Introduction

Every year the US Centers for Disease Control and Prevention estimate that 300,000 concussions are sustained during sport-related activity in the United States, although the exact incidence is unknown due to the lack of recognition or failure of the individual to report symptoms. The majority of these injuries have favorable outcomes, however if not recognized and managed appropriately, concussion can cause significant long-term cognitive impairment. Recently, sport concussion has received notable media attention, as high-profile athletes are reporting poor outcomes such as depression and memory loss from repeated head injuries incurred during their careers. In this light, much research and debate has ensued as to how sport concussion is defined and how it should be evaluated, treated, and prevented.

Sport concussion currently is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Defining sport concussion as such indicates that concussion is from disruption of normal brain function, and not due to structural injury of the brain itself. In addition to direct head injury, concussion can be inflicted by force transmitted to the head from a blow to the body, or can be caused by sudden movement of the head and neck. Sports well known to be high-risk include football, hockey, boxing, and soccer; but may be recognized in any sporting activity. Over the years rule changes have been enacted in an attempt to protect athletes from devastating head injuries, however concussion still occurs at a significant rate. This article is intended to provide an overview of sport-related concussion management and its sequelae. It should not be used for guiding self-treatment, as a qualified healthcare provider should evaluate all head injuries.

Concussion Signs & Symptoms
It is a common misconception that an athlete must have a loss of consciousness in order to be diagnosed with a concussion. In reality, loss of consciousness is seen in less than 10% of concussions. It is important to note the fact that concussion signs and symptoms are typically transient, and resolve in a sequential manner. It is also important to be aware that symptoms may appear minutes to hours after the initial impact and may be a sign of a more severe injury. Common symptoms that are seen in a concussed athlete include headache, dizziness, nausea, visual problems (seeing “stars”), tinnitus (ringing in ears), irritability, and labile emotions. Currently, signs and symptoms as a consequence of concussion fall under two categories (see table below). The first category can be referred to as cognitive symptoms. These include confusion, retrograde amnesia (inability to recall events prior to injury), anterograde amnesia (inability to recall events after injury), and loss of consciousness. The second category is reserved for physical signs. These may include convulsions or brief seizures, poor coordination/balance, slowed reaction time, poor concentration, vomiting, vacant stare, slurred speech, personality changes, and decreased playing ability. Suffice it to say that a concussed athlete may display a multitude of signs and symptoms, however in practicality, any athlete with a head injury that displays any additional symptoms should be considered to have a concussion and treated appropriately.

### Cognitive Symptoms
- Confusion
- Retrograde amnesia
- Anterograde amnesia
- Loss of consciousness

### Physical Signs
- Brief seizures
- Poor coordination/balance
- Slowed reaction time
- Poor concentration
- Vomiting
- Vacant stare
- Slurred speech
- Personality changes
- Decreased playing ability

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## Concussion Grading Systems

Several grading systems exist that are used to classify the severity of concussions (Cantu, Colorado, American Academy of Neurology), and in turn guide restriction and return to play. The consequence of using such grading systems is that management becomes less individualized. Furthermore, many of the grading systems use loss of consciousness as the main factor in determining severity. Studies have shown that test results of athletes that have lost consciousness do not differ from the results of athletes that did not lose consciousness. Failure to individualize the management of concussed athletes by strictly adhering to classical grading systems may lead to too lenient or too conservative restrictions. Currently, sport related concussions can be classified as either simple or complex as described in the Prague Summary and Agreement Statement.

