Sports-Related Concussion in High School Athletes: Assessment and Management

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Definition

- **A traumatic brain injury** is “an insult to the brain, not of a degenerative or congenital nature, caused by an external force, that may produce a diminished or altered state of consciousness” (National Head Injury Foundation, 1985).
  - Key: an *acquired* injury that is caused by an *external mechanical force* such as blow to head, concussive forces, acceleration-deceleration forces, or projectile missile
Classification of Initial Severity

• Severity of traumatic brain injury most often assessed with a Glasgow Coma Scale score (GCS; Teasdale & Jennett, 1974)
  – measures level of consciousness based on three observable variables: Eye Opening (4) + Best Motor Response (6) + Verbal Response (5)
  – Coma Score (E + M + V) = range 3-15
  – used to grade initial severity into categories of mild, moderate, and severe
Spectrum of Injury

• **Acute Injury Characteristics**
  – *Mild*: GCS 13-15 LOC < 20-30 minutes
    • Typically fully alert to mildly confused; no deterioration of GCS or focal neurological deficit
  – *Moderate*: GCS 9-12 or >12 with complication or focal brain lesion on neuroimaging
    • Typically clearly impaired consciousness
  – *Severe*: GCS 3-8 Coma duration >/= 6 hrs
    • Initially comatose or deteriorate into coma (no eye opening, no motor response to command, no comprehensible words spoken)
Concussion

• Concussion is essentially a mild traumatic brain injury
  – Latin *concussus* meaning “a shaking”
  – “…a trauma-induced alteration in mental status that may or may not involve loss of consciousness. Confusion and amnesia are the hallmarks of concussion” (Practice Parameter, Quality Standards Subcommittee, American Academy of Neurology, 1997)
Concussion

- Brief/transient disorientation or loss of consciousness
- Anterograde amnesia: 5-10 minutes
- Retrograde amnesia in more severe cases
- Normal acute head CT
Summary of Outcomes

- **Severe**
  - Almost always causes substantial, persisting impairments across a range of functions and significant disability

- **Moderate**
  - More like severe TBI than mild TBI

- **Mild**
  - Vast majority of older children and adults recover well within weeks to 3 months
  - Pain problems add considerable complications
  - Persistent post-concussive syndrome (15% of cases)
Historical Perspectives

• Differential outcomes for different grades of traumatic brain injury
  – Barth et al. (1989) “College football study”
• Increased awareness of the incidence of traumatic brain injury in sports
  – 1980s medical/public health concerns
  – High profile cases/elite athletes (1990s)
    • Forced retirements of high-profile athletes
• Growing research literature documenting that children and adolescents are more vulnerable to the effects of neurological trauma, including TBI
Historical Perspectives

- 1904: 19 student athletes were killed or paralyzed playing football
  - Concerns about growing brutality
    - Leaders from Harvard, Yale & Princeton decide to change rules to ban mass formations and gang tackling
- 1906: President Teddy Roosevelt established the Intercollegiate Athletic Athletic Association of the US (becomes NCAA in 1910)
- 1980s: Pro Football bans “spearing”
  - Greater attention paid to protective gear
Historical Perspective

• Prior to 1980s, mTBI received limited attention
• Disagreement: definition, expected course of recovery, role of psychological factors, and pathophysiological mechanisms of mTBI
• Research problem: use of controls & accounting for effects of premorbid functioning
  – Sports as a natural clinical laboratory
University of Virginia Study of Mild Head Injury in Football

• Sample
  – 10 site study of 2350 college football players
  – Prospective longitudinal data collection: pre-season baseline, 24h, 5 days, & 10 days post-injury
  – 195 athletes sustained concussion in 1987 season compared to orthopedic & non-concussed subjects

• Findings
  – A single mTBI causes cognitive-information processing deficits at 24h and 5 days later compared to baseline (including self-report of headaches, dizziness, memory problems)
  – NP measures are sensitive to concussion effects
  – Recovery occurs in 5 to 10 days
  – SLAM: Sports as a Laboratory Assessment Model
    • Set a methodological standard
Epidemiology

• A major public health concern: the “silent” epidemic

• Incidence
  – 2 million per year; 75,000 die annually from TBI
  – Peak age of incidence: 15-24 years and increase again > 60-65
  – Males:Females::2-3:1 after age 5
  – Adults: 85% mild; 8% moderate; 5-6% severe
  – Children: 76% mild; 10% moderate; 13-24% severe
    • 30% of all deaths related to childhood injury result from TBI (case-fatality ratio greatest in kids < 5)
    • 25% of hospital admissions for TBI in kids < 2 years are due to abuse
Epidemiology: Causes

• Most common (Kraus, 1995)
  – Transportation-related (motor vehicles & bicycles)
  – Falls
  – Sports/recreation accidents
  – Interpersonal violence (assault/abuse)
  – ETOH in 56% of cases

• Distribution of causes varies based on age
  – Infants & young children: falls, violence
  – Older children: sports & recreational accidents; pedestrian or bike collisions with motor vehicles
  – Adolescents & young adults: MVAs
  – Elderly: falls
Athletes: An At-Risk Group

• **Conservative Estimates:**
  – 300,000 sports-related concussions per year (CDC, 1997)
    • 10% of all athletes involved in contact sports suffer a concussion each season
    • Increased risk during games v. practice
  – At least 1.25 million HS athletes in contact sports
  – High School contact sports produce 62,816 concussions/year (Powell & Barber-Foss, 1999)
    • Football players account for 63% of cases
      – Tackling or being tackled seem to cause the most injuries (about 60%)
  – College football players most at-risk
    • 34% with one concussion
    • 20% with multiple concussions
Athletes: An At-Risk Group

• 30-55% college athletes reported at least one mTBI prior to college (Echemendia, 1997)

