demonstrates differential concussion outcomes between male and female collegiate athletes and between HC users and nonusers among females.
Sex and Gender Differences: Reporting Behaviors
Survey of 328 college student athletes in the US

- Found greater symptom reporting intention among females
- No difference in their likelihood continued play while experiencing symptoms
Gender Differences in Concussion Reporting Among High School Athletes

Survey of 454 high school athletes in the US

Percentage of girls and boys reporting concussion.
PMH – previous medical history

Girls were more likely to report a concussion and more likely to report future concussions after educational intervention

Both males and females believe concussions are not a serious enough injury to warrant reporting to a medical professional
Survey from 288 high school athletes in the US.

Key Points

- High school males and females had similar concussion knowledge, but females were more likely to use that knowledge to report a sport-related concussion.
- Males were 4 to 11 times more likely than females to not report a sport-related concussion for reasons focused on the reactions and perceptions of others:
  - Males: did not want coach, parents, or team mates to be mad
  - Males: did not want to miss playing time, miss a game, team was going to playoffs
- Both males and females did not report a sport-related concussion because they did not think it was serious.
Sex and Gender Differences: Access to Care
Factors Affecting Recovery Trajectories in Pediatric Female Concussion

Natasha Desai, MD, CAQSM,* Douglas J. Wiebe, PhD,† Daniel J. Corwin, MD,‡ Julia E. Lockyer, MS,§ Matthew F. Grady, MD, CAQSM,§¶ and Christina L. Master, MD, CAQSM§¶

However, females presented later to specialty care for concussion than males. Suggest this is due to fewer athletic trainers and sports medicine personnel at female sport competitions. This is modifiable!
### Time to Authorized Clearance from Sport-Related Concussion:
The Influence of Healthcare Provider and Medical Facility (Bretzin, in press)

#### The Initial Examiner for SRC
Stratified by Sex (n = 16,001)$^a$

<table>
<thead>
<tr>
<th>Initial examiner $^b$</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>n</strong></td>
<td><strong>%</strong></td>
</tr>
<tr>
<td>Athletic director</td>
<td>317</td>
<td>3.02</td>
</tr>
<tr>
<td>Athletic trainer</td>
<td>7,772</td>
<td>74.14</td>
</tr>
<tr>
<td>Coach</td>
<td>3,287</td>
<td>31.36</td>
</tr>
<tr>
<td>DO</td>
<td>150</td>
<td>1.43</td>
</tr>
<tr>
<td>MD</td>
<td>572</td>
<td>5.46</td>
</tr>
<tr>
<td>NP</td>
<td>41</td>
<td>0.39</td>
</tr>
<tr>
<td>PA</td>
<td>61</td>
<td>0.58</td>
</tr>
<tr>
<td>Sideline emergency personnel</td>
<td>232</td>
<td>2.21</td>
</tr>
<tr>
<td>Other appropriate HCP$^c$</td>
<td>333</td>
<td>3.18</td>
</tr>
</tbody>
</table>

$^a$ These data are inclusive of all SRC cases included in the Head Injury Reporting System.

$^b$ SRC cases may have had more than one initial examiner, so frequencies do not total to 100%.

$^c$ HCP, Health Care Provider.

$$ (\chi^2 = 122.2, p \leq 0.001, V = 0.08) $$

#### Medical Facility Providing Authorized Clearance to RTP from SRC
Stratified by Sex (n = 12,856)$^a$

<table>
<thead>
<tr>
<th>Medical Facility</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>n</strong></td>
<td><strong>%</strong></td>
</tr>
<tr>
<td>Hospital</td>
<td>417</td>
<td>(4.9)</td>
</tr>
<tr>
<td>Neurologist’s office</td>
<td>712</td>
<td>(8.4)</td>
</tr>
<tr>
<td>PCP $^b$</td>
<td>5,864</td>
<td>(69.3)</td>
</tr>
<tr>
<td>Team Physician</td>
<td>957</td>
<td>(11.3)</td>
</tr>
<tr>
<td>Urgent/Ready Care</td>
<td>509</td>
<td>(6.0)</td>
</tr>
</tbody>
</table>

$^a$ These data are inclusive on SRC cases that obtained authorization to return to unrestricted participation.

$^b$ PCP, Primary Care Physician or Pediatrician’s Office.

$$ (\chi^2 = 34.4, p \leq 0.001, V = 0.05) $$
High schools with ATs demonstrate higher rates of SRC
• High schools with ATs demonstrate higher rates of SRC
• Shorter symptom durations and faster RTP with immediate removal, and no have delayed symptom reporting.
• High schools with ATs demonstrate higher rates of SRC
• Shorter symptom durations and faster RTP with immediate removal, and no have delayed symptom reporting.
• High schools with ATs demonstrate higher rates of SRC
• Shorter symptom durations and faster RTP with immediate removal, and no have delayed symptom reporting.

Therefore, interventions that include appropriate on-site medical coverage may mitigate the risk of SRC, especially regarding pre-mature return or continued participation, and the burden of resulting symptoms through early recognition and management.
Sex and Gender Differences: Rules
Rule Differences
Learning Objective 4:
Differentiate between sex and gender related effects in concussion incidence, outcomes, and recovery.

Summary
• There are both sex and gender specific effects that can influence concussion incidence, outcomes, and recovery.
Thank you!

Questions?

Abigail Bretzin, PhD, ATC
Abigail.bretzin@pennmedicine.upenn.edu
@bretzina

Carrie Esopenko, PhD
Carrie.esopenko@Rutgers.edu
@cesopenko