### Simple Concussions

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Most common type (90% of all concussions)
- Exhibit symptoms that progressively resolve in 7-10 days

**COMPLEX CONCUSSIONS** (only need to satisfy one)
- Cause persistent symptoms (>1-2 weeks)
- Loss of consciousness greater than 1 minute
- Associated with post-concussive convulsions
- Athlete with previous concussion that sustains additional concussion with minimal trauma

By using simple and complex to classify sport-related concussions, care is more tailored to the athlete’s symptoms, and specific management is possible balancing safety with return to play decisions. (see Management section, below)

**Assessment & Evaluation**

Any athlete who exhibits a head injury should have a rapid evaluation. The initial assessment should first focus on airway, breathing, and circulation. Level of consciousness and attention to a possible neck or skull injury is also crucial. This becomes even more important if the athlete is unconscious or unable to respond appropriately to questioning. Once an athlete is able to respond, and a possible neck or skull injury is ruled out, a comprehensive neurological evaluation should be performed on the sideline by a qualified individual (preferably team physician; if no qualified medical personnel on site, the athlete should not be moved and 911 should be alerted for assistance). Documentation of any neurological changes should be made and followed. One error that is commonly made is that once the athlete is initially evaluated, they are not followed sequentially. As mentioned previously, symptoms may occur minutes to hours later, therefore the acutely concussed athlete should not be left unattended, and several periodic neurological examinations should be performed to assure improvement. The first and foremost guiding principal is that an athlete should NEVER return to competition until they are asymptomatic (See Return to Play section, below). After the competition the athlete should be monitored for a period of several hours, and it is beneficial to arouse a concussed athlete every 2 hours to assure improvement if he/she falls asleep. If the athlete has reliable guardians available, they should be educated on the nature of concussions, and how to obtain proper follow up. A point to make clear to guardians is that if at any time the athlete has any new signs or symptoms (see table below), or those that are worsening, 911 should be alerted for rapid transport to the nearest appropriate medical facility. If reliable guardians are not available, it may be prudent to send the athlete to an emergency department for further monitoring.

There are many tools that have been developed to assess concussed athletes on the sideline such as the Standardized Assessment of Concussion (SAC) and Maddock’s questions, however each have limitations and may be more sport specific. The Sport Concussion Assessment Tool (SCAT), which was developed during the Prague Conference 2, is a validated tool that can standardize assessment, and also provides education to athletes and their families in regards to head injury. The CDC also has literature available. (see References below)

**Concussion Management**
The initial assessment and evaluation of an acutely concussed athlete is outlined above. Once the athlete is determined to be stable, initial restrictions should be enforced. *In all circumstances, if an athlete exhibits ANY signs or symptoms after a head injury, a concussion is diagnosed and the athlete should NOT return to play in the same competition.* Furthermore, an athlete should never compete if ANY signs and symptoms are present. Management principles of simple and complex concussions follow:

**SIMPLE CONCUSSIONS**

- Rest until asymptomatic
- Once asymptomatic, subject to graded return to play protocol (see Return to Play section, below)
- Final clearance by medical doctor

**COMPLEX CONCUSSIONS**

- Should be evaluated by medical specialist (sports medicine physician, neurologist, neurosurgeon)
- Formal neuropsychological testing
- Neuroimaging should be considered

It is useful to use written inventories of symptoms that can be used to track symptom resolution; the SCAT is an excellent example. In the situation of a student-athlete, a period of cognitive rest (e.g., limit television, videogames, school work) is beneficial, and communication should start with teachers immediately to avoid negative impact in the classroom. *A medical doctor should clear ALL concussed athletes prior to return to play.*

**Neuroimaging**

The role of diagnostic imaging in the evaluation of sport related concussion is controversial. Examples of such imaging include computed aided tomography (CAT or CT scan) and magnetic resonance imaging (MRI). Typically a CT scan is the study of choice when evaluating a recently concussed athlete. CT scans are able to detect potentially life-threatening injury such as intracranial bleeding and skull fractures. MRI is more suited for identifying structural damage to the brain itself, and is used in the setting of athletes who exhibit more prolonged symptoms. In the event of a simple concussion only, CT and MRI imaging is normal and is non-contributory to management. Indications for imaging are outlined below.

