American Medical Society for Sports Medicine Position Statement: Concussion in Sport

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Key Words: concussion, athlete, head injury, brain injury

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Executive Summary

Purpose of the Statement

• To provide an evidence-based, best practices summary to assist physicians with the evaluation and management of sports concussion.
• To establish the level of evidence, knowledge gaps, and areas requiring additional research.

Importance of an AMSSM Statement

• Sports medicine physicians are frequently involved in the care of patients with sports concussion.
• Sports medicine physicians are specifically trained to provide care along the continuum of sports concussion from the acute injury to return-to-play decisions.
• The care of athletes with sports concussion is ideally performed by healthcare professionals with specific training and experience in the assessment and management of concussion. Competence should be determined by training and experience, not dictated by specialty.
• While this statement is directed toward sports medicine physicians, it may also assist other physicians and healthcare professionals in the care of patients with sports concussion.

Definition

• Concussion is defined as a traumatically induced transient disturbance of brain function and involves a complex pathophysiologic process. Concussion is a subset of mild traumatic brain injury that is generally self-limited and at the less severe end of the brain injury spectrum.

Pathophysiology

• Animal and human studies support the concept of post-concussive vulnerability, showing that a second blow before the brain has recovered results in worsening metabolic changes within the cell.
• Experimental evidence suggests the concussed brain is less responsive to usual neural activation, and when premature cognitive or physical activity occurs before full recovery the brain may be vulnerable to prolonged dysfunction.

Incidence

• It is estimated as many as 3.8 million concussions occur in the US per year during competitive sports and recreational activities; however, as many as 50% of concussions may go unreported.
• Concussions occur in all sports with the highest incidence in football, hockey, rugby, soccer, and basketball.

Risk Factors for Sports-related Concussion

• A history of concussion is associated with a higher risk of sustaining another concussion.
• A greater number, severity, and duration of symptoms after concussion are predictors of a prolonged recovery.
• In sports with similar playing rules, the reported incidence of concussion is higher in females than males.
• Certain sports, positions, and individual playing styles have a greater risk of concussion.
• Youth athletes may have a more prolonged recovery and are more susceptible to a concussion accompanied by a catastrophic injury.
• Preinjury mood disorders, learning disorders, attention deficit disorders (ADD/ADHD), and migraine headaches complicate diagnosis and management of concussion.

Diagnosis of Concussion

• Concussion remains a clinical diagnosis ideally made by a healthcare provider familiar with the athlete and knowledgeable in the recognition and evaluation of concussion.
• Graded symptom checklists provide an objective tool for assessing a variety of symptoms related to concussions, while also tracking the severity of those symptoms over serial evaluations.
• Standardized assessment tools provide a helpful structure for the evaluation of concussion, although limited validation of these assessment tools is available.

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‘Sideline’ Evaluation and Management

- Any athlete suspected of having a concussion should be removed from play and assessed by a licensed healthcare provider trained in the evaluation and management of concussion.
- Recognition and initial assessment of concussion should be guided by a symptom checklist, cognitive evaluation (including orientation, past and immediate memory, new learning, and concentration), balance tests, and further neurologic physical examination.
- 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.
- Balance disturbance is a specific indicator of concussion but is not very sensitive. Balance testing on the sideline may be substantially different than baseline tests because of differences in shoe/cleat type or surface, use of ankle tape or braces, or the presence of other lower extremity injury.
- Imaging is reserved for athletes where intracerebral bleeding is suspected.
- There is no same-day return to play for an athlete diagnosed with a concussion.
- Athletes suspected or diagnosed with concussion should be monitored for deteriorating physical or mental status.

Neuropsychological Testing

- Neuropsychological tests are an objective measure of brain-behavior relationships and are more sensitive for subtle cognitive impairment than clinical exam.
- Most concussions can be managed appropriately without the use of neuropsychological testing.
- Computerized neuropsychological testing should be interpreted by healthcare professionals trained and familiar with the type of test and the individual test limitations, including a knowledgeable assessment of the reliable change index, baseline variability, and false positive and false negative rates.
- Paper and pencil neuropsychological tests can be more comprehensive, test different domains, and assess for other conditions that may masquerade as or complicate assessment of concussion.
- Neuropsychological testing should be used only as part of a comprehensive concussion management strategy and should not be used in isolation.
- The ideal timing, frequency, and type of neuropsychological testing have not been determined.
- In some cases, properly administered and interpreted neuropsychological testing provides added value to assess cognitive function and recovery in the management of sports concussions.
- It is unknown if use of neuropsychological testing in the management of sports concussion helps prevent recurrent concussion, catastrophic injury, or long-term complications.
- Comprehensive neuropsychological evaluation is helpful in the postconcussion management of athletes with persistent symptoms or complicated courses.

