Concussions

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Scottsdale Sports Medicine

• No Financial Disclosures
My Life
Objectives

- Definitions
- Epidemiology
- Pathophysiology
- Symptoms
- Management
- Long-Term Effects
- Return-to-play
- Prevention
- Recent Literature

Concussion Grading Scales
(Prior to 2000)

1. Colorado
2. American Academy of Neurology
3. Cantu
4. Maroon
5. Hugenholtz
6. Wilberger
7. Roberts
8. VNI
9. AMSSM
10. Ommaya & Gennarelli
11. Torg
12. Gersoff
13. Rugby Football league
14. (UK) Federation Internationale de Ski
15. Amateur Boxing Association
16. Auto Cycle Union (UK)
17. The Jockey Club
18. Rugby Union
19. Rugby League (Australia)
20. Schneider
21. Kulund
22. Kolb
23. Saal
24. Nelson
25. Parkinson
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1. Colorado
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Clinical Points of Emphasis

1. Abandonment of grading scale approach, recommend individualized management of injury.
2. When player exhibits any signs/symptoms of concussion, he/she should be removed from contest and not allowed to return to play in that same contest.
3. Following concussion, athlete should engage in stepwise exertional progression prior to RTP.
4. Objective tools (e.g. neurocognitive/balance testing) should augment post-injury clinical evaluation. No athlete should return to play if any symptoms, neurocognitive, or balance deficits persist at rest or with exertion.

60,000 published articles
SRC, Sports-related Concussion, representing the immediate and transient symptoms of TBI.
The term mild Traumatic Brain injury (mTBI) is used interchangeably with concussion; term is vague and not based on validated criteria.
Unresolved issue is whether concussion is part of a TBI spectrum associated with lesser degrees of diffuse structural change than are seen in severe TBI or whether the concussion is the result of reversible physiological changes.

What is a Sports-Related concussion?

“Complex pathophysiologic process affecting the brain, induced by biomechanical forces.”

By way of.....

- Direct blow to head or neck on the body or impulsive force transmitted to head
- Rapid, short-lived neurologic dysfunction
- Functional (NOT Structural) disturbance
- No findings on head imaging
- Constellation of symptoms, +/- LOC
Zurich, 08,12 & Berlin, 2016: 
Mechanism of Injury

- **Rotational (angular) acceleration:** diffuse shearing forces deep in brain causing axonal injury

- **Translational (linear) acceleration:** tensile (pulling apart) and compressive forces resulting in focal brain injury

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**Video Concussion**
Pathophysiology: Normal Neuron

- Dendrites
- Mitochondria
- Axon
- Nucleus
- Synapse
- Cell Body

Pathophysiology: SRC

- NO STRUCTURAL DAMAGE
- Neurometabolic Cascade Theory
  - Axonal Stretch
  - Release of excitatory amino acids
  - Cellular depolarization
  - Ca influx to mitochondria
  - Cellular membrane disruption
  - Axolemmal disruption
  - Neurofilament compaction,
  - Microtubule disruption
  - Axonal swelling
  - Axonotmesis
Neuron During Injury

- Widespread depolarization due to release of Excitatory Neurotransmitters
- Massive efflux of Potassium (K⁺)
- Massive influx of Calcium (Ca++)

Neuron Following Injury

Neurometabolic Dysfunction leads to Energy Crisis

Nerve Cell is extremely Vulnerable

Further injury or stress could cause serious cell damage or cell death
**Neuron Following Injury**

- Increased activity of membrane ionic pumps (Na⁺-K⁺ pump) to restore homeostasis
- This requires energy (ATP)
- ATP produced by mitochondria
- Ca²⁺ is toxic to cell (especially the mitochondria)
- Also, decreased blood flow limits availability of glucose

**Neurometabolic Cascade Following Cerebral Concussion**

(Giza & Hovda, 2001)

- Glutamate
- Glucose
- Calcium

Cerebral Blood Flow

UCLA Brain Injury Research Center
Individual Recovery From Sports MTBI: How Long Does it Take?

Concussion by the Numbers

- For 1 concussion in NFL, there are ~50,000+ in youth football
- NCAA rate of 0.43/1000 athletic exposures
- HS rate 0.23/1000 athletic exposures
- ~1.8-3.8 million sport TBI annually
- Highest in Men’s football (Women’s Cheer)
- Competition > Practice
- Women > Men
Researchers at CHOP and the Centers for Disease Control and Prevention (CDC) examined the mechanism of injury for concussion in children aged 0 to 17 years seen for at least one clinical visit with an International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis of concussion in CHOP’s electronic health record system between July 1, 2012, and June 30, 2014. Of 8233 selected, 20% were randomly selected for manual record review (n = 1625 after exclusions).