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<table>
<thead>
<tr>
<th>Common indications for transport to emergency department (ALERT 911)</th>
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<tbody>
<tr>
<td><strong>Altered level of consciousness</strong></td>
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<tr>
<td><strong>Nausea and vomiting</strong></td>
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<tr>
<td><strong>Drowsiness / unable to be woken up</strong></td>
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<tr>
<td><strong>New or focal neurological deficits</strong></td>
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</table>
As stated earlier, the decision whether or not to image can be difficult, and obviates the need for a concussed athlete to have a rapid evaluation by a healthcare professional. If there is no medical support at the event, transport to an emergency department is advisable. It is well known that pediatric and adolescent brains are more susceptible to structural injury and may respond more poorly to injury, therefore the threshold to order more advanced imaging is lower as compared to older athletes. If there is any suspicion of a neck injury, regular x-rays of the cervical spine are essential.

### Indications for advanced medical imaging (CT, MRI) for concussed athletes

<table>
<thead>
<tr>
<th>Progressive worsening symptoms</th>
<th>Focal neurological deficits</th>
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<tbody>
<tr>
<td>Prolonged loss of consciousness (&gt;1-2 min)</td>
<td>Complex concussions</td>
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</tbody>
</table>

### Return-to-Play Guidelines

Return to play is perhaps the most controversial topic when discussing sport related concussions. *The first and foremost guiding principal is that an athlete should NEVER return to competition until they are asymptomatic.* Once symptom resolution has occurred, and if the athlete has a simple concussion, the 6-step return to play protocol can be followed (see table). Return to play decisions for athletes with complex concussions should be guided by experienced physicians.

**Step-Wise Return-to-Play Protocol**

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
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<tbody>
<tr>
<td>1</td>
<td>No activity, complete rest. Once asymptomatic, proceed to level 2</td>
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<tr>
<td>2</td>
<td>Light aerobic exercise such as walking or stationary cycling, no resistance training</td>
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<tr>
<td>3</td>
<td>Sport-specific exercises (e.g., skating in hockey, running in soccer), progressive addition of resistance training at steps 3 or 4</td>
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<tr>
<td>4</td>
<td>Non-contact training drills</td>
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<tr>
<td>5</td>
<td>Full contact training after medical clearance</td>
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<tr>
<td>6</td>
<td>Game play</td>
</tr>
</tbody>
</table>

*If at anytime the athlete becomes symptomatic, he/she should return to the previous asymptomatic level and re-attempt to progress after 24 hours.*

### Post-Concussive Sequelae

Proper management of athletes with head injuries can minimize further risk and disability. However there are several post-concussive complications that should be recognized as they can cause long-term or even permanent impairment.
1) Second Impact Syndrome

Second impact syndrome is one of the most devastating injuries in sports. Although the true incidence is unknown, an estimated rate of 1-2 cases annually per 100,000 sport related concussions is reported. This syndrome occurs when an athlete receives a second blow after he/she is still symptomatic from a recent concussion; typically the initial injury was sustained in the same contest. Often the second injury is minor and goes unnoticed, which causes the brain to lose normal regulation of blood flow leading to massive swelling. The progression of symptoms from rapid brain swelling occurs over seconds to minutes. There is little that can be done when second impact syndrome occurs, other than rapid transport to the nearest medical facility that has neurosurgery services. Overall the prognosis is grim, with nearly 50% resulting in death, and nearly all those that survive sustaining permanent brain damage. Early recognition of the initial head injury and withholding a concussed athlete from competition is the only preventative measure.

2) Post-Concussion Syndrome

Any athlete with symptoms that last more than one or two weeks after injury should be suspected as having post-concussive syndrome. This syndrome obviates any continued competition, and is an indicator of a significant head injury. Treatment is best guided by an experienced physician, and often necessitates formal neuropsychological testing and advanced imaging. Common symptoms of post-concussion syndrome are listed below, and athletes/coaches/families should be notified that symptoms might be present for up to 3 months or longer. Premature return to play is often the instigating factor, which further supports the rationale of no return to play until completely symptom free. Academic concessions should be made for student-athletes suffering these injuries.

