Are Girls More Vulnerable to Sports-Related Concussions?

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  - http://www.sportsneuropsychologysociety.com/
Everybody is Talking about Concussions

- Center for Disease Control (CDS)
  - Heads Up Concussion in Youth Sports
  - Tool Kits for Youth Sports
  - Information for Coaches (and others)
- [http://www.cdc.gov/concussion/headsup/youth.html](http://www.cdc.gov/concussion/headsup/youth.html)

“Concussion and Our Kids” R. Cantu
Cumulative Effects

Argument


"Our study suggests that players with a history of previous concussions are more likely to have future concussive injuries than those with no history; 1 in 15 players with a concussion may have additional concussions in the same playing season; and previous concussions may be associated with slower recovery of neurological function."

Concussion

- Reversible impairment of neurologic function for a period of minutes to hours following head injury
- Mechanism is unknown
  - May involve transient diffuse neuronal dysfunction
How Concussions Occur

- Coup injury
  - A moving blow occurs to the resting head
- Contrecoup injury
  - Usually occurs when the moving head collides with a non-moving object
  - Rapid change in head velocity

Common Features

- Direct blow to head, face, neck, or elsewhere on the body
- Rapid onset of short-lived impairments
- Neuropathological changes that usually reflect functional disturbance not structural damage
- Resolution typically follows a sequential course
- Normal imaging studies

Symptoms of Concussion (Zurich)

- Somatic (e.g., headache)
- Cognitive (e.g., "fogginess")
- Emotional (e.g., emotional lability)
- Physical signs (e.g., loss of consciousness, amnesia)
- Behavioral changes (e.g., irritability)
- Cognitive impairment (e.g., slowed reaction, unawareness of period/opposition/score)
- Sleep disturbance (e.g., drowsiness)
Pathophysiology of Concussion

- Signoretti, Lazzarino, Tavazzi, and Vangozzi (2011)
  - Concussion
    - Biochemically induced brain injury, absence of anatomic lesions
  - Early and late clinical symptoms (memory impairments, attention, headache and altered mental status)
  - Due to functional versus structural abnormalities

Mechanical Insult

- Complex cascade of metabolic events that disturbs neuronal homeostatic balances
- Neurotoxicity, energetic metabolism disturbance
  - (Mitochondrial dysfunction)
- State of vulnerability
- Second concussion, potential for irreversible damage (swelling)

Neurometabolic Cascade of Concussion (Giza and Hovda, 2001)
Pruning of Gray Matter

MRI Tractography (White Matter)

Brain Facts
- Brain is 95% of peak size by age 6
- White matter (myelin) increases throughout childhood and adolescence
  - As much as 50% change over 2-year period of time
  - Allows for greater and more efficient connectivity
  - Fosters ability to change in response to environmental factors
    - Inhibit sprouting of axons
    - Creation of new synapses
**Cortical Gray Matter**

- Cell bodies, dendrites, dendritic processes
- Axons, glia, blood vessels, and extracellular space
- Peak development varies by region
  - Frontal lobes
    - 9.5 years in girls
    - 10.5 years in boys
  - Temporal lobes
    - 10.0 in girls
    - 11.0 in boys

**Cortical and Subcortical GM**

- Integration of primary sensorimotor functions
- Mediation of movement, higher cognitive functions, attention, affective/mood states
  - Neuropsychiatric disorders
- Role of temporal, amygdala and hippocampus
  - Emotion, language and memory
Key Points
- All types of "connectivity" increase during adolescence
- Late maturation of dorsolateral prefrontal cortex
  - Neurocircuitry involved in judgment, decision making, and impulse control
  - Implications for social, legislative, judicial, parenting, and educational domains

Interplay Between Limbic and Cognitive Systems
- "Cold" versus "Hot" cognition
  - High arousal, peer pressure, and real consequences
- Treatment goals
  - Facilitate decision-making
  - Preparation for next stage in life

Temporal Discounting
- Giving less weight to future events
  - Larger rewards and shorter waiting times
  - Inhibition of impulses challenged
Positives