• most concussions (70%) were related to sports and recreation activities, 30% were due to nonsports and nonrecreational mechanisms, including falls, motor vehicle crashes, and assault.

• 40% of all concussions were from contact sports, including football, soccer, basketball, and hockey. The remaining concussions occurred in limited or noncontact sports and recreation activities (playground, recess, gym) and nonsports and nonrecreation activities.

### Modifying Factors

- Previous Number of Concussions
- Severity of previous concussions
- Gender
- Age
- Medications- psychoactive, anticoagulants
- Style of play
- Sport
- PMH/FH of ADHD, learning disability, headaches/migraines, psychiatric disease
Sideline Management: Be Prepared

- Emergency Action Plan
  - Ensure that proper equipment are in place
- Assembly of an Emergency Assessment Team
  - Name a captain of the team
  - Define roles for personnel
  - Practice
- Pre Participation Physical Exams
  - Proper history, pupil exam, baseline testing (Computerized NP testing?, symptom score?, balance testing?, KD Testing?)
- Concussion Management Plan
- Educate coaches, athletes, administration, parents
- Be a Team Physician! – not a just a spectator

Temporal Awareness

- Day of week, ‘Fri Night Games’
- Awareness of clinical settings
- Impact on temporal decisions, follow up, etc.
Sideline Management

- REMOVE FROM PLAY
- Evaluation/Diagnosis
- Monitor symptoms
- Parental Instructions
**Components of Sideline Evaluation**

- Level of Consciousness (Glasgow)
- Symptom Evaluation
- Assessment of Amnesia
  - Retrograde
  - Anterograde
- Cognitive Assessment
  - Orientation
  - Memory (immediate & delayed)
  - Concentration
- Neurologic Exam
  - Cranial Nerves
  - Focal Deficits
  - Coordination
  - Balance
  - Vestibular/ Oculomotor Screen

**Sideline Testing**

- Glasgow Coma Scale (GCS)
- King-Devick Test
- Bess Test
- SCAT 5
- Maddocks Questions
Red Flags!

- Decreased level of consciousness/somnolence
- Neurologic signs - weakness, disorientation, severe headache, agitation
- Severe neck pain
- Signs of spinal injury or basilar fracture

Go To The ER!

Sideline Guidelines

Concussion suspected

<table>
<thead>
<tr>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>History:</td>
</tr>
<tr>
<td>• &quot;RED FLAGS&quot;:</td>
</tr>
<tr>
<td>• Head pain</td>
</tr>
<tr>
<td>• Increased confusion or irritability</td>
</tr>
<tr>
<td>• Repeated vomiting</td>
</tr>
<tr>
<td>• Seizure/convulsion</td>
</tr>
<tr>
<td>• Weakness/tingling/burning in arms/legs</td>
</tr>
<tr>
<td>• Decreased conscious state</td>
</tr>
<tr>
<td>• Severe/increased headache</td>
</tr>
<tr>
<td>• Unusual behavior</td>
</tr>
<tr>
<td>• Double vision</td>
</tr>
</tbody>
</table>

Physical Examination Pearls:

- Serial evaluations:
- Pupillary responses
- Extra-ocular movements
- Mental status
- Cervical spine tender to palpation
- Neck range of motion
- Strength, sensation, balance
- Other injuries
Primary Goal of Evaluation

Rule out Emergent Problems by assessing for possible “Red Flags”

- Skull Fracture
- C-Spine Injury
- Intracranial Bleeding
  - Subdural hematoma
  - Epidural hematoma
- Blood Test
  - Rules out Intracranial Bleed... Doesn’t diagnose a concussion.

Banyan Brain Trauma Indicator

- Could eliminate the need for CT scans in at least a third of those with suspected brain injuries.
- Pentagon financed a 2,000-person clinical trial. Measuring the levels of proteins, known as UCH-L1, and GFAP, that are released from the brain into blood and measured within 12 hours of the head injury. Levels of these blood proteins can help predict which patients may have intracranial lesions visible by CT scan, and which won’t.
- F.D.A.: It may be able to predict the presence of intracranial lesions on a CT scan 97.5 percent of the time, and those who did not have such lesions 99.6 percent of the time.
• From SCAT and SCAT2, all designed to help make return to play decisions
• 2013 \(\rightarrow\) SCAT3
• Was used on sidelines and during office Assessments
• Incorporates GCS, SAC, Maddocks Score
BACKGROUND

