Concussion and Sports: Gambling with our children’s brains
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Organizations/Protocols
• American Academy of Pediatrics (2013)
• Return to Learning
• American Medical Society for Sports Medicine (2013)
  • 4th International Conference on Concussion and Sport (2012)
  • Consensus statement
  • Sports Concussion Assessment Tool V.3 (SCAT-3)
• Centers for Disease Control and Prevention (2011-2014)
  • Acute Concussion Evaluation Form (ACE)
• National Federation of State High School Associations (2013)
• American Academy of Neurology (2013)

Prevalence
• 4 million concussions/year in US (half are unreported)
  • 1 million are <19
  • 40,000 are sport-related in high schools
  • 47% of ER visits for concussion are 12-15 (girls>boys)
• 1.1 million teens play high school football
  • Another 3 million 6-14 play in organized youth leagues
• 68,000 college players
• Significant increase in concussions(22%) from 2006-2010; but no significant increase in catastrophic brain injuries. Rate doubled 2005-2012, but may just reflect increased awareness.
• Females>males for same sport with same rules
Sports and concussion

- Most dangerous sports: football, ice hockey, lacrosse, girls' soccer, wrestling, field hockey, girls' basketball, cheerleading
  - Football: kickoffs had 4x higher risk than rushing or passing plays
  - Soccer: most concussions are due to player contact with 25% associated with illegal activity
  - Hockey: most concussions occur during checking
- Competition results in higher rates than Practice sessions

Traumatic brain injury

- TBI is on a continuum from mild to severe
- Concussion is considered ONE TYPE of mild TBI
  - All concussions are mTBIs; but not all mTBIs are concussion
- Most reports interchange the words concussion and mild TBI (not AAN)
- 26% of mTBIs are sports and bicycle related in those 5-14

Concussion - definition

- “A traumatically induced transient disturbance of brain function and involves a complex pathophysiological process” [AMSSM, 2013]
- “may be caused by a direct blow to head, face, neck, or elsewhere on the body with an ‘impulsive’ force transmitted to the head”
  - Occurs when linear and/or rotational forces transmitted to brain
  - Therefore, do not have to hit your head to sustain a concussion
  - Results in damage to blood vessels and nerve fibers
- Generally self-limited
  - Not degenerative or congenital; not due to a disease
- Acceleration-deceleration process
  - When running and then stop, brain keeps going
- Coup-contracoup
  - Coup is injury due to impact of brain hitting skull; contracoup is injury when brain bounces back and hits skull on opposite side
pathophysiology

- **CONCUSSION IS A BRAIN INJURY**
  - Alteration in electrical system of brain
    - Brain cells become depolarized; they fire all neurotransmitters at once, flooding the brain with chemicals and deadening certain receptors linked to learning and memory
    - Then try to regain equilibrium - *takes time and energy*
    - Disruption of ionic balance; imbalance of energy supply and demand
    - Results in water uptake by injured cells up to 4 months after concussion (Mayer, 2013)
  - Alteration in physiology of neuron
    - **DIFFUSE MICROSCOPIC AXONAL INJURY**
      - One protein in neurons = Tau protein
      - Stabilizes the microtubules of astrocytes and oligodendrites
      - "Without tau, neurons would collapse, cutting off the flow of nutrients and molecules to the cell," (League of Denial, 2013)
      - Results in generalized damage to white matter of brain

- NO bruise, NO bleeding, NO swelling
  - Therefore, nothing will show up on MRI
  - Until normal brain cellular function is restored, studies support the concept of increased post-concussive vulnerability; therefore a 2nd injury can result in worsening cellular metabolic changes and more significant cognitive deficits (AMSSM, 2013)
  - Concussion is an invisible injury

**symptoms**

- **PHYSICAL**
  - HEADACHE (may be head pressure)
  - Dizziness/lightheadedness – BALANCE PROBLEMS
  - Visual symptoms (light sensitivity, double vision, blurry vision [trouble with slide presentations, movies, smart boards, computers, tablets, artificial lighting, reading, copying, and paying attention to visual tasks])
  - Noise sensitivity [trouble with lunchroom, shop class, music class, gym class, hallway, assemblies]
  - Nausea/vomiting
  - **SLEEP DISTURBANCE** (fatigue, drowsy, sleepy; sleeps more or less than usual; trouble falling asleep; frequent waking, excessive napping)
Symptoms