- “Everything is coming on-line”
  - Interaction of hormones, connectivity, greater efficiency in some cognitive skills
- The “Fullness of Feeling”
  - Moved and motivated
  - Inspired and disappointed
  - Internalization of positive and negative influences

Sex Differences in Cerebral Organization: Research Summary

<table>
<thead>
<tr>
<th>Cognitive Skill</th>
<th>M &gt; F</th>
<th>F &gt; M</th>
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<tbody>
<tr>
<td>Target throwing and catching</td>
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<td>Fine motor skills</td>
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<td>F &gt; M</td>
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<td>Mental rotation</td>
<td>M &gt; F</td>
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<td>Spatial navigation</td>
<td>M &gt; F</td>
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<tr>
<td>Geographical knowledge</td>
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<td>Spatial memory</td>
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<td>Computation</td>
<td>F &gt; M</td>
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<td>Mathematical reasoning</td>
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Sex Differences

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<tr>
<th>Cognitive Skill</th>
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<tr>
<td>Sensitivity to sensory stimuli</td>
<td>F &gt; M</td>
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<tr>
<td>Perceptual speed</td>
<td>F &gt; M</td>
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<tr>
<td>Sensitivity to facial and body expression</td>
<td>F &gt; M</td>
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<tr>
<td>Visual recognition memory</td>
<td>F &gt; M</td>
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<tr>
<td>Fluency</td>
<td>F &gt; M</td>
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<tr>
<td>Verbal memory</td>
<td>F &gt; M</td>
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Female Attributes

- Conflicting studies on the role of estrogen
- Stage of menstrual cycle is not a factor.
- Severity and number of symptoms is higher in those not taking oral contraception.
- They are more concerned about future health and may be more willing to “sit-out”.

Role of the Neck/Head in Sports

- Neck size and strength lower in females compared to males.
- During head/neck acceleration, peak is higher in females and displacement is higher.
- Greater effect from external force
- In soccer, female athletes have a smaller ball-to-head ratio than males.

Sport Differences

- Female university soccer players are more than twice as likely as male soccer players to experience a concussion in a 12 month period.
- High school female soccer players experience more concussions at the high school level than age matched males.
- Female soccer players have the highest number and injury rate of concussions at the high school level.


Sideline and Clinical Management

- Must consider three parts:
  - Detailed history, including previous relevant history
  - Neurocognitive assessment
  - Vestibular and balance screening
- When reporting symptoms, males tend to focus on cognitive difficulties and females on neurobehavioral somatic symptoms.

Youth, Female Soccer Players

- Relative risk of probable concussion for 11-13 year old soccer players.
  - n = 394
  - Soccer = 195
  - Non-Soccer = 147
- Relative risk = 2.09 (P<.001)

Reported Signs/Symptoms
Post-Concussion

- Greater likelihood of post-concussive syndrome at one month follow-up
  - Also, at one year follow-up
- Increased risk of depression following a concussion
- Less likely to lose consciousness, but 1.7 times more cognitive impairment than males.
- Slightly higher risk of seizure

Meta-Analysis (Dougan, 2013)

- 92 studies analyzed for various factors
- First assessment (1-10 days post injury) showed female athletes had larger neuropsychological deficits than males.
  - No difference depending on length since injury
  - Males had a higher total number of symptoms.
Basketball Case Study

- 21 y/o female pinned and struck on left side of head at a tournament.
- Immediately c/o headache, nausea, loss of appetite- Led to crying and confusion later
- Played next night and was removed from game for 3 charging fouls
- Received second blow in practice 4 days later and then reported to ATC- removed from competition approximately 18 days.

Case Study, Cont.

- Season ended 6 weeks later and athlete admitted her symptoms never fully went away.
- All activity was ceased by team physician, and headache, dizziness, short-term memory loss and concentration lasted for 11 weeks following the season at which point activity was gradually re-introduced.
- No symptoms were reported for her senior season.