• Guskiewicz et al. (2000)
  – Surveyed ATCs who worked in high school and collegiate football
  • Of the 17,459 players:
    – 5.1% sustained at least one concussion
    – 14.7% of those sustained a second concussion in the same season
    – greatest incidence was found in high school and Division III collegiate levels
High School Athletes

• Based on participation levels, HS athletes represent the largest majority of at-risk athletes
• Fewest resources to identify and manage risk
  – Less medical supervision/control
• Difficult to estimate true incidence
• Heterogeneity of symptom presentation
  – Varying definitions of concussion/dx criteria
  – Symptoms go unrecognized
• Athletes reluctant to report symptoms
  – Jeopardize status on team
  – “Play through” concussion
  – “If you’re in the tub, you’re not on the club.”
Some High Profile Cases

- Al Toon, NY Jets Wide Receiver
- Merril Hoge, Steelers Running Back
- Steve Young, SF 49ers QB
- Troy Aikman, Cowboys QB
- Eric Lindros, the Next One
The Challenge

“I don’t want guesswork for my players. Give me objective data for return to play.”

Chuck Noll, Head Coach
Pittsburgh Steelers, 1990

“It hurts not being able to play. But it hurts more not being able to think.”

Merrill Hoge, Former NFL Running Back
Merril Hoge

- 7 year NFL veteran as a Running Back
- Injured on running play
- History of 4-5 concussions during one season
- Initial symptoms included LOC (seconds), retrograde amnesia for game, confusion on sideline, irritability, feeling “drunk”
- Lengthy recovery and eventual retirement in 1994
Merril Hoge

• “I thought a concussion meant a player was knocked out…I thought of times on the team bus when we would talk about the guy who got knocked out and then tried to go to the other team’s huddle. Incidents like that weren’t anything of great concern to me as a player. They were something funny, not worrisome.”
Pediatric Outcomes of mTBI

• Recent meta-analytic review of pediatric literature suggested that permanent adverse effects (> 1-3 months) of a single mTBI in any outcome domain are uncommon (Satz & Zaucha, 1998)

• Unresolved issues
  – Spectrum of severity within the category of mild
  – What is needed is an operational definition of injury severity along multiple dimensions
  – More variable outcome in context of learning problems, hyperactivity, abuse
  – Cumulative effects of multiple injuries
  – Age at time of injury
Maturational Change

- **Adult**
  - presumed full maturity of brain systems: deficit is commonly expressed as loss of function

- **Child** (Taylor & Alden, 1997)
  - brain development proceeds at different rates in different regions of the brain
  - child TBI may have at least 3 general effects:
    - injury to a mature brain system: loss of function
    - injury to a developing system: alteration or delay of function
    - injury to a brain system(s) not yet “on-line”: failure to mature or highly abnormal trajectory
Primary Clinical Concerns

• Rule out more serious intracranial pathology
• When to resume play after a concussion
  – No evidence-based guidelines for return to play decisions
  – Risk/prevention of second impact syndrome (SIS)
• Effect of multiple concussions
  – Possibility of cumulative effects of repeated trauma
• Effect of age, gender, and interval between concussions
• Goal: safe return of concussed athlete to play
Neuropathological Mechanisms

- Two basic mechanical forces produce TBIs
  - Contact/Collision
    - causes distortions or fractures of the skull with contusion or laceration at point of contact
    - coup/countrecoup contusions
  - Inertial loading (acceleration/deceleration)
    - common in contact/collision sports
    - strains the brain tissue leading to damage
    - damage based on direction and degree of rotational force
    - tension, compression, shearing
Biomechanical Forces

• Rapid deceleration due to impact with stationary or opposing forces
  – Newtonian physics: a football player running at 10 ft/sec will decelerate at a rate of 9.3g after making contact with another player and stopping within two inches
  – Forces acting on brain are 9.3x that of its resting weight
  – Neuronal damage is a function of mass, weight, velocity, hardness and surface area of the impacting objects
Acute Mechanisms of Injury

- 1. Direct contusion
- 2. Direct/gliding contusion on bony protrusions at base of skull (anterior fossa)
- 3. Contrecoup contusion
- 4. Shearing forces (DAI)
- 5. Stretching & tearing of bridging veins along convexity (SDH)

*Most TBI involves shaking and impact*
Metabolic Effects of Concussion

- Hovda et al. (1999) animal-rodent models document metabolic dysfunction
- Glucose metabolism *increases* early after TBI (*hyperglycolysis*) in an attempt to maintain energy
- Blood flow or CBF (and glucose delivery) decreases after trauma.
  - Duration of decreased CBF seems to be critical in determining neurological outcome
- Results in a period of energy crisis that can last *up to* 10-14 days
  - Most experts believe that neurocognitive manifestations are related to acute metabolic dysfunction
- Period of vulnerability during which secondary insults should be avoided.
Energy Crisis

- Biomechanics result in tissue movement
- Tissue movement results in physiological changes
- Levels of ATP are critically low post TBI
- Energy demand could overwhelm energy production
- Fuel for metabolism could be insufficient
- Mitochondria could be dysfunctional (due to increased intracellular calcium)
- These metabolic changes after TBI in humans occur at all levels of injury severity
- Energy demands and metabolic dysfunction combine to produce an energy crisis—injury induced state of vulnerability
Neurophysiology

- Time periods for post-traumatic physiological brain abnormalities (dysautoregulation) in humans can last days to weeks or months.