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examiner:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sport / team / school:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date / time of injury:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender: [M] [F]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years of education completed:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant hand: [right] [left] [neither]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many concussions do you think you have had in the past?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>When was the most recent concussion?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How long was your recovery from the most recent concussion?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you ever been hospitalized or had medical imaging done for a head injury?</td>
<td>[Y]</td>
<td>[N]</td>
</tr>
<tr>
<td>Have you ever been diagnosed with headaches or migraines?</td>
<td>[Y]</td>
<td>[N]</td>
</tr>
<tr>
<td>Do you have a learning disability, dyslexia, ADD / ADHD?</td>
<td>[Y]</td>
<td>[N]</td>
</tr>
<tr>
<td>Have you ever been diagnosed with depression, anxiety or other psychiatric disorder?</td>
<td>[Y]</td>
<td>[N]</td>
</tr>
<tr>
<td>Has anyone in your family ever been diagnosed with any of these problems?</td>
<td>[Y]</td>
<td>[N]</td>
</tr>
<tr>
<td>Are you on any medications? If yes, please list:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Glasgow Coma Scale (GCS)

<table>
<thead>
<tr>
<th>BEST EYE RESPONSE (E)</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No eye opening</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Eye opening in response to pain</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Eye opening to speech</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Eyes opening spontaneously</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BEST VERBAL RESPONSE (V)</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No verbal response</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Incomprehensible sounds</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Inappropriate words</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Confused</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Oriented</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BEST MOTOR RESPONSE (M)</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>No motor response</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Extension to pain</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Abnormal flexion to pain</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Flexion / Withdrawal to pain</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Localizes to pain</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Obys commands</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Glasgow Coma score (E + V + M) of 15

Maddocks Score

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>What venue are we at today?</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Which half is it now?</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Who scored last in this match?</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>What team did you play last week / game?</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Did your team win the last game?</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Maddocks Score of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not used for serial testing.
### 3. How do you feel?

You should score yourself on the following symptoms, based on how you feel now:

<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>&quot;Pressure in head&quot;</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>Trouble falling asleep</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>
</tbody>
</table>

Total number of symptoms (Maximum possible 22)

Symptom severity score (Maximum possible 132)

Do the symptoms get worse with physical activity? [Y/N]

Do the symptoms get worse with mental activity? [Y/N]

<table>
<thead>
<tr>
<th>Method</th>
<th>self rated</th>
<th>self rated and clinician monitored</th>
<th>clinician interview</th>
<th>self rated with parent input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation (1 point for each correct answer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What month is it?</td>
<td>0 or 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the date today?</td>
<td>0 or 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the day of the week?</td>
<td>0 or 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What year is it?</td>
<td>0 or 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What time is it right now? (within 1 hour)</td>
<td>0 or 1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Orientation score of 5

Immediate memory score total of 15

Concentration: Digits Backward

<table>
<thead>
<tr>
<th>List</th>
<th>Trial 1</th>
<th>Alternative digit list</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5-3</td>
<td>0 1</td>
<td>6-2-8</td>
</tr>
<tr>
<td>3-8-14</td>
<td>0 1</td>
<td>3-2-9</td>
</tr>
<tr>
<td>3-9-2</td>
<td>0 1</td>
<td>1-5-2-6</td>
</tr>
<tr>
<td>7-1-8-62</td>
<td>0 1</td>
<td>5-3-9-1-4-8</td>
</tr>
</tbody>
</table>

Total score of 4

Concentration: Months in Reverse Order (1 pt. for entire sequence correct)

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec-Nov-Oct-Sep-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan</td>
<td>0 1</td>
</tr>
</tbody>
</table>

Concentration score of 4

---

### 4. Cognitive assessment

Standardized Assessment of Concussion (SAC)

**Orientation**: 0 or 1 points

**Immediate Memory**: Total of 15

**Concentration**: Digits Backward

**Concentration**: Months in Reverse Order

**Concentration**: Score of 4
Balance testing – types of errors
1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec
### Coordination Examination

- **Upper Limb Coordination**
  - Which arm was tested: [L, R]
  - Coordination score: [of 10]

### SAC Delayed Recall

- **Delayed recall score**: [of 6]
17 year old boy presents with persistent headache, neck pain, dizziness, balance problems, and difficulty concentrating after a hard hit at a football game 3 days ago. What is the best diagnostic tool for evaluating this case condition?

- SCAT5
- MRI BRAIN
- MMSE
- APACHE II
- GLASGOW COMA SCALE

What is the best treatment plan for the patient in question?