Prevention

- Neck strengthening programs
- Soccer- ball inflation and size
  - Delay in age for heading?
- Education of parents and coaches
- Access to health care professionals
Neurocognitive Functioning @ 1 Month and 1 Year Post Injury

- UCLA longitudinal, mild, uncomplicated pediatric TBI study
  - Looked at minority of children with mTBI with persistent neurocognitive deficits
  - Compared to matched group of children with injury to other body part/area (OI)
  - Investigating potential predictors of those that show persistent deficits

Typical Predictors

- Severity of brain injury
  - Glasgow Coma Scale (GCS)
  - Length of impaired consciousness
  - Number of observable lesions

Other Predictors

- Premorbid symptoms and behavioral adjustment
  - Predicts post-injury concussion-based symptoms
- Other factors
  - Lower cognitive ability
  - Retrospective reports of pre-injury symptoms by parents
    - Predicted post-concussive symptoms at 3 months
Findings

- Best predictor at 1 month, post-injury
  - None of injury severity indicators, or type of injury
- Premorbid variables
  - School achievement
  - Parent education
  - Premorbid behavioral and academic problems
- Best predictor @ 1 year
  - 1 month impairment classification
  - Those deemed to be cognitively impaired

Consistent with McNally et al (2013)

- Demographic variables important and predictive of PCS symptoms, post-mTBI in children
- Retrospective ratings of premorbid symptoms
- Family factors (parent adjustment) predict parental ratings of PCS
- Injury factors predict PCS in first months post TBI
- Non-injury factors consistently related to PCS over longer period

Implications

- Not likely to have long-term neurocognitive problems after a single, uncomplicated mTBI
- For the minority of those with cognitive impairment
  - Most like due to pre-injury factors
    - Learning difficulties, behavioral challenges, poor school performance
    - Place children at greater risk for injury (TBI and OI)
- Need to pay close attention to pre-injury factors that may affect post-injury prognosis
Basic Mechanisms of Recovery from Acquired Developmental Brain Injury

- General principles
  - Injury types vary by age and contribute to age-dependent, post-injury pathophysiology
  - Ongoing neural processes that mediate normal brain development
    - Associated with different cellular and physiological mechanistic properties (to acquired injury)
  - Effects of environment on normal development and recovery are complex, but crucial to understand

Relevant Concepts

- "Growing into the Lesion"
  - Extends Margaret Kennard’s work
  - Early injury somehow affects or perturbs normal maturation
  - Not necessarily better to be injured at younger developmental age
    - Example of frontal lobe dysfunction that becomes more evident as child ages
      - Later-emerging problems

Repetitive Trauma

- Evidence supports recovery from single, uncomplicated mTBI
- Persistent cognitive deficits present with repeated mTBI
- High school students take longer to recover, compared to college students
- Proposed association with earlier onset of AD, PD, dementia syndrome (premature and excessive neurofibrillary tangles – CTE)
Age-at-Injury Mechanisms

- Very immature brain exquisitely sensitive to excitotoxic injuries
- Multiple metabolic abnormalities
- Cellular and network destruction, dysfunction
- Extracellular mediators of developmental connectivity affected
- Oxidative stress
- Compromised cerebral blood flow
- Myelination issues

Myelination

- One of final stages of cerebral maturation
- Continues into young adulthood in humans
- FL last cortical area to myelinate (quantitative MRI and DTI studies; NP testing)
- Age-dependent changes in FL function
- Unmyelinated fibers may be vulnerable to effects of TBI
  - Functional impairments

Environmental Effects: Experience-Dependent Plasticity

- Maternal rearing behaviors affect long-term brain development
- Neonatal stress problematic
  - Long-term developmental effects
    - Hormonal dysfunction (hypothalamic-pituitary-adrenal axis)
    - Neurotransmission alterations
    - Reductions in neurogenesis
    - Altered neurotrophic expression
  - Further mediated by genetic susceptibility, increasing risk of later (emergent) behavioral or NP sequelae
Enriched/Complex Environments
- Affect brain structure and function, positively
- More elaborate anatomical structures and functions
- Socioeconomic factors and/or family status implicated as playing a role
- Not yet known (humans)
  - Underlying, neurobiological mechanisms that enhance recovery