- Implication: overly simplified clinical assessment may not detect phases of altered brain physiology and, hence, vulnerability.
  - Careful clinical examination of the recently head-injured athlete is crucial.
Developmental Aspects

– Initial data suggests HS athletes may recover more slowly than collegiate counterparts (Collins et al., 1999)—symptoms appear to last longer

– Biomechanics
  • Thinner skull
  • Greater proportional cranial mass

– Energy Metabolism
  • Increased basal cerebral glucose metabolism

– Vascular Reactivity and Autoregulation
  • Greater brain water content
  • Increased susceptibility to cerebral edema

– Neurotransmission
  • Increased excitatory amino acid receptors
• Excessive activation of the recently injured brain can lead to increased damage and worsen recovery.
• The developing brain may be uniquely vulnerable to diffuse brain injury.
• Deford, Wilson, et al., J Neurotrauma, 2002
  – In animal studies, a single mild TBI did not cause cognitive problems
  – But multiple mild TBI did result in learning deficits
Second Impact Syndrome (SIS)

- First described in 1973 (Schneider)
- Termed SIS in 1984 (Saunders & Harbaugh)
- When *an athlete who has sustained an initial head injury, most often a concussion, sustains a second head injury before symptoms associated with the first have fully cleared* (Cantu, 1995)
  - Mortality rate of 50%, morbidity rate of 100%
- Since 1984:
  - 26 SIS-related deaths (Maroon et al., 2000)
  - Most in High School athletes
Second Impact Syndrome

- The second impact sets in motion the rapid development of cerebral vascular congestion
  - Malignant cerebral edema
- Causes increased intracranial pressure
- Often results in brainstem herniation and death
- Estimated that the immature/less mature brain is 60 times more sensitive to glutamate-mediated NMDA excitotoxic brain injury (Field, 2002)
- Possibility of SIS underscores the importance of reliable assessment and return to play criteria
Second Impact Syndrome

- Onset within 15 seconds to several minutes
- Symptoms include collapse, rapid decline in mental status, loss of eye movement, respiratory failure
- Thought to involve a loss of autoregulation of the brain’s blood supply
- Cerebrovascular engorgement --> increased ICP --> herniation of medial surface of TL (uncus) or lobes below tentorium
  - Brainstem failure can be as quick as 2-5 min
- Animal models suggest the process is nearly impossible to control (Cantu, 1996)
Second Impact Syndrome

• SIS remains a controversial issue
  – An indistinct and poorly understood diagnostic entity
  – One attempt to provide diagnostic criteria failed to identify any of 17 cases as definite SIS (McCrory & Berkovic, 1998)
  – In 12 cases, the possibility of SIS was ruled out
Baseline NP Testing

• Revisiting Barth et al. (1989) paradigm
• Mark Lovell (U Pittsburgh Medical Center) establishes first clinically oriented program to inform post-concussion RTP decision-making with the Pittsburgh Steelers
• Why use a baseline?
  – Uncertainty about when brain normalizes
    • Prior studies documented sensitivity of NP
  – Allows assessment of pre-existing factors that might influence testing
  – High variability among athletes
NFL Concussion Program

• 1995: NFL establishes MTBI Committee
• League-wide network established
• 29 teams now participating (2002)
• Test results used as tool in evaluating recovery and informing RTP decisions
NFL Concussion Project
Testing Protocol

• Pre-Season Baseline (prior to contact drills)
  – Concussion History
  – Neuropsychological Evaluation
• 24-48 Hours Post-Injury
  – Repeat Neuropsychological Evaluation
• 5-7 days Follow-up
  – Repeat Neuropsychological Evaluation
# Postconcussion Symptoms Scale

(Adapted from Lovell and Collins, *Journal of Head Trauma and Rehabilitation* 1998; 13:9-26)

<table>
<thead>
<tr>
<th>Symptom</th>
<th>None</th>
<th>Minor</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>Nausea</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Vomiting</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>Dizziness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fatigue</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>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sleeping less than usual</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>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>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>Nervousness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Numbness or tingling</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 mentally “foggy”</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>Visual problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Postconcussion Scale

• Essentially a “state” measure of perceived symptoms associated with concussion.

• Athlete is asked to report his/her “current” experience of the symptoms.
  – Allows for tracking of symptom levels over very short intervals, such as consecutive days or every few days.
Postconcussion Scale
Iverson, Lovell, Podell, & Collins (2003)

• HS-Regular Education
  – Boys (n = 588) M = 4.8 (sd = 7.9, 0-54)
  – Girls (n = 199) M = 7.7 (sd = 13.7, 0-78)

• HS-Special Education
  – Boys (n = 156) M = 8.8 (sd = 13.0, 0-64)
  – Girls (n = 31) M = 5.3 (sd = 6.3, 0-26)

• Note: women report more sx$s than men, and those with a SE/learning problem history report more symptoms than those without.
Postconcussion Scale

- Athletes with concussions
  - Males (n = 83) \( M = 26.8 \) (sd = 20.2)
  - Females (n = 32) \( M = 35.8 \) (sd = 25.2)
How Long Does It Take The Athlete to Recover?

• Lovell, Collins, Maroon, Cantu & Powell (2002)
  – N = 210 athletes suffered concussion in 01-02 season
    • Males = 172, Females = 38
    • 143 high school, 41 college, 26 others
    • Evaluated at 2, 5, & 8 days post-injury
    • Compared with 50 HS & college controls
How Long Does It Take?

- Lovell et al. (2002) findings:
  - ImPACT Memory Composite
    - Significant difference between groups out to 8 days post-injury
  - ImPACT Reaction Time Composite
    - Significant difference between groups out to 5 days post-injury
  - Importantly, self-report of symptoms resolved by day 4 post-trauma in all Ss
  - By days 5 and 8: better than baseline
How Long Does It Take?