Cognitive Impairment
- Feel like in a fog – difficulty thinking clearly; feel dazed/stunned
- Difficulty concentrating/remembering (difficulty learning new tasks and comprehending new material; difficulty recalling and applying previously learned material; lack of focus/attention; easily distracted; trouble with test taking; slowed reaction time (THINK DRIVING); difficulty multi-tasking; difficulty following directions; difficulty problem solving; difficulty with abstract thought, organization, being consistent; difficulty with multi-step problems; forgetful of recent information or conversations

Emotional Impairment
- Emotional lability, irritable, moody, depressed, fidgety/nervous, impulsive, sad, flat affect

Sideline Assessment

- ABCs; attend to cervical spine injury
- SCAT3
- Do not leave player alone following injury; do not send home
- Assess for deterioration over initial hours following injury
- DO NOT RETURN TO PLAY ON DAY OF INJURY
  - When in doubt, sit it out
- Check for signs of serious brain injury
  - Deteriorating mental status
  - Pupil changes
  - Worsening symptoms
  - Glasgow Coma Scale (eye, motor, and verbal responses to commands) [≥9 = mild]

Assessment

- “While standardized sideline tests are a useful framework for examination, the sensitivity, specificity, validity and reliability of these tests among different age groups, cultural groups and settings is largely undefined. Their practical usefulness with or without an individual baseline test is also largely unknown” (AMSSM, 2013)
- A diagnosis of concussion and fitness to play are medical decisions based on clinical judgment; it is a hidden condition
- The diagnosis is largely symptom driven; but symptoms may not occur for hours or days after initial injury due to evolving injury
  - First sign may be behavior changes (easily frustrated, more aggressive, depressed, decreased attention)
- Concussions can be difficult to diagnose
Neuropsychological assessment tools

- Assess cognitive, physical, behavior, and emotion
- **NOTE:** most concussions can be managed appropriately without the use of neuropsychological testing
  - "There is insufficient evidence to recommend the widespread routine use of baseline neuropsychological testing" (AMSSM)
- Tests must be developmentally sensitive related to cognitive development
  - Cognitive development increases, so baseline tests should be evaluated with suspicion after 6 months
- If there is no testing – BE CONSERVATIVE (you only have one brain)
- **THESE ARE TOOLS; NONE CAN DIAGNOSE A CONCUSSION**

### SCAT-3 (Sport Concussion Assessment Tool – 2013) [AMSSM]
- What venue are we at today? Which half is it now? What team did you play last game? Did your team win?
- Developed for on-site evaluation; includes Glasgow Coma Scale immediately and then after 15 minutes (to avoid influence of exertion and fatigue)
- Child SCAT3 available for ages 5‐12
- FREE from British Journal of Sports Medicine

### ACE (Acute Concussion Evaluation) [CDC 2006/2010; goes with HEADS UP program]
- Characteristics of the injury
- Types and severity of symptoms (physical, cognitive, emotional, sleep)
- Risk factors that can lead to a protracted recovery period
- Can be used to serially track symptoms and recovery

### ImPACT (Immediate Post Concussion Assessment and Cognitive Testing)
- 20 minute computerized neurocognitive test battery to evaluate recovery
  - Usually have a baseline done before the season
  - Includes verbal and visual memory, attention span, brain processing speed, reaction time, and post-concussive symptoms
  - Can be used to track recovery
  - **COST:** $400 for 100 baseline and 15 post injury tests per year ($800 for 500 baseline and 100 post injury tests; for professionals, $10 per baseline and $20 per post injury)
- BESS (Balance Error Scoring System) – postural stability
  - Not very sensitive
- Sensory Organization Test (gold standard for balance – research only)
- SAC (Standardized Assessment of Concussion)
  - A cognitive test; weak psychometrics
- King-Devick Vision Test (speed and accuracy of reading numbers in 1 minute)
Blood biomarkers

- 3 biomarkers associated with brain injury: neuron-specific enolase (NSE), 5-100 calcium-binding protein B (S-100B), and Tau
  - First 2 increase after exercise without concussion; tau increases 5-10 times with concussion; NSE does not
- Tau is usually only in CSF, but can get into blood if blood-brain barrier is damaged
  - Secreted by axons of unmyelinated nerve cells when they are injured
  - Highest tau level immediately after injury and declined in first 12 hours; then second peak 12-36 hours
  - Tau concentrations at 1 hour after concussion predicted the number of days it took for symptoms to resolve (JAMA, 2014)
  - Only in research phases now