Return to Class

- Students will require cognitive rest and may require academic accommodations such as reduced workload and extended time for tests while recovering from concussion.

Return to Play

- Concussion symptoms should be resolved before returning to exercise.
- A return-to-play progression involves a gradual, step-wise increase in physical demands, sports-specific activities, and the risk for contact.
- If symptoms occur with activity, the progression should be halted and restarted at the preceding symptom-free step.
- Return to practice/play after concussion should occur only with medical clearance from a licensed healthcare provider trained in the evaluation and management of concussion.

Short-term Risks of Premature Return to Play

- The primary concern with early return to play is decreased reaction time leading to increased risk of repeat concussion or other injury and prolongation of symptoms.

Long-term Effects

- There is increasing concern that head impact exposure and recurrent concussions contribute to long-term neurological sequelae.
- Some studies have suggested an association between prior concussions and chronic cognitive dysfunction. Large-scale, epidemiological studies are needed to more clearly define risk factors and causation of any long-term neurological impairment.

Disqualification from Sport

- There are no evidence-based guidelines for disqualifying/retiring an athlete from sport after concussion. Each case should be carefully deliberated and an individualized approach to determining disqualification taken.

Education

- Greater efforts are needed to educate involved parties including athletes, parents, coaches, officials, school administrators, and healthcare providers to improve concussion recognition, management, and prevention.
- Physicians should be prepared to provide counseling regarding potential long-term consequences of concussion and recurrent concussion.

Prevention

- Primary prevention of some injuries may be possible with modification and enforcement of the rules and fair play.
- Helmets, both hard (football, lacrosse, and hockey), and soft (soccer, rugby), are best suited to prevent impact injuries (fracture, bleeding, laceration, etc) but have not
been shown to reduce the incidence and severity of concussions.
• There is no current evidence that mouth guards can reduce the severity of or prevent concussions.
• Secondary prevention may be possible by appropriate return-to-play management

Legislation

• Legislative efforts provide a uniform standard for scholastic and nonscholastic sports organizations regarding concussion safety and management.

Future Directions

• Additional research is needed to validate current assessment tools, delineate the role of neuropsychological testing, and improve identification of those at risk of prolonged post-concussive symptoms or other long-term complications.
• Evolving technologies for the diagnosis of concussion, such as newer neuroimaging techniques or biologic markers, may provide new insights into the evaluation and management of sports concussion.

BACKGROUND AND PURPOSE

The recognition and management of concussion in sport is an evolving and controversial topic with a myriad of groups and organizations producing statements and recommendations.\(^1\)\(^-\)\(^6\) The purpose of this statement is to provide an evidence-based, best practices summary to assist physicians with the evaluation and management of sports-related concussion and to establish the level of evidence, knowledge gaps, and areas requiring additional research. The American Medical Society for Sport Medicine (AMSSM) represents over 2100 nonsurgical sports medicine physicians who have completed additional training in sports medicine after a residency program in family medicine, internal medicine, pediatrics, emergency medicine, or physical medicine and rehabilitation, many of whom have extended expertise in concussion evaluation and management.

Sports medicine physicians are frequently involved in the care of patients with sports concussion and are specifically trained to provide care along the continuum of sports concussion from the acute injury to return-to-play decisions. The care of athletes with sports-related concussions is ideally performed by healthcare professionals with specific training and experience in the assessment and management of concussion. Competence should be determined by training and experience, not dictated by specialty. While this statement is directed towards sports medicine-trained physicians, it may also be used by other physicians and healthcare professionals to improve the care of patients with sports-related concussion.

Level of Evidence

This statement uses the Strength of Recommendation Taxonomy (SORT) to grade recommendation based on athlete outcomes (Table 1).\(^7\)

Definition of Concussion

Concussion is defined as a traumatically induced transient disturbance of brain function and is caused by a complex pathophysiologic process. Concussions have also been referred to as mild traumatic brain injuries (MTBI). While all concussions are MTBIs, not all MTBIs are concussions. Concussions are a subset of mild traumatic brain injury on the less severe end of the brain injury spectrum and are generally self-limited in duration and resolution.