- Implications:
  - Corresponds with animal models of concussion and its resolution
  - Such findings bring into question the common practice of returning mildly concussed athletes to the context in which they are injured.
    - Especially when relying on athlete report
  - Data also contradict widely used grading systems (such as AAN)
Significance of On-Field Markers of Concussion

• Examined the significance of LOC, amnesia, and disorientation
• 78 HS/college athletes with concussion
• All athletes received baseline ImPACT
• Athletes re-evaluated within 72h post-concussion
  – “Good” outcome in 44 athletes
  – “Poor” outcome in 34 athletes
• Groups compared on presence of on-field markers of concussion following in-study injury (determined by ATCs)
• Athletes with on-field retrograde amnesia are 10x more likely to have “poor” early outcome.
• Athletes with on-field anterograde amnesia are 4.2x more likely to have “poor” acute outcome.
• LOC not predictive of outcome.
• Disorientation not predictive of outcome.
• Athletes with 3-4 on-field markers are 15.3x more likely to have poor outcome.
Useful On-Field Markers of Severity

- 125 concussed HS & college athletes
  - Preseason and 24-48h post-injury ImPACT
- On-field retrograde and anterograde amnesia predicts measurable neuropsychological performance decrements 24-48h post-injury.
- LOC did not predict early neuropsychological performance.
Implications

• Need for careful post-injury follow-up
• May be prudent to remove HS athlete from contest (do not return to play same day)
• Recovery from concussion may not be linear process
• Need for further research with “mild” concussion
• Replication needed with college/professional athletes
Do Current Grading Systems Detect Mild Concussion?

  - N = 43 high school athletes with Grade 1 concussion (AAN, 1997)
  - 81% male; 56% football players
  - All athletes diagnosed with “bell ringer” or “ding”
    - Confusion, amnesia, signs/symptoms cleared within 15 minutes
    - No athlete sustained loss of consciousness
    - No athlete returned to play in contest
  - ImPACT evaluation obtained at baseline, 2 & 6 days post-concussion
## Concussion Grading Systems

<table>
<thead>
<tr>
<th>System/Grade</th>
<th>Cantu</th>
<th>Colorado</th>
<th>AAN</th>
<th>McGill</th>
</tr>
</thead>
</table>
| **1 mild**   | No LOC  PTA/PCS<30 | No LOC  Confusion w/o amnesia | No LOC Transient confusion PCS<15 min | No LOC  No PTA  
1A: No PCS, transient confusion  
1B: PCS or confusion<15min  
1C: PCS and/or confusion>15min |
| **2 moderate** | LOC<1min or PTA>30min<24h  PCS>30min<7d | No LOC  Confusion w/amnesia | No LOC Transient confusion PCS>15min | PTA<30min and/or LOC<5min |
| **3 severe**  | LOC≥1 minor PTA>24h  PCS>7d | Any LOC  | Any LOC  | PTA>30min and/or LOC>5min |
Concussion Grading Systems

- **Cantu (2001)**
  - Emphasizes post-traumatic amnesia
    - Mild: PTA < 30’
    - Moderate: PTA > 30’ or LOC < 5’
    - Severe: PTA > 24h or LOC > 5’

- **American Academy of Neurology (1997)**
  - Emphasizes LOC
    - Mild: sx < 15’
    - Moderate: sx > 15’
    - Severe: any LOC
Do Current Grading Systems Detect Mild Concussion?

• ImPACT Memory Composite and Symptom Total Scores were significantly different at day 2 post-injury (but not day 6)

• “Bell-Ringer” Summary
  – Findings challenge assumption that Grade 1 concussion is associated with rapid and complete recovery
Implications

• Findings challenge assumption that Grade 1 concussion is associated with rapid and complete recovery
  – Need for careful post-injury monitoring
  – Prudent to remove HS athlete from play that day
  – Recovery from concussion may not be a linear process (perceived symptoms resolve before performance on ImPACT)
Multiple Prior Concussions

• Do multiple prior concussions lead to a lowered threshold for concussive injury? (Collins, Lovell, Iverson, Cantu, Maroon & Field, 2003)
  – N = 173 HS/college concussed athletes
  – Design: Groups determined by concussion history
    • N = 45: no concussion history
    • N = 27: 3+ concussions
  – Groups compared re: presence of on-field LOC, retrograde amnesia, anterograde amnesia following in-season concussion
### On-field concussion severity markers by concussion history group\(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of athletes</th>
<th>No previous Concussions (%)</th>
<th>3 or more previous concussions</th>
<th>X(^2)</th>
<th>p</th>
<th>Odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive LOC</td>
<td>87</td>
<td>5.0%</td>
<td>25.9%</td>
<td>8.0</td>
<td>0.005</td>
<td>6.7</td>
</tr>
<tr>
<td>Retrograde amnesia</td>
<td>73</td>
<td>11.1%</td>
<td>21.1%</td>
<td>1.2</td>
<td>0.278</td>
<td>2.7</td>
</tr>
<tr>
<td>Anterograde amnesia</td>
<td>74</td>
<td>14.8%</td>
<td>40.0%</td>
<td>5.5</td>
<td>0.019</td>
<td>3.8</td>
</tr>
<tr>
<td>Confusion</td>
<td>60</td>
<td>44.2%</td>
<td>76.5%</td>
<td>5.1</td>
<td>0.024</td>
<td>4.1</td>
</tr>
<tr>
<td>5+ minutes mental status change(^b)</td>
<td>72</td>
<td>9.4%</td>
<td>31.6%</td>
<td>5.3</td>
<td>0.021</td>
<td>4.4</td>
</tr>
<tr>
<td>3-4 abnormal markers</td>
<td>73</td>
<td>3.7%</td>
<td>26.3%</td>
<td>8.3</td>
<td>0.004</td>
<td>9.3</td>
</tr>
</tbody>
</table>

\(^a\) Total study sample consisted of 88 athletes. Varying degrees of missing data were present. The number of athletes who had each marker coded ranged from 60 to 87. LOC, loss of consciousness; - , not significant.