- Patient can immediately return to play with observation without further testing
- Patient should be evaluated by a physician qualified to manage concussions and schedule IMPACT testing with a neuropsychiatrist, be provided symptomatic relief for headaches, ensured appropriate classroom accommodations at school are made, and follow up 1 week later to perform SCAT 5.
- The patient should return to school prior to return to play
- The patient can return to play in 2 weeks at 50% intensity of normal routine with gradual increase to 75% intensity as tolerated.
Medical Team Progression

Office-Based Evaluation

Aspects of the Evaluation Process
1. Symptom Evaluation
2. Evaluation of pertinent medical history
3. Balance Testing on a Force Plate or WiFit Board (evals Vestibulospinal)
4. King-Devick Test (evals Occulomotor)
5. VOMS Screen (evals Vestibulo-ocular)
6. ImPACT-Computerized Neurocognitive Testing
Commonly Reported Symptoms

- within 3 days of injury

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Headache</td>
<td>71 %</td>
</tr>
<tr>
<td>#2 Feeling slowed down</td>
<td>58 %</td>
</tr>
<tr>
<td>#3 Difficulty concentrating</td>
<td>57 %</td>
</tr>
<tr>
<td>#4 Dizziness</td>
<td>55 %</td>
</tr>
<tr>
<td>#5 Fogginess</td>
<td>53 %</td>
</tr>
<tr>
<td>#6 Fatigue</td>
<td>50 %</td>
</tr>
<tr>
<td>#7 Visual Blurring/double vision</td>
<td>49 %</td>
</tr>
<tr>
<td>#8 Light sensitivity</td>
<td>47 %</td>
</tr>
<tr>
<td>#9 Memory dysfunction</td>
<td>43 %</td>
</tr>
<tr>
<td>#10 Balance problems</td>
<td>43 %</td>
</tr>
</tbody>
</table>

Lovell, Collins et al., 2004; N = 215

Four Symptom Categories

**Physical Symptoms**
- Headache
- Fatigue
- Dizziness
- Sensitivity to light and/or noise
- Nausea
- Balance problems

**Emotional Symptoms**
- Irritability
- Sadness
- Feeling more emotional
- Nervousness

**Cognitive Symptoms**
- Difficulty remembering
- Difficulty concentrating
- Feeling slowed down
- Feeling mentally foggy

**Sleep Symptoms**
- Drowsiness
- Sleeping less than usual
- Sleeping more than usual
- Trouble falling asleep

Gioia, Collins, Isquith, JHTR; 23 (4), pp 230-242
Concussions Hinder Daily Function

- **Home**
  - Difficulty completing tasks at home
  - Reduced play / activity
  - Fatigue
  - Irritability with challenges

- **School**
  - Impaired concentration
  - Difficulty remembering directions
  - Disorganization
  - Difficulty completing assignments
  - Increased fatigue with thinking stress
  - Fall behind, fail tests, reduced grades

### Office-Based Evaluation

- **Balance Testing**
  - Balance Error Scoring System (BESS)
  - "NeuroCom"

Figure 3. Six testing conditions for Sensory Organization Test used with NeuroCom's Smart Balance Master System.
4. **Office-Based Evaluation**

**Clinical Oculomotor Assessment**

- The VOMS consists of brief assessments in the following five domains:
  1. Smooth Pursuits (H-Test)
  2. Horizontal & Vertical Saccades
  3. Near Point Convergence
  4. Horizontal & Vertical Vestibular Ocular Reflex (VOR) – *(aka-Gaze Stabilization)*
  5. Visual Motion Sensitivity (VMS)

- Following each aspect of the VOMS assessment, patients rate on a scale of 1-10 changes in:
  - HA, dizziness, nausea & fogginess

- Convergence is assessed by both symptom provocation and distance (> 5 cm)

- Should take less than 5 minutes

\*Mucha, Collins, Elbin, Furman, Troutman-Enseki, DeWolf, Marchetti, Kontos, AJSM, 2014

\*Bloom, Athletic Training & Sports Health Care, 2013

---

6. **VOMS**

**UPMC Vestibular Ocular Motor Screening Examination**

- The VOMS consists of brief assessments in the following five domains:
  1. Smooth Pursuits (H-Test)
  2. Horizontal & Vertical Saccades
  3. Near Point Convergence
  4. Horizontal & Vertical Vestibular Ocular Reflex (VOR) – *(aka-Gaze Stabilization)*
  5. Visual Motion Sensitivity (VMS)

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\*Mucha, Collins, Elbin, Furman, Troutman-Enseki, DeWolf, Marchetti, Kontos, AJSM, 2014

\*Bloom, Athletic Training & Sports Health Care, 2013
Where does ImPact testing fit in?
Where does ImPact testing fit in?