UNDIAGNOSED CONCUSSIONS

- 2004 – 47.3% of HS football players reported their symptoms; 2005 – 17% of college athletes reported symptoms, although 48% had symptoms
- 2013 – 30% reported having sustained a blow to the head previously with symptoms of concussion, but not diagnosed; these individuals were 31% more likely to lose consciousness with their current injury
- Culture of Resistance – a desire by athletes NOT to report
  - Feel they are letting their teammates down
  - Feel the need (or pressure from coach) to tough it out.
  - Parents push for focus on college scholarship
- "Athletes should know that they should never try to "tough out" a suspected concussion" Do not play through the symptoms (Natl. Fed. State HS Associations)

Factors affecting recovery

- Number, duration, and severity of symptoms
- Frequency of concussions over time: recency and timing between concussions
  - Those who had concussion were 2 – 5.8 times higher risk of sustaining another
  - Due to failure to completely heal or related to poor judgment
- Those with prior concussion report more symptoms at baseline
- Threshold: repeated concussions occur with progressively less impact force needed – and slower recovery after each successive concussion
- Age: “Pediatric brain differs in water content, degree of myelination, blood volume, blood-brain barrier, cerebral metabolic rate of glucose, blood flow, number of synapses...” May have less cognitive reserve than more mature brains (AMSSM)
Factors affecting recovery

- Comorbidities/premorbidities
  - CONCUSSION IS THE GREAT AMPLIFIER; MAKES PROBLEMS WORSE
  - Especially migraines, depression, anxiety, ADHD, LD, sleep disorders
  - LD and ADHD associated with increased cognitive dysfunction and prolonged recovery after concussion
  - Children with concussion up to 5 times more likely to be diagnosed with depression
- Medications taken, especially psychoactive drugs and anticoagulants
- Type of sport
- Intellectual and functional levels prior to injury
- Personality characteristics prior to injury
- Gender: girls with concussion have symptoms 22 days longer than males (56v34)
- Do they buy into the treatment plan

recovery

- 50% resolve in 7-10 days – but may be longer in children and teens
- 80% resolve within 3-4 weeks
- 10%-15% recover in 3+ months
- 1%-2% take one year to recover [consider other etiologies]
- The more concussions they have, the longer it takes to resolve
- Severe symptoms do not necessarily mean a longer recovery (but may increase risk of post-concussive syndrome

management

- CONCUSSION IS A BRAIN INJURY: REST AND BOREDOM ARE NEEDED FOR REPAIR
- First 12 hours
  - No longer recommend frequent awakening to make sure they are OK; let them sleep
  - No ASA or NSAIDS; no drugs that can alter mental status; no alcohol
    - Give acetaminophen, ice, dim/quiet environment
  - Observe for worsening of symptoms; if so, call 911
- Goal is to determine appropriate balance between how much cognitive exertion and rest is needed to eliminate symptoms
Management

**STEP 1**
- Physical and cognitive rest at least 24-48 hours – the goal is recovery
  - Cognitive rest is anything that taxes the brain (reading, homework, watching TV, movies, texting, being on the phone, being on the computer, video games, driving, trips, social visits); it does not mean total bedrest
  - 2014 study followed 335 8-23 year olds who presented within 3 weeks of initial injury; those with most cognitive activity took 100 days to recover compared to 20-50 for those who rested

*DO NOTHING: IF NOT SYMPTOMS, DO SUB-THRESHOLD ACTIVITY FOR 15-20 MINUTES*

- IF SYMPTOMS OCCUR, GO BACK
- Graduated approach
- **MINIMUM OF 24 HOURS BETWEEN STEPS**

Management

**STEP 2**
- Light mental activities (watch TV, light reading, interaction with family); keep computer use, texting, and video games to a minimum
- Do NOT have homework sent home
- Progress to light physical activity (walk around block, light biking on stationary bike)
- When they can tolerate cognitive activity and stimulation for 30-45 minutes (arbitrary), they can consider returning to school