\(^b\) 5 or more minutes of retrograde amnesia, anterograde amnesia, or confusion.
Multiple Prior Concussions

• On-field severity markers of concussion were significantly more frequent for those athletes with a concussion history
  – LOC odds ratio = 6.7 (p < .005)
  – RA odds ratio =  2.7 (p < .05)
  – AA odds ratio =  3.8 (p < .019)
  – At least two hypotheses:
    • Increased sx vulnerability
    • Lower threshold for concussion
To Play or Not to Play: Significance of Post-Concussion Headache

- 109 High School athletes with concussion
  - 84% male; 64% football players
- Prospective cohort study: athletes evaluated via ImPACT on post-injury day 7
  - 73 (66%) reported no HA at follow-up
  - 36 (34%) reported some degree of HA
- Groups compared on ImPACT composite and symptom scales at day 7
  - No baseline differences between groups
    » (Collins et al., 2003)
Relevance of Headache Symptoms

- Athletes reporting post-traumatic headache showed worse performance on ImPACT reaction time and memory composite scores.
  - Also: more post-concussion symptoms & more likely to have demonstrated on-field anterograde amnesia (ES = .80)
- Any degree of lingering headache in HS athletes is likely associated with incomplete recovery.
- Conservative management indicatedz’ never return to play with HA
  - (Collins et al., 2003)
Recovery from Mild Concussion in HS Athlete

- **Sample** (Lovell, Collins, Iverson et al., 2003)
  - 64 concussed (no LOC) HS athletes (60 males)
  - 24 non-concussed HS athletes (16 males)

- **Protocol**
  - Preseason baseline testing & history
    - Non group x group baseline differences
  - Tested post-injury: 36h, 4 days, 7 days

- **Key Findings** (similar to prior college athlete study)
  - Even in mildly injured group, there was pronounced memory decline in some HS athletes that remained at least 7 days
  - In contrast, self-report symptoms showed resolution within 4 days
Age and Recovery

  – Compared recovery rates from concussion in 92 HS v. college athletes
    • HS athletes showed prolonged memory dysfunction
    • HS athletes performed significantly worse than age-matched controls at 7 days post-injury
    • College athletes (despite more severe in-season concussions) displayed commensurate performance with matched controls by day 3
    • Perhaps require age-based RTP guidelines v. assuming standards apply for all age groups and playing levels
Summary

- Accurate on-field diagnosis of concussion is critical.
- Need for careful post-injury assessment of symptoms and cognitive status.
  - PCS is a useful tool, especially acutely
  - NP testing has demonstrated good sensitivity to effects
- Athletes may not return to play until symptom free at rest and exertion.
  - Mean window of vulnerability 5-10 days
  - Majority of athletes with one concussion likely to have good recovery, but...
- Specific assessment tools are available for the sports-medicine clinician.
- Evidence-based RTP guidelines are forthcoming.
Sports-Related Concussion in High School Athletes:
Assessment and Management
Part II

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MA Statewide Head Injury Program

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Dartmouth Medical School
Clinical Management: RTP

- Clinical Management Guidelines
- On-field assessment
- Concussion assessment programs
- Establishing a concussion program
Clinical Management

• Individual decision-making that depends upon:
  – Athlete’s concussion history
  – Severity of the injury
  – Duration of symptoms
  – Time between injuries
  – Availability of experienced/trained personnel to conduct repeated assessments and monitor recovery
Clinical Management

• Postconcussion Checklist
• Neurological/neuropsych evaluation
• Athlete with any postconcussion symptoms
  – prohibit RTP in game or practice
  – do not leave athlete alone
  – insure regular monitoring until symptoms resolve
  – if symptoms not cleared by end of game or in 15 minutes, refer for medical evaluation
  – “When in doubt, sit them out.”
Clinical Management

- Do not return an athlete to competition until:
  - Normal neurological assessment
  - Asymptomatic at rest and exertion
    - No athlete should be returned to play while still symptomatic first at rest and then exertion
      - Includes presence of post-traumatic headache
  - If available, performance on neuropsychological battery is at baseline or above
Gradual Return to Play

• RTP follows a graduated step-wise process
  – While symptomatic, rest/activity restriction.
    • No substance use
  – Once asymptomatic, engage in light aerobic activity (e.g., walking, stationary cycling)
  – Sport-specific activity (e.g., skating in hockey, running in soccer)
  – Non-contact training drills
  – Full contact training after medical clearance
  – Return to regular game play
Conclusions

• Finding a balance between what is safe and what is “fair” and practical.

• Use a conservative criterion
  – “When in doubt, sit them out.”

• Concussions as “career killers”
  – Better understanding of reasons athletes continue to play after sustaining a medically significant concussion(s)
# AAN Guidelines for Return to Play After a First Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Guidelines for return to play after a first concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Return to play when asymptomatic* for 15 minutes</td>
</tr>
<tr>
<td>2</td>
<td>May return to play if asymptomatic* for one week.</td>
</tr>
<tr>
<td>3</td>
<td>Transport to hospital. Return to play when asymptomatic for 1 week.</td>
</tr>
</tbody>
</table>

*rest and exertion
# AAN for Return to Play After a Second or Third Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Second Concussion</th>
<th>Third Concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Terminate contest or practice play if without symptoms for at least 1 week.</td>
<td>Terminate season; may return to play in 3 months if without symptoms.</td>
</tr>
<tr>
<td>2</td>
<td>Consider terminating season. May return to play in 1 month without symptoms.</td>
<td>Terminate season; may return to play next season if without symptoms.</td>
</tr>
<tr>
<td>3</td>
<td>Terminate season; may return to play next season if without symptoms.</td>
<td>Terminate season; strongly discourage return to contact or collision sports.</td>
</tr>
</tbody>
</table>
On-Field Identification

• The challenge
  – signs and symptoms may be subtle
  – no loss of consciousness or incoordination
  – athlete reluctance to report initial symptoms