- Computerized neuropsych testing
- Preseason “baseline”
- Postconcussion to document improvement or help RTP decision

Symptoms often resolve earlier than neurocognitive deficits
Dr. Abeare of University of Wisconsin and his team reviewed data on nearly 7,900 male and female athletes aged 10 to 21 who underwent baseline testing with the Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) test in 2012-2016, using four published ImPACT validity indicators to gauge baseline rates of failure.

Baseline rate of failure ranged from 29.2% for 21 year olds to 83.6% for 10 year olds. Overall rates of failure at baseline ranged from 6.4% to 47.6%, and 55.7% of study participants failed at least one of the four validity indicators.

Summary: Carefully proctored, and they really shouldn’t be done in large groups, because the kids will be inattentive, and I think that’s what a lot of these results show. There are many, many factors that can influence computer test performance. It’s only test the kids are taking, and if invalid, may result in athlete going back to soon. Be conservative.

Value of ImPACT and other CNTs?

Gaudet et. al (Jan. 2017) – systematic review & meta-analyses on prevalence of invalid baseline results and effectiveness of ImPACT embedded mechanism to detect suspect effort

Methods:
• Systemic review and meta-analyses
• Four databases reviewed (17 total studies)

Results:
• ImPACT correct in identifying ~80% of individuals instructed to underperform

Conclusions:
• ImPACT missed 20% of the time
• Invalid performance increases with: larger groups, nonclinical settings, ADHD, learning disabilities \(\rightarrow\) more studies needed
• 2 tests (or more) are better than 1

Level of Evidence: I
What’s the big deal about concussion?

Second Impact Syndrome

• Brain swelling from a 2nd trauma while still symptomatic from previous concussion
• Rapid neurologic deterioration and cerebral herniation
• Cerebral dysautoregulation and posttraumatic catecholamine release
• RARE
Second Impact Syndrome

A 20 year old star quarterback is playing in his last collegiate game and suffers a blow to the head on the final drive before halftime. In the locker room during the break, you observe his vomiting before rejoining the huddle. You pull him aside, he reports having a headache, and begins crying about the “last half of football he will ever play.” His GCS is 15 and the neurological exam is normal. He becomes very irritable during the exam desperately wanting to rejoin his team. Which of the following is the next best step in management?

• Perform Serial Evaluations, but allow cautious return to play.
• Call the parents down from the stands, and discuss return to play with them.
• Do not allow return to play and take his helmet.
• Arrange for EMS transport, and suggest CT scan once in the emergency department.

What pathophysiologic changes have occurred in this player’s central nervous system that most predisposes to risk of second impact syndrome?

• A. Injury to oligodendrocytes resulting in disruption of myelination
• B. Ion fluctuations, acute metabolic changes, cerebral blood flow alterations leading to an inability to autoregulate cerebral perfusion pressures
• C. Acute decreases in cytokine and chemokine production
• D. Increased permeability of blood brain barrier leading to increase of toxic insults
Post Concussion Syndrome

- Symptoms lasting >3 months
- DSMIV- must have neuropsych impairment and 3 of the following:
  - Headache, dizziness, fatigue, irritability, sleep changes, mood changes, personality changes, apathy

Treatment - Symptomatic
- Medications for h/a, depression
- Physical/Occupational Therapy for balance, vision
- Behavioral/Cognitive therapy

Long Term Sequelae

- Cognitive impairment
- Headaches
- Depression
- Dementia (Lancet Psychiatry 2012, etc)
- Chronic Traumatic Encephalopathy
**Predictive Factors of Recovery**

1975 Lancet Study: LOC > one minute was predictive of severity

Other studies have shown that LOC of less than one minute is not predictive of recovery


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**Predictive Factors of Recovery**

Other Factors

1) Amnesia
2) Prolonged Confusion
3) Prolonged Symptoms

Predictive Factors of Recovery

Magnitude of Force?

- Study used accelerometers imbedded into helmets
- Impact magnitude of concussive hits ranged from 60.51 to 168.71 g
- No relationship between impact force and Symptom Score, Balance Parameters, and NC scores


Concussion Modifiers

- Duration of symptoms
- Number of symptoms
- Severity of symptoms
- Prolonged LOC (>30 seconds)
- Presence of amnesia
- History of concussive convolution
- Number of concussions
- Other recent concussion
- History of two concussions in a short period of time
- Concussion caused by a lower threshold force
- Age (younger athlete takes longer to recover)
- History of migraine (personal or family)
- History of depression or other mental health disorder
- History of ADD/ADHD
- History of a learning disability
- History of a sleep disorder
- Psychoactive medication
- Dangerous style of play
- High risk activity

Reformatted from:
Zurich Statement
BJSM;43;i76-i84
Chronic Traumatic Encephalopathy

- Progressive cognitive decline, confusion, disorientation, behavior changes
- Tauopathy- involving superficial cortical layers, frontal/temporal cortices- atrophy, ventricular dilation, tau deposits
Treatment

- Relative Cognitive AND Physical Rest!!
How strict to be about complete cognitive rest?