### Common Symptoms of Post-Concussive Syndrome

<table>
<thead>
<tr>
<th>Loss of intellectual capacity</th>
<th>Fatigue</th>
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<tbody>
<tr>
<td>Poor recent memory</td>
<td>Irritability</td>
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<tr>
<td>Personality changes</td>
<td>Phono/Photophobia</td>
</tr>
<tr>
<td>Headaches</td>
<td>Sleep disturbances</td>
</tr>
<tr>
<td>Dizziness</td>
<td>Depressed mood</td>
</tr>
<tr>
<td>Lack of concentration</td>
<td>Anxiety</td>
</tr>
<tr>
<td>Poor attention</td>
<td>Loss of appetite</td>
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3) Post-Concussive Convulsions

Post-concussive convulsions or seizures are rare, but are concerning to spectators and teammates. This type of convulsion is not due to structural brain damage, and is of brief duration. There is no need for special medication, and treatment is the same as described above for an acute concussion. Reassurance should be given.
Neuropsychological Testing

Neuropsychological testing has become more readily available at all levels of competition. This type of testing is most often completed by the use of specialized computer programs that assess cognitive function by measuring parameters such as memory and reaction time. The advantage of these tests is that subtle deficits in psychological function can be uncovered in an athlete that states he/she is asymptomatic, thus avoiding premature return to play. Neuropsychological testing is also useful in the management of complex concussions and post-concussive syndrome by the ability to measure and follow cognitive recovery. Despite these advantages, there are several drawbacks to formal testing. The most common drawback is that most athletes do not complete baseline testing (testing prior to injury), which limits interpretation of post-injury results. Significant cost and quality of interpretation are also considerations. Overall, neuropsychological testing is gaining acceptance and importance in the management of concussion, but care should be taken not to view formal testing as the sole basis for return to play decisions.

Prevention

Prevention of sport related concussion should begin when the athlete undergoes his or her pre-participation exam. Any previous history of concussion should be documented. Additional information such as type of symptoms experienced, any prolonged symptoms, time lost from practice or competition, and the results of any imaging or psychological testing should be acquired. The goal is to assure that the athlete with a history of concussion is asymptomatic prior to engaging in any further activity. Any athlete that is a possible candidate for a complex concussion based on history should be referred to a neuropsychologist for evaluation before clearance.

Rule changes and equipment design in sports have been guided in a large part by the desire to minimize traumatic injury. Examples include illegal spear tackling in football, and new helmet design for specific sports. It is true that these changes help to decrease head injuries, however to what extent is still being researched. It is worthy to mention that some researchers believe that helmets actually increase the number of head injuries by promoting a false sense of security, thereby increasing risk-taking behavior.

Summary

Sport related concussion is a common phenomenon in competition. Fortunately, the vast majority of concussed athletes recover swiftly and completely, returning to their original level of performance. Return to play only when asymptomatic, and no return to the same contest or game in which the concussion was sustained is paramount to management. Over the past several years much research has been conducted as to how to best manage head injuries in sport, and controversy still exists. There is little controversy however in the statement that simple recognition of concussion, and proper evaluation by qualified medical personnel can prevent nearly all complications and assure continued safe play.

Selected Web Resources

http://knol.google.com/k/sports-related-concussion

7/1/2010
American Academy of Neurology
http://www.aan.com

Brain Injury Association, Inc.
http://www.biausa.org

Think First Foundation
http://www.thinkfirst.org

National Safe Kids Campaign
http://www.safekids.org

CDC Coaches Concussion Tool Kit
http://CDC.gov/ncipc/tbi/Coaches_Tool_Kit.htm

References


NFL MLB Sports Predictions

Sports fans should check out this site for free sports predictions for NFL, MLB, soccer, and cricket teams. http://www.decisioncare.org/sports/sports-astrology-free-winner-team-predictions/

http://digg.com/football/Sports_Astrology_Free_Team_Predictions_in_NFL_MLB_Soccer