• Use of standard sideline evaluation
  – Sideline Concussion Checklist
  – Other evaluations
On-Field Identification

• **Sideline Concussion Checklist** (Kutner & Barth, 2001)
  – Provides a format for evaluating athletes who have sustained a sports-related MHI or concussion
  – It functions as a checklist and is not a scale
  • Time of injury, LOC, pupillary response, orientation, thumb-to-fingertip sequencing, vomiting, headache, dizziness, nausea, dysmetria, diplopia, tandem gait, cognitive status, exertion stress test.
On-Field Identification

- **Signs Observed by Staff**
  - Appears to be dazed or stunned
  - Is confused about assignment (play, position)
  - Is unsure of game, score, or opponent
  - Moves clumsily
  - Answers questions slowly or forgets plays
  - Loses consciousness
  - Shows behavior or personality change
  - Forgets events prior to play (retrograde)
  - Forgets events after hit (anterograde)
On-Field Identification

• Symptoms Reported by Athlete
  – Headache
  – Nausea
  – Balance problems or confusion
  – Double or fuzzy vision
  – Sensitivity to light or noise
  – Feeling sluggish
  – Feeling foggy
  – Change in sleep pattern
  – Concentration or memory problems
Standardized Assessment of Concussion

Orientation

• Ask the athlete the following questions.
  – What stadium is this? What month is it?
  – What city is this? What day is it?
  – Who is the opposing team?
Amnesia

**Anterograde amnesia** (new learning)

- Ask the athlete to repeat the following words.
- Girl, dog, green

**Retrograde amnesia**

- Ask the athlete the following questions.
- What happened in the prior quarter/period?
- What do you remember just prior to the hit?
- What was the score of the game prior to the hit?
- Do you remember the hit?
Concentration

• Ask the athlete to do the following.  
• Repeat the days of the week backward (starting with today).  
• Repeat these numbers backward:  
• 63 (36 is correct) 419 (914 is correct)
Word list memory

• Ask the athlete to repeat the three words from earlier. (Girl, dog, green)

• Any failure should be considered abnormal.

• Consult a physician following a suspected concussion.
Sports-Concussion Testing Software

- **ANAM**
  - Automated Neuropsychological Assessment Metrics (Reeves, Throne, Winter, & Hegge, 1989)

- **CRI**
  - Concussion Resolution Index (Erlanger et al., 2001)
    - Web-based program (Headminder)

- **CogSport**
  - Web-based program

- **ImPACT**
  - Freestanding Windows-based application run on PCs or networks (has Spanish version)
The Unconscious Athlete

- Do not move the athlete.
- Do not remove the helmet.
- Do not use ammonia inhalants, which may cause the head to jerk from the noxious stimulus.
- Do not give liquids or food.
- Do not rush the evaluation.
- Do not worry about delaying the game.
RTP: Computer-Based Testing

• Advantages Over Traditional Testing
  – Minimizes practice effects
    • improved reliability
  – Measures reaction time to 1/100th sec
    • improved sensitivity
  – Can be administered in a group setting
    • more efficient
  – Can be administered by athletic trainer
    • more practical
Negative Aspects

• Cost can be high for limited school budgets
• Faking bad at baseline
• Availability of professional support
• Sensitive but not specific
• Must be supported by coaches
ImPACT

• Immediate Post-concussion Assessment and Cognitive Testing
  – Promote safe return to play through timely evaluation
  – Develop a better understanding of recovery
  – Investigate the relationship of test performance to functional/anatomical brain imaging
  – Evaluate the role of protective equipment
ImPACT

- Symptom Inventory
- Word Memory
- Design Memory
- Xs and Os
- Symbol Matching
- Color Match
- 3 Letters (trigrams)
- Self-report of symptoms
- Verbal memory
- Visual memory
- Visual working memory
- Processing speed/memory
- Reaction time
- Working memory/processing speed
CURRENT SYMPTOMS

- Headache
- Nausea
- Vomiting
- Balance Problems
- Dizziness
- Fatigue
- Trouble falling asleep
- Sleeping more than usual
- Sleeping less than usual
- Drowsiness
- Sensitivity to light
- Sensitivity to noise
- Irritability
- Sadness
- Nervousness
- Feeling more emotional
- Numbness or tingling
- Feeling slowed down
- Feeling mentally foggy
- Difficulty concentrating
- Difficulty remembering
- Visual problems (blurry or double vision)

Symptom Inventory

Click the box or button below that indicates the degree to which you are currently experiencing the following symptom:

Headache

Not experiencing this symptom

1 2 3 4 5 6

Minor

Severe

Cancel  << Previous  Next >>  Finish

The Best Approach To Concussion Management
Module 1: Word Discrimination

- Evaluates attentional processes/verbal recognition memory
- Utilizes a word discrimination paradigm.
- Twelve target words are presented for 750 milliseconds (twice to facilitate learning of the list)
- The subject is then tested for recall via the presentation of the 24-word list that is:
  - comprised of 12 target words and 12 non-target words
  - Words chosen from the same semantic category as the target word.
  - EX: the word “ice” is a target word, while the word “snow” represents the non-target word.
  - The subject responds by mouse-clicking the “yes” or “no” buttons
  - Individual scores are provided both for correct “yes” and “no” responses - In addition, a total percent correct score is provided.
- There are five different forms of the word list.