+ Correlation
  - Majerske 2008
  - Zurich Conference 2012
  - Brown 2014
  - Atabaki 2013

- Correlation
  - Moser 2012
  - Gibson 2013
  - Corwin 2014
  - Leddy 2017

Cognitive Rest may be most important in first week when most symptomatic. Prolonged cognitive rest may not be as beneficial—Corwin et al. 2014.
Medical Treatments for PCS

Pharmacologic Management only considered after:

1. The athlete’s symptoms have exceeded the typical recovery period for a sport related concussion.
2. The symptoms are negatively affecting the patient’s life to such a degree that the possible benefit of treatment outweighs the potential risks of the medication being considered.
Medical Treatments for PCS

Sleep Disturbance
- Melatonin
- Trazodone
- Benzodiazepines - no
- Zolpidem (Ambien)
- Tricycles
- Psychotherapy
- Phototherapy
- Chronotherapy

Emotionality
- SSRIs
  - Sertraline (Zoloft)
  - Escitalopram (Lexapro)
  - Citalopram (Celexa)
  - Fluoxetine (Prozac)
- Tricycles
- Antidepressants/Dual Analgesia
- Cephalgia
  - Amitriptyline

Counseling by Psychologist
Support Groups
Family Support

Medical Treatments for PCS

Cognitive Symptoms

- Neurostimulants
  - Amantadine
  - Methylphenidate (Ritalin)
  - Atomoxetine (Strattera)

- Cognitive Therapy

Exertion Based Treatment of

Sub-Symptom Threshold Exercise Training

- Determine Symptom Threshold (ST) by treadmill test with Bruce protocol
- Exercise 5-6 days per week at 80% of ST
- Retest ST in 2-3 weeks
5 Stage Post-Concussion Exertion Program

Target Exertion calculated by Karvonen’s equation:

\[
\text{Max. H.R. (220-Age)} - \text{Resting H.R.} \times \text{Target %} + \text{Resting H.R.}
\]

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1</strong></td>
<td><strong>Target Heart Rate</strong>: 30-40% of maximum exertion</td>
</tr>
<tr>
<td></td>
<td>Recommendations: 10-15 minutes of cardio exercise; low stimulus environment; no impact activities; balance and vestibular treatment (prn); limit head movement/position change; limit concentration activities</td>
</tr>
<tr>
<td></td>
<td>-Very light aerobic conditioning</td>
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<tr>
<td></td>
<td>-Sub-max strengthening</td>
</tr>
<tr>
<td></td>
<td>-ROM/ Stretching</td>
</tr>
<tr>
<td></td>
<td>-Very low level balance activities</td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td><strong>Target Heart Rate</strong>: 40-60% of maximum exertion</td>
</tr>
<tr>
<td></td>
<td>Recommendations: 20-30 minutes of cardio exercise; exercise in gym areas; use various exercise equipment; allow some positional changes and head movement; low level concentration activities</td>
</tr>
<tr>
<td></td>
<td>-Moderate aerobic conditioning</td>
</tr>
<tr>
<td></td>
<td>-Light weight strength exercise</td>
</tr>
<tr>
<td></td>
<td>-Stretching (active stretching initiated)</td>
</tr>
<tr>
<td></td>
<td>-Low level balance activities</td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td><strong>Target Heart Rate</strong>: 60-80% of maximum exertion</td>
</tr>
<tr>
<td></td>
<td>Recommendations: any environment ok for exercise (indoor, outdoor); integrate strength, conditioning, and balance / proprioceptive exercise; incorporate concentration challenges</td>
</tr>
<tr>
<td></td>
<td>-Moderately aggressive aerobic exercise</td>
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<tr>
<td></td>
<td>-All forms of strength exercise (80% max)</td>
</tr>
<tr>
<td></td>
<td>-Active stretching exercise</td>
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<tr>
<td></td>
<td>-Impact activities running, plyometrics (no contact)</td>
</tr>
<tr>
<td></td>
<td>-Challenging proprio-balance activities</td>
</tr>
<tr>
<td><strong>Stage 4</strong></td>
<td><strong>(Sports Performance Training)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Target Heart Rate</strong>: 80-90% of maximum exertion</td>
</tr>
<tr>
<td></td>
<td>Recommendations: continue to avoid contact activity, resume aggressive training in all environments</td>
</tr>
<tr>
<td></td>
<td>-Non-contact physical training</td>
</tr>
<tr>
<td></td>
<td>-Aggressive strength exercise</td>
</tr>
<tr>
<td></td>
<td>-Impact activities/plyometrics</td>
</tr>
<tr>
<td></td>
<td>-Sports specific training activities</td>
</tr>
<tr>
<td><strong>Stage 5</strong></td>
<td><strong>(Sports Performance Training)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Target Heart Rate</strong>: Full exertion</td>
</tr>
<tr>
<td></td>
<td>Recommendations: Initiate contact activities as appropriate to sport activity; full exertion for sport</td>
</tr>
<tr>
<td></td>
<td>-Resume full physical training activities with contact</td>
</tr>
<tr>
<td></td>
<td>-Continue aggressive strength/conditioning exercise</td>
</tr>
<tr>
<td></td>
<td>-Sport specific activities</td>
</tr>
</tbody>
</table>
Prevention