**STEP 3: RETURN TO SCHOOL/ RETURN TO LEARN**
- “Using a concussed brain to learn may worsen concussion symptoms and perhaps even prolong recovery” (AAP, 2013)
- Prepare staff
  - Help faculty understand that student will look normal, but may not catch on as well
  - Avoid negative behavioral and academic consequences
  - Coordinate adjustments that will be made; **FOCUS ON FUNCTION VS. SYMPTOMS**
- PHYSICIAN NOTE OF “ACTIVITY AS TOLERATED” IS NOT ACCEPTABLE
- AAP guidelines based on Rocky Mountain Youth Sports Medicine Institute
- REAP: Reduce, Educate, Accommodate, Pace
  - Limited research on benefits or harm; validated down to age 6
- Adding additional restrictions may not be needed and may add further stress
- School nurses should reassess weekly
- **RECOMMEND GRADUAL RETURN TO SCHOOL AND SOCIAL ACTIVITIES**
• American Medical Society of Sports Medicine (2013)
  • Those with concussion missed a median of 37 school days; 13% missed >6 months
  • 2/3 had some form of school accommodation
  • 61% saw their grades drop
  • 28% had co-morbidities
  • Patients were symptom-free after a median of 66 days

Practical strategies - physical

• Headache
  • Schedule rests in SN office
  • Frequent breaks (identify aggravator and reduce exposure)
  • Cover up other lines of text to keep eyes on same plane

• Dizziness
  • Allow extra time to get to class through crowded hallways
  • Allow student to put head down if symptoms worsen
  • Five early dismissals to avoid crowded hallways

• Light sensitivity
  • Permit sunglasses and hats/hoods to be worn indoors
  • Reduce exposure to computers, smart boards, videos
  • Reduce brightness of screen; turn off fluorescent lights

Practical strategies - physical

• Noise sensitivity
  • Wear earplugs
  • Remove from building before fire drills
  • Allow student to lunch in a quiet area with classmate
  • Limit/avoid band, choir, shop class, noisy gym,
  • Avoid crowded hallways

• SLEEP problems
  • Allow for late start or shortened school day
  • Schedule strategic rest breaks mid-morning and mid-afternoon (to prevent emotional melt-down)
    • Quiet reading is NOT rest
Practical strategies - cognitive
• Reduce cognitive load; comprehension in small doses
• Focus on what student does well and expand from there
• Teachers must only grade work completed and not all work due
• Adjust due dates, avoid testing
• Perhaps start by auditing class (sitting in) with gradual return to expectations
• Identify distractions so they can get back on task
• 504: reader, books on tape, dictate responses for tests, take tests in quiet setting, have directions read/reworded, alter formats, special seating, peer note-taker, INDIVIDUALIZE

Practical strategies - EMOTIONAL
• Be aware they are emotional
  • May be anxious about missed work, missed social experiences, missed games
  • May be depressed
  • If student is frustrated with failure in one area, redirect him to other elements that result in success; provide positive reinforcement; empathize with frustration
  • If concussion was the result of bullying or assault, be aware of an increase in anxiety on return to school and deal with the problem
• Be aware that separation from friends while recovering at home may result in fears and isolation on return to school

• “GOAL DURING RECOVERY IS TO AVOID OVER-EXERTING THE BRAIN TO THE LEVEL OF WORSENING OR REPRODUCING SYMPTOMS” (AAP)

STUDENT COMES BEFORE ATHLETE
• “NO RETURN TO SPORT OR ACTIVITY SHOULD OCCUR BEFORE THE CHILD/ ADOLESCENT ATHLETE HAS MANAGED TO RETURN TO SCHOOL” (AMSSM)
• “STUDENTS SHOULD BE PERFORMING AT THEIR ACADEMIC BASELINE BEFORE RETURNING TO SPORTS, FULL PHYSICAL ACTIVITY, OR OTHER EXTRACURRICULAR ACTIVITIES FOLLOWING A CONCUSSION” (AAP)
  • When in doubt….sit it out
  • Loophole is denying symptoms…..but it is hard to ‘fake’ baseline academic performance
Return to play

1. no activity
2. light aerobic exercise
3. sport-specific exercise
4. non-contact training drills; initiate progressive resistance training
   - Observe impact of exercise; observe impact on coordination and cognitive load
   - Physical symptoms improve prior to cognitive symptoms
5. full contact practice after medical clearance
6. return to play

Post-concussion syndrome

- Chronic
- Controversial; poor understanding of the etiology; no tools to predict it
- Correlated with increased # of concussions
- Correlated with premorbid conditions and stress
- 14% (6%-35%) >age 6 had increased fatigue, emotionality, irritability, headache 3 months after concussion (Barlow, 2010; Reuben, 2014)
  - may have lower concussion threshold
  - Represents a challenge to schools