Delay Condition: Following the administration of all other test modules (approximately 20 minutes), the subject is again tested for recall via the same method described above. The same scores that are described above are provided for the delay condition.
Module 2 (Design Memory)

- Evaluates attentional processes and visual recognition memory
- Utilizes a design discrimination paradigm.
- Twelve target designs are presented for 750 milliseconds (twice to facilitate learning)
- The subject is then tested for recall via the presentation of the 24-designs

- Comprised of 12 target designs and 12 non-target designs
- EX: target designs that have been rotated in space
- The subject responds by mouse-clicking the “yes” or “no” buttons
- Individual scores are provided both for correct “yes” and “no” responses
- In addition, a total percent correct score is provided

- There are five different forms of this task
X-O’s
Module 3 (X’s and O’s)

- Measures visual working memory, visual processing speed, and visual memory paradigm
- Incorporates a distractor task.
- The subject can practice the distractor task prior to presentation of the memory task
- The distractor is a choice reaction time test: the subject is asked to click the left mouse button if a blue square is presented and the right mouse button if a red circle is presented.
- Once the subject has completed this task, the memory task is presented.

✓ Memory task: a random assortment of X’s and O’s is displayed for 1.5 seconds
✓ For each trial: three of the X’s or O’s are illuminated in YELLOW (the subject has to remember the location of the illuminated objects).
✓ Immediately after the presentation of the 3 X’s or O’s, the distractor task re-appears on the screen.
✓ Following the distractor task, the memory screen (X’s and O’s) re-appears and the subject is asked to click on the previously illuminated X’s and O’s.
✓ Scores are provided for correct identification of the X’s and O’s (memory), reaction time for the distractor task, and number of errors on the distractor task.

For each administration of ImPACT, the subject completes 4 trials.
Symbol Matching

Module 4 (Symbol Matching)

- Evaluates visual processing speed, learning and memory
- Initially, the subject is presented with a screen that displays 9 common symbols (triangle, square, arrow, etc).
- Directly under each symbol is a number button from 1 to 9
- Below this grid, a symbol is presented.

✓ The subject is required to click the matching number as quickly as possible and to remember the symbol/number pairings.
✓ Correct performance is reinforced through the illumination of a correctly clicked number in GREEN. Incorrect performance illuminates the number button in RED.
✓ Following the completion of 27 trials, the symbols disappear from the top grid.
✓ The symbols again appear below the grid and the subject is asked to recall the correct symbol/number pairing by clicking the appropriate number button.

This module provides an average reaction time score and a score for the memory condition.
Color Match

Module 5 (Color Match)

- Represents a choice reaction time task and measures impulse control/response inhibition
- First, the subject is required to respond by clicking a red, blue or green button as they are presented on the screen. This procedure is completed to assure that subsequent trials would not be affected by color blindness
- Next, a word is displayed on the screen in the same colored ink as the word (e.g. RED), or in a different colored ink (GREEN or BLUE)

✓ The subject is instructed to click in the box as quickly as possible only if the word is presented in the matching ink.

- In addition to providing a reaction time score, this task also provides an error score.
Module 6 (Three letters)

3 Letters

- Measures **working memory** and **visual-motor response speed**
- First, the subject is allowed to practice a distractor task
  - Consists of 25 numbered buttons (5 x 5 grid).
  - The subject is instructed to click as quickly as possible on the numbered buttons in backward order starting with “25.” (has an initial practice task)
  - Then they are presented with three consonant letters displayed on the screen.
  - Immediately following display of the 3 letters, the numbered grid re-appears and the subject is instructed to click the numbered buttons in backward order, again
  - After a period of 18 seconds, the numbered grid disappears and the subject is asked to recall the three letters by typing them from the keyboard.
  - Both the number placement on the grid and letters displayed are randomized for each trial.
- Yields a **memory score** (total number of correctly identified letters) and a score for the average number of correctly clicked numbers per trial from the distractor test.
- Five trials of this task are presented for each administration of the test.
Verbal Memory Composite

Is comprised of the average of the following scores:

1) Total percent correct score from Module 1 (Word Discrimination)
2) Total correct hidden symbols from Module 4 (Symbol Matching)
3) Percent of total letters correct from Module 6 (3 Letters)

Graphic Display of Verbal Memory Composite over time
Visual Memory Composite

Average of these scores:

- X’s and 0’s Total correct (memory) / 12 * 100
- Design memory-total percent correct (immediate + delay) / 2
RT Composite

Is comprised of the average of the following scores:
1) Average Correct RT of interference stage of module 3 (X’s & O’s)
2) Average Correct RT /3 of module 4 (Symbol Match)
3) Average Correct RT of module 5 (Color Match)
Proc. Speed Composite

Is comprised of the average of following scores:

1) Total number correct /4 during interference of module 3 (X’s & O’s)
2) Average counted correctly x3 from countdown phase of module 6 (3 Letters)

Graphic Display of Processing/Visual Motor Speed Composite over time
Further Information

• www.impacttest.com
• www.concussionsafety.com
Making the call:

Case studies
How can you know when they have fully recovered and are ready for safe RTP?

• Case example
  – 19 y.o. RB makes helmet-to-helmet contact with LB
    • 5” LOC, no self-report of sx, passes SAC at 5, 10, and 15 minutes
  – Colorado Guideline
    • Grade 3, hospital evaluation, no practice/play for month and asymptomatic 2 weeks (rest & exertion)
  – AAN Guidelines
    • Grade 3: Disallow RTP for 1 week if sx free
  – Cantu Guidelines
    • Grade 2, RTP in 1 week if no sx rest/exertion
H.S. Lax player

15-yr. old. Male. Unknown mechanism of injury...struck in the chest initially and in the lower back. Whiplash potential, unsure of other mechanisms. No pretest

Concussion Details

• Loss of consciousness 1-20 seconds
• Retrograde amnesia > 15 minutes
• Anterograde amnesia 31-180 minutes
• Confusion / disorientation > 30 minutes
• Taken to hospital Yes
• CT/MRI scan of head Negative
• Symptoms headache, nausea, personality change, numbness or tingling, fatigue
Memory composites

Memory composite (verbal)  Memory composite (visual)*

6th%  4th%  49th%  51st%  13th%  85th%
<table>
<thead>
<tr>
<th>Symptoms</th>
<th>4 days</th>
<th>12 days</th>
<th>24 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Nausea</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Balance Problems</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Dizziness</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fatigue</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Sleeping more</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sadness</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nervousness</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Feeling mentally foggy</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Visual problems</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total Symptom Score</td>
<td>15</td>
<td>26</td>
<td>4</td>
</tr>
</tbody>
</table>
Symptom Totals

Total Symptom Score

4 days
12 days
24 days
Sx. Graph

Graph showing symptoms over time:
- Headache
- Nausea
- Balance Problems
- Dizziness
- Fatigue
- Trouble sleeping
- Sleeping more
- Irritability
- Sadness
- Nervousness
- Feeling more emotional
- Feeling slowed down
- Feeling mentally foggy
- Difficulty concentrating
- Difficulty remembering
- Visual problems

Symptoms measured over 4 days, 12 days, and 24 days.
<table>
<thead>
<tr>
<th>Concussion Details</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of consciousness</td>
<td>&gt; 5 minutes</td>
</tr>
<tr>
<td>Retrograde amnesia</td>
<td>&gt; 15 minutes</td>
</tr>
<tr>
<td>Anterograde amnesia</td>
<td>&gt; 3 Hours</td>
</tr>
<tr>
<td>Confusion / disorientation</td>
<td>&gt; 30 minutes</td>
</tr>
<tr>
<td>Returned to play</td>
<td>no</td>
</tr>
<tr>
<td>Taken to hospital</td>
<td>Yes</td>
</tr>
<tr>
<td>CT/MRI scan of head</td>
<td>Positive</td>
</tr>
<tr>
<td>Symptoms</td>
<td>09/19/2003</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Fatigue</td>
<td>0</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0</td>
</tr>
<tr>
<td>Sadness</td>
<td>3</td>
</tr>
<tr>
<td>Feeling more emotional</td>
<td>3</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0</td>
</tr>
<tr>
<td>Feeling mentally foggy</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>1</td>
</tr>
<tr>
<td>Visual problems</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Symptom Score</strong></td>
<td><strong>8 (4)</strong></td>
</tr>
</tbody>
</table>
JM Disposition

- Did not return to play
- Scheduled for full NP eval.
Concussion Management Program at the High School Level

• What’s needed?
  – Commitment from team physician and AT-C and/or school nurse
  – AD and coaches approval
  – For computer-based assessment program: Computer lab at school with tech support
  – Policies and procedures for testing and handling mTBI events in student athletes
  – Support personnel for student athletes: consulting neuropsychologist, school counselor or school psychologist, tutors/liaison
Concussion Management Programs at the High School Level

• Prevention through education
• Education/Awareness: AD, ATC, coach, players, parents, teachers, school personnel
• Skills development as a protective factor
  • Teaching proper technique
  • Time, skill, persistence
  • Train in protective behavior
Fitness as protection

– Being in shape allows skilled performance
– Developmental aspects of conditioning
  • More is not necessarily better
– Monitor fatigue during practices and games
– Neck muscle conditioning
  • Possibility of reducing impact forces, but no evidence
Equipment and rules

- Proper fit and maintenance of equipment is important
- Use of equipment needs teaching and monitoring
- Unintended consequence of “invulnerability”
- KEY: Rules modifications \textit{and enforcement}
  - No spearing in football, no head checking in hockey
- Enforcement of rules
  - game rules, coach’s rules, School rules, MD’s rules
  - Modify rules of games as needed
Sports Medicine

- Get organized (A.D.)
- Use of EMT’s, school nurses, MD’s, trainers
  - Make sure to have established a connection for follow-up prior to the start of the season
  - Verify concussion protocol
  - Coaches should not do on-field assessments during competitions
- Use of testing protocols
  - Availability, costs, reliability
H.S. Concussion Program

• Collaborate
  – With schools in your conference, division

• Advocate
  – E.g., for state level action (e.g., NH Interscholastic Athletic Association (NHIAA))

• Initiate
  – A process for assessing needs, resources and responsibilities
Educational outcomes

• Educating the educators
  – Recuperating student athletes may require short-term modification of their educational program
  – Administrators, school psychologists
Summary

• Accurate on-field diagnosis of concussion is critical.
• Need for careful post-injury assessment of symptoms and cognitive status.
  – PCS is a useful tool, especially acutely
  – NP testing has demonstrated good sensitivity to effects
• Athletes may not return to play until symptom free at rest and exertion.
  – Mean window of vulnerability 5-10 days
  – Majority of athletes with one concussion likely to have good recovery, but...
• Specific assessment tools are available for the sports-medicine clinician.
• Evidence-based RTP guidelines are forthcoming.
What we think we know

• Prevention is the best intervention
• Concussions (mTBI) can produce lasting negative effects
• Multiple concussions makes the chances of more/severe concussions greater
• Amnesia is the best indicator of severity
  – Orientation and LOC are not good markers for severity
• Err on the side of caution
Future Matters

• Role of exertion on recovery from concussion and utility of stress test in RTP?
• Longitudinal studies of outcome
  – Long term effects for whom, when, and in what context?
  – Role of prior events/history & genotype (ApoE-4)?
• Value of research examining component symptoms of concussion to inform evidence-based clinical management.
What we need to know

- Are some athletes more susceptible to
  - initial concussion?
  - multiple concussions?
- Do subsequent concussions occur with less trauma?
- What leads to post-concussive syndrome?
- What leads to second impact syndrome?
- What impact might steroids or other drug use/abuse have on metabolic dysregulation and vulnerability
What we need to know

- What function(s) is most vulnerable to disruption?
- Are grading systems accurate/useful?
- What should the RTP guidelines be?
- Does concussion “grade” matter?
- How close together can multiple concussions be?
Thank you