- Education
- Rule changes
- Padded goal posts/field-goal markers
- Biomarkers- S100B, Tau, CPK-BB, etc

Berlin 2016, Biomechanical Studies and SRC

- Current helmet-based measurement devices may be useful for collision sports, they do not yet provide data for non collision sports.
- Accelerations detected by a sensor or video-based system do not necessarily reflect the impact to the brain itself.
- Helmets do NOT prevent concussion
Level of Evidence: V

**TABLE 1.** Summary of current institutional approach to RTP and retirement considerations in children and adolescents with structural brain abnormalities

<table>
<thead>
<tr>
<th>Clinical Indication</th>
<th>Institutional Approach/RTP Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traumatic structural brain injury</td>
<td>Retirement from future contact &amp; collision sports participation</td>
</tr>
<tr>
<td>Skull fractures &amp; prior craniotomy for nontraumatic brain lesions</td>
<td>Individualized approach. RTP considered following radiographic evidence of healing</td>
</tr>
<tr>
<td>Craniotherapy for traumatic lesions (e.g., subdural hematoma, intraparenchymal hemorrhage, second-impact syndrome)</td>
<td>Retirement from future contact &amp; collision sports participation</td>
</tr>
<tr>
<td>Transsphenoidal endovascular approaches to intracranial lesions</td>
<td>Individualized approach</td>
</tr>
<tr>
<td>Cavernous septum pendae</td>
<td>No contraindication to safe RTP</td>
</tr>
<tr>
<td>Arachnoid cyst</td>
<td>Individualized approach. Patient must be informed of risk of intracyclic subdural hematoma/hyroma. RTP considered in patients w/i small, &lt;5 cm or incidental arachnoid cysts w/o minimal mass effect</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>Individualized approach. Patient must be informed of risk of shunt malfunction, hardware damage, subdural hematoma/hyroma. RTP considered in patients treated w/endoscopic third ventriculostomy</td>
</tr>
<tr>
<td>Chiari Type I malformation</td>
<td>Individualized approach. RTP considered for patients w/asymptomatic or minimal tonsillar herniation w/o syrinx. RTP considered in patients w/fornamen magnum decompression w/o a tension cyst</td>
</tr>
</tbody>
</table>

Level of Evidence: III

- Deficits in neurocognition after concussion → may impair neuromuscular control → increase risk of LE MSK injury
- Study design: 87 concussion cases among 75 NCAA Division 1 athletes
  - 58 men; 17 women
  - Inclusion criteria:
    - Sports: football, soccer, hockey, softball, basketball, wrestling, volleyball
    - Must have played at a single institution from 2011-2014
- 90-day period after RTP of each concussion reviewed
  - Each RTP case was matched to the same 90-day period in 1-3 controls
    - Controls = athletes without a history of concussion in the previous year
    - Matched by sport team, sex, games played and position
- 182 controls
- Results: 17% of recently concussed vs. 9% of controls suffered acute MSK injury
- Odds of acute MSK injury after concussion = 2.48x higher vs controls (p=0.04)
Concussion diagnosis and management: Knowledge and attitudes of family medicine residents.

Mann A*, Talor CH*, Carson JD*.