Executive Functions in Girls with ADHD
- Followed prospectively into adulthood
- Girls with persistent ADHD and remitted group (Sx at non-dx level)
  - Both showed executive function deficits, relative to matched comparison group @ 10 year follow-up
  - Childhood ADHD predicts NP/EF deficits that persist

Inhibitory Control in Young Adolescents
- Looked at role of sex, intelligence and temperament
  - Contribute to the ability to regulate behavior adaptively
  - Evaluated older adolescents (12.6 mean age; 153)
  - Modified Stroop (strategic and evaluative control)
  - Females more efficient in use of strategic (proactive) control to reduce magnitude of response conflict (verbal ability helpful)
  - High intelligence benefitted both males and females
Sex Differences in Concussion Sx of High School Athletes

- Compared symptoms, symptom resolution time, RTP time between males and females with SRC
  - 100 high schools via HS Reporting Information Online (RIO)
- Symptom type differed
  - Males (amnesia and confusion/disorientation) more frequently than females
  - Females reported more drowsiness, noise sensitivity
- Symptom resolution time and RTP similar

Basic Points

- Regardless of gender, younger athletes/individuals at risk for poorer outcome
- Injury severity variables
- Pre-injury factors
- Lower intelligence
- SES factors
- Some suggestion of different symptom pictures
  - Raises possibility of gender-specific expression of symptoms

NP Tools

- CNS Vital Signs (https://www.cnsvs.com)
- ImPACT (https://www.impacttest.com/)
- Axon Sports (http://www.axonsports.com)
Need More

- Sideline evaluation measure
  - SAC
    - 5 orientation measures
    - 5-word list learning
    - Digits backward
    - Reversing months of year
    - Delayed recall of word list
  - Standard neurological measures
    - SCAT-2

RTP Process: NHL

- Injured player is examined at rink
  - Team physician and head athletic trainer
  - Dx made: concussion
- Player instructed to rest
  - Monitored daily by athletic training staff and team physician
- Asymptomatic at rest
  - Graduated return to physical activity (e.g., walking, riding bike, light skate, heavier skate)
- Asymptomatic at activity
  - Post-Injury NP testing

Current Amateur Athlete

- Middle school soccer player (13), with recent concussion (symptomatic)
- 3rd concussion in last 2 years
- Above average player (high school prospect)
- Has struggled academically since onset of concussions
- Parents wonder what to do re: play, "retirement," etc.
Current Amateur Athlete

- High school football player
- New onset of concussion symptoms
- Symptomatic, but determined to RTP
- Had probable concussion in first half, but opted to continue to play (“My team needed me”)
- Good student
- Your role beyond assessor

Treatment and Management

- Follow current international guidelines
- Try to involve professionals with the appropriate training and expertise
  - AT and NP
  - Sports medicine-trained physician
- Consider educational setting and impact on developmental trajectory
  - IEPs, Section 504 Plans
- Target variables that increase risk for prolonged PCS

Education

- Given increase in exposure, due to greater involvement in sports
  - Need to educate girls as clearly as we do boys in more traditionally (violent) sports
- Role models important
  - Maladaptive and adaptive coping
- Provide message in culturally sensitive manner, given SES background
Are Girls at Greater Risk for Concussions?

- Consider ADHD study re: Executive Function difficulties
- Clinical case/anecdotal evidence
  - Consistent with pre-morbid complexity affects post-injury trajectory
  - Consider social pressures to conform, “fit in”

Recent Article: The Female Athlete: The Role of Gender in Assessment and Management of Sport-Related Concussion

Basic Points

- More than 178k female athletes (NCAA teams)
- More than 3 million playing organized HS sports
- Role of gender in assessment and management of SRC
  - Females present with more concussion symptoms, take longer to recover, have slower RTs, greater total Sx’s
Symptom Predictors

- Dr. Michael Collins reported the following:
  - Dizziness on the field was the largest predictor of 3+ weeks to recovery
  - Brief loss of consciousness and vomiting recovered faster than other symptoms

Thanks!