Pathophysiology

Concussions occur when linear and/or rotational forces are transmitted to the brain. Currently, there is no known biomechanical threshold for a clinical concussion. A demonstrated cellular process, the “neurometabolic cascade” underlying the clinical presentation of concussive injury, describes a complex cascade of ionic, metabolic, and pathophysiological events that is accompanied by microscopic axonal injury.\(^8\)\(^-\)\(^10\) This disruption of ionic balance and normal metabolism requires energy to reestablish homeostasis. However, the need for increased energy occurs in the presence of decreased cerebral blood flow and ongoing mitochondrial dysfunction, resulting in a mismatch of energy supply and demand.\(^8\)\(^-\)\(^10\)\(^11\) Until normal brain cellular function is restored, animal and human studies support the concept of increased postconcussive vulnerability, showing that a second injury before the brain has recovered results in worsening cellular metabolic changes and more significant cognitive deficits.\(^8\)\(^-\)\(^10\)\(^11\)\(^-\)\(^16\) Experimental evidence further suggests the concussed brain is less responsive to physiological neural activation.\(^9\)\(^10\) Thus, excessive cognitive or physical activity before full recovery may result in prolonged dysfunction. Some of these pathophysiological perturbations are more pronounced in youth, raising concerns that the immature brain may be even more susceptible to repeat concussion before full recovery.\(^9\)

Reported Incidence of Sports-related Concussion

Concussions occur commonly in helmeted and non-helmeted sports, and recent data suggest a trend of increased annual concussion rates over the past decade.\(^17\)\(^18\) Reasons for the apparent increased incidence are unknown, but it is widely speculated to be a result of the emphasis on concussion education and awareness leading to increased identification and reporting.\(^17\)\(^18\) Despite the increased reported incidence of concussion in recent years, there has not been a corresponding increase in the incidence of sports-related catastrophic brain injuries such as subdural and epidural hematomas or malignant cerebral edema (ie, Second Impact Syndrome).

<table>
<thead>
<tr>
<th>TABLE 1. Strength-of-Recommendation Taxonomy (SORT)</th>
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<tbody>
<tr>
<td>Strength of Recommendation</td>
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<tr>
<td>A</td>
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<td>B</td>
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<td>C</td>
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The Centers for Disease Control and Prevention (CDC) estimates that between 1.6 and 3.8 million sports-related concussive injuries occur annually in the United States and account for 5% to 9% of all sport injuries. Thirty percent of all concussions in individuals between 5 to 19 years of age are sport related and result in a significant number of emergency room visits. The majority of concussions occurring in organized sports in the United States are sustained in football, wrestling, girls’ soccer, boys’ soccer, and girls’ basketball. Competition concussion rates are consistently higher than practice rates, and in high school and college sports with the same rules (basketball and soccer) there is an increased incidence of concussion reported in female athletes. Several studies contend the true incidence is likely higher than documented because many athletes fail to report concussions. With greater focus on concussion awareness and state legislation, the reported incidence is likely to continue to increase.

**Signs and Symptoms**

There are many signs and symptoms that can be observed with a concussion (Table 3). Headache is the most common reported symptom, with dizziness the second most common. Loss of consciousness only occurs in about 10% of concussions. Several symptoms of concussion are nonspecific, eg, nausea, vomiting, and headache are a common presentation of acute gastroenteritis, and dizziness is a common symptom of acute cardiac compromise. Some symptoms overlap with other disorders such as sleep disturbances, depression, and attention deficit disorder and it is helpful to determine whether these symptoms were present prior to the injury. In college athletes, 59% reported concussion-like symptoms in the prior year with no history of head injury, and 50% to 84% of high school athletes reported similar symptoms of concussion at baseline testing. There have been no consistently demonstrated differences in the symptoms reported between males and females.

Most studies report that 80% to 90% of athletes will have symptom resolution by 7 days following their injury, although symptom resolution may not always indicate a full cognitive recovery as persistent deficits may be present on neuropsychological testing. However, the clinical importance of persistent neuropsychological testing changes in the absence of continued symptoms is unknown.

**Risk Factors/Modifiers for Sports-related Concussion**

A history of prior concussion, a greater number, severity or duration of symptoms after concussion, female sex, genetic predisposition, a history of a learning disorder, attention deficit disorder, migraines, or mood disorder, and playing certain positions have all been suggested to affect the risk of sustaining a concussion or having a more protracted course.