Level of Evidence: VI

• University of Toronto, ON
• FM Residents surveyed to assess knowledge, attitude towards, and learning needs with concussion patients
• EMAIL qualitative and quantitative survey/quiz
• 348 surveyed
• 73 respondents

Concussion: Physician Education
Concussion: Physician Education

Attitudes and Counseling Practices of Pediatricians Regarding Youth Sports Participation and Concussion Risks

Michael Fishman, BA, Eleanor Stringer, AB, Meryl Pedman, MD, Kyan Qureshi, MD, MPH, Holly J. Reigunin, MD, Lelie Friedman Ross, MD, PhD

Qualitative study on attitudes and practices of pediatricians toward sports-related head trauma and youth participation in football and ice hockey

- 791 eligible pediatricians
- 227 (29%) respondents; 85% of respondents treat sports-related concussions at their practice; 83% have an "establish RTP protocol" at their practice
- 96% treating concussion have a heightened awareness/concern as a parent
- 77% would not allow their son to play tackle football
- 35% and 34% would not allow their son or daughter, respectively, to play hockey
- Limit or Eliminate tackling and checking from practice
- Almost 50% of respondents would counsel AGAINST youth participation in full-contact sports

CONCLUSIONS:
Most Pediatricians treating concussions, would not allow their own child to play tackle football; AAP should consider recommending restrictions on tackling in football to support the current concussion concerns of its members
Recent Position Papers on Concussion

AMSSM Position Statement
January 2013

American Medical Society for Sports Medicine
position statement: concussion in sport

Kimberly G Harmon,1 Jonathan A Drezner,1 Matthew Gammons,2 Kevin
M Guskiewicz,2 Mark Halstead,3 Stanley A Hening,1 Jeffrey S Kutcher,5
Andrea Pannu,6 Margot Putukian,7 William G Roberts5

Endorsed by the National Trainers’ Athletic Association and the American College of Sports Medicine

Recent Position Papers on Concussion

2012 Zurich Consensus Statement
February 2013

Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012

Paul McCrory,1 Willem H Meeuwisse,1,2 Mark Aubry,4,5 Bob Cantu,7,8
Jill Dicker,10,11 Robin J Echemendia,12,13 Lars Engelbrecht,14,15,16
Karen Johnston,17,18 Jeffrey S Kutcher19 Karen Rutberg20 Allen Silz21
Brian W Benson22,23,24 Gavin A Davis,25 Richard G Ellenbogen26,27
Kevin Guskiewicz28,29 Stanley A Hening30,31 Grant L Iverson,32 Barry D Jordan2,32,33,34
James Kasser25,35,36,37 Michael McCrea26 Andrew S McDermott38
David Madden,42 Michael Makdissi43,44 Laura Furey45,46 Margot Putukian47,48
Kathryn Schneider,49 Charles H Tutor,50,51,52,53 Michael Turner45,46

4th International Conference on Concussion in Sport held in Zurich, Switzerland, 17-18 November 2012

Editors: Paul McCrory, Willem H Meeuwisse, Mark Aubry, Bob Cantu, and Richard G Ellenbogen
Recent Position Papers on Concussion

AAN Concussion Guidelines
March 2013

Summary of evidence-based guideline update:
Evaluation and management of concussion in sports

Christopher G. Giza, MD
John L.out, MD
Stephen W. Fuisz, MD
Seth A. Anz, MD
Thomas S. Guskiewicz
Gerald A. Gennarelli, MD
Scott C. Coolidge, PhD
Aaron I. Levin, MD
Catherine Nalty, MD
David B. Roebuck, MD
David R. Thomas, MD
Ron A. Seliger, MD

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AAP Policy Statement

American Academy of Pediatrics

Clinical Report—Sport-Related Concussion in Children and Adolescents

Mark E. Halstead, MD, Kevin D. Walter, MD, and THE
COUNCIL ON SPORTS MEDICINE AND FITNESS

FROM THE AMERICAN ACADEMY OF PEDIATRICS

http://aappolicy.aappublications.org/cgi/reprint/pediatrics;126/3/597.pdf
References

Books and Publications:
Books and References:


Websites:


- [https://badgerherald.com/features/2016/03/08/head-strong-researchers-struggle-to-define-how-many-concussions-is-too-many/](https://badgerherald.com/features/2016/03/08/head-strong-researchers-struggle-to-define-how-many-concussions-is-too-many/)

- [https://i.ytimg.com/vI/Ym7JwMVWqBZ/maxresdefault.jpg](https://i.ytimg.com/vI/Ym7JwMVWqBZ/maxresdefault.jpg)

- [https://i.ytimg.com/vI/h6pBbLqKfKI/hqdefault.jpg](https://i.ytimg.com/vI/h6pBbLqKfKI/hqdefault.jpg)