Second impact syndrome

- "occurs when individual sustains a second head injury before the symptoms associated with the initial injury have completely cleared...Thought to involve a loss of autoregulation of the brain's blood supply, leading to vascular engorgement, marked increase in ICP; brain herniation and ultimately coma and death" (AMSSM)
- Debate whether SIS is due to prior head injury or if it represents a separate pathophysiologial malignant brain edema/ diffuse cerebral swelling seen in children
- More common in boxers and athletes <18
- American Academy of Neurology does not agree with SIS
- At least 17 deaths in the literature
Chronic traumatic encephalopathy (CTE)

- 1920s-1973, research on boxers showed they developed cerebral atrophy and destruction of cerebral tissue; = dementia pugilistica
- Symptoms similar to Parkinson Disease; due to a different type of protein
- Among 5 boxers with >20 fights, all had cerebral atrophy; of the 5 with <12 fights, only 1 had it
- Alzheimer has beta amyloid plaques/hardened tangled proteins that surround the brain cells and poison them
- In hippocampus first and then in cortex
- 1975 Tau protein discovered in neurons with a role of stabilizing the microtubules (without tau, neurons would collapse, cutting off the flow of nutrients and molecules to the cells)
- 2001, Guskiewicz found that players who reported at least 3 concussions were 5 times more likely to be diagnosed with early signs of dementia; this is first study to link football and brain damage

CTE

- 2002 – Bennet Omalu, forensic pathologist, identified CTE in Mike Webster, 50, professional football player who had significant behavior and memory problems in his 40s and killed himself
- Identified protein tangles within the neuron; strangles it
- None found in hippocampus; very little beta amyloid found
- CTE is a tauopathy
- A neurodegenerative disease of brain tissue and accumulation of Tau
- Diagnosis can only be made after death
  - Decreased brain weight, atrophy of frontal and temporal lobes, change in white matter
- First sign: decreased memory, disorientation, confusion, executive dysfunction
- Next: unprovoked mood swings, anger without provocation, aggression, suicidality

cte

- Thought to develop decades after exposure
- American Academy of Neurology does not support CTE as a diagnosis
- Chris Benoit, a professional wrestler, killed his wife and 7 year old son, and then hung himself; he had it
- Terry Long (45), Andre Waters (44), Dave Duerson (50), Ray Easterling (62), Junior Seau (43) – all committed suicide and all had CTE
- As of 2013, 50 cases identified in professional sportmen
- Ryan Freel (36) first baseball player
- April, 2010, Owen Thomas (21), UPenn lineman hung himself; no diagnosed concussions, but was ‘hard hitting’, had early stage of CTE
- November 2010, Nathan Stiles (17) died hours after his high school homecoming football game from SIS; 4 areas of his frontal lobe had beginning CTE
### cte

- No agreement as to how much contact results in CTE
- Not all athletes with CTE had a history of reportable concussions during play
  - Might it have been sub-concussive blows that contributed to CTE
  - May be a dose-related phenomenon

### Protective equipment

- **Protective equipment do NOT prevent concussion or decrease the incidence**
  - They DO decrease the impact forces to the head
  - They DO protect against head and facial injury (fracture, bleeding)
  - No brand of helmet is better than another in reducing concussions
    - Head impact sensors do NOT diagnose concussion
  - Mouth guards DO prevent dental and orofacial injury, but not concussions
    - Generic mouth guards are more protective than custom-fitted devices

### Prevention education

- Talk about protecting the brain
  - REWARE of NFL campaign labeled ‘Play Safe’. It teaches kids to tackle ‘properly. The message is ‘play safe and avoid injury’, but THERE IS NO SUCH THING AS PLAYING SAFE FOOTBALL
  - NO TACKLING <12 YEARS
  - NO HEADING IN SOCCER
  - NO BODY CHECKING IN HOCKEY <15
  - NO HEAD-FIRST SLIDING IN LITTLE LEAGUE
  - Add batting helmets to field hockey and girls lacrosse
  - As of 10/13, there had been no reduction of concussions due to these rule changes, fines, or improved equipment
conclusion

- It is time to tackle concussions
  - How many concussions are too many
  - At what point is the child/teen at risk
- It affects the family, the school, and the sport
  - Is concussion just an occupational hazard; what are the stakes?
  - Parents have to make the final decision – BUT SCHOOL NURSES CAN HELP IN THIS EDUCATIONAL PROCESS
- The NFL is very rich and powerful; they hid this problem for a decade
- Brain injury is complex and unique. The road to recovery is a long process

DON’T GAMBLE WITH OUR CHILDREN’S BRAINS

CONCUSSION IS A BRAIN INJURY

AND YOU ONLY HAVE ONE BRAIN!

SELECTED REFERENCES