**Previous Concussion**

A history of concussion is associated with a 2 to 5.8 times higher risk of sustaining another concussion. Athletes with a prior history of concussion may also report more symptoms at baseline than those without a history of concussion. However, there is conflicting evidence on whether a prior concussion is associated with a prolonged recovery course. Lau found no difference in history of concussion and time to recovery, while Slobounov demonstrated significantly slower recovery rates of neurological functions after a second concussion. As with other sports injuries, the greatest risk factor for concussion is a previous concussion, and progressively prolonged symptoms with subsequent concussions is a concerning prognostic sign.

**Number, Severity, or Duration**

A greater number, severity, and duration of symptoms after concussion are predictors of a prolonged recovery. Dizziness at the time of injury was found to be the greatest predictor in high school football players for a recovery taking longer than 21 days, and athletes who had more symptoms in the cognitive or migraine symptom clusters often required more recovery time. In rugby players, headaches lasting longer

**TABLE 2. Concussion Rates Per 1000 Athlete Exposures**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>High School</td>
<td>High School</td>
<td>College</td>
<td>High School</td>
<td>High School</td>
<td>High School</td>
</tr>
<tr>
<td>Baseball</td>
<td>0.05</td>
<td>0.11</td>
<td>0.07</td>
<td>0.05</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Softball</td>
<td>0.10</td>
<td>0.10</td>
<td>0.14</td>
<td>0.07</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>Boys’ basketball</td>
<td>0.11</td>
<td>0.10</td>
<td>0.16</td>
<td>0.07</td>
<td>0.10</td>
<td>0.16</td>
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<tr>
<td>Girls’ basketball</td>
<td>0.16</td>
<td>0.17</td>
<td>0.22</td>
<td>0.21</td>
<td>0.16</td>
<td>0.21</td>
</tr>
<tr>
<td>Girls’ soccer</td>
<td>0.18</td>
<td>0.23</td>
<td>0.28</td>
<td>0.22</td>
<td>0.17</td>
<td>0.19</td>
</tr>
<tr>
<td>Boys’ soccer</td>
<td>0.23</td>
<td>0.13</td>
<td>0.41</td>
<td>0.36</td>
<td>0.35</td>
<td>0.34</td>
</tr>
<tr>
<td>Football</td>
<td>0.59</td>
<td>0.33</td>
<td>0.37</td>
<td>0.47</td>
<td>0.60</td>
<td>0.64</td>
</tr>
<tr>
<td>Field hockey</td>
<td>0.09</td>
<td>NR</td>
<td>0.18</td>
<td>NR</td>
<td>0.10</td>
<td>0.22</td>
</tr>
<tr>
<td>Volleyball</td>
<td>0.02</td>
<td>NR</td>
<td>0.09</td>
<td>0.05</td>
<td>NR</td>
<td>0.06</td>
</tr>
<tr>
<td>Wrestling</td>
<td>0.25</td>
<td>0.09</td>
<td>0.25</td>
<td>0.18</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>Ice hockey</td>
<td>0.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.54</td>
</tr>
<tr>
<td>Overall</td>
<td>0.17</td>
<td>0.28</td>
<td>0.43</td>
<td>0.24</td>
<td>0.24</td>
<td>0.024</td>
</tr>
</tbody>
</table>

Nr, Not reported.
TABLE 3. Signs and Symptoms of a Concussion

<table>
<thead>
<tr>
<th>Physical</th>
<th>Headache</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Nausea</td>
</tr>
<tr>
<td></td>
<td>Vomiting</td>
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<tr>
<td></td>
<td>Balance problems</td>
</tr>
<tr>
<td></td>
<td>Dizziness</td>
</tr>
<tr>
<td></td>
<td>Visual problems</td>
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<tr>
<td></td>
<td>Fatigue</td>
</tr>
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<td></td>
<td>Sensitivity to light</td>
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<td></td>
<td>Sensitivity to noise</td>
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<tr>
<td></td>
<td>Numbness/tingling</td>
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<tr>
<td></td>
<td>Dazed</td>
</tr>
<tr>
<td></td>
<td>Stunned</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Feeling mentally “foggy”</td>
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<tr>
<td></td>
<td>Feeling slowed down</td>
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<tr>
<td></td>
<td>Difficulty concentrating</td>
</tr>
<tr>
<td></td>
<td>Difficulty remembering</td>
</tr>
<tr>
<td></td>
<td>Forgetful of recent information and conversations</td>
</tr>
<tr>
<td></td>
<td>Confused about recent events</td>
</tr>
<tr>
<td></td>
<td>Answers questions slowly</td>
</tr>
<tr>
<td></td>
<td>Repeats questions</td>
</tr>
<tr>
<td>Emotional</td>
<td>Irritable</td>
</tr>
<tr>
<td></td>
<td>Sadness</td>
</tr>
<tr>
<td></td>
<td>More emotional</td>
</tr>
<tr>
<td></td>
<td>Nervousness</td>
</tr>
<tr>
<td>Sleep</td>
<td>Drowsiness</td>
</tr>
<tr>
<td></td>
<td>Sleeping more than usual</td>
</tr>
<tr>
<td></td>
<td>Sleeping less than usual</td>
</tr>
<tr>
<td></td>
<td>Difficulty falling asleep</td>
</tr>
</tbody>
</table>

Sex

Recent data suggests that in sports with similar rules females sustain more concussions than their male counterparts. In addition, females experience or report a higher number and severity of symptoms as well as a longer duration of recovery than males in several studies. Decreased head-neck segment mass of females compared to male athletes may contribute to greater angular acceleration of the head after concussive impact as a mechanism for more severe injury. Estrogen and differential cerebral blood flow may also play a role in influencing concussion severity and outcome. Further study is needed to understand if sex is a risk factor for concussion and what mechanisms may account for it, or if sex is merely a predictor of symptom reporting.

Age

Youth athletes may have a more prolonged recovery and are more susceptible to concussion accompanied by catastrophic injury. The developing brain differs physiologically from the adult brain when comparing the brain water content, degree of myelination, blood volume, blood-brain barrier, cerebral metabolic rate of glucose, blood flow, number of synapses, and geometry and elasticity of the skull’s sutures. Developmentally younger brains have less established engrams and may have less cognitive reserve than more mature brains. This may account for the demonstrated increase in time to recovery from concussion seen in younger athletes. It is difficult to compare studies at different levels of play (high school, college, and professional) as longer recovery times could reflect differences in study methodology, in risk tolerance and return-to-play protocols, or all of the above. Recovery patterns have not been adequately studied in athletes less than 15 years old. Catastrophic injury is more likely in younger athletes and is hypothesized to be related to the physiologic differences between younger and older brains.

Sport, Position, and Style of Play

Certain sports, positions, and individual playing styles have a greater risk of concussion. The rate of concussion also varies by level of play. Position and style of play also appear to affect the risk of concussion. Mechanisms of concussive injury may vary based on the sport as well as the level of play. The most common mechanism of concussion is player-to-player contact. It is not surprising, therefore, that sports and positions involved in frequent collision impacts sustain more concussions. Studies on professional football players have shown that “backs” (quarterbacks, wide receivers, running backs, and defensive backs) have a 3 times greater risk of concussion than “linemen,” and kickoffs had a 4 times higher risk of concussion than rushing or passing plays. In high school football players, linebackers were the most commonly concussed on the defense and running backs on the offense. In soccer players, concussions most commonly occur from player contact both at the high school level and at the college level. At the high school level, 1 study demonstrated that 25.3% of concussions were associated with illegal activity. In a prospective study of college soccer players, the mechanism of concussion was again primarily player contact, and importantly none were related to purposeful heading. In hockey the most common mechanism of concussive injury is checking.

Genetics

Studies on the association between concussion and genetic polymorphisms such as APOE e4, APOE G-219T promoter, or tau exon 6 are limited by small sample sizes, limited sports populations, retrospective study design, use of self-reported concussion history, and a lack of control groups. Some studies have suggested potential associations, but methodological weaknesses do not support definitive conclusions. A study of college athletes showed prior self-reported concussion was associated with increased odds of having either 1 APOE e4 allele or at least 1 APOE G-219T “T” allele. In other reports, a cross-sectional study showed college athletes with a self-reported history of concussion...
were 2.7 times as likely to have APOE promoter G-219T ‘TT’ genotype after controlling for various cofounders, and a small prospective cohort study showed no significant association between genotype and concussion risk.

The largest prospective cohort study available (n = 234 athletes with 45 prospective concussions) showed no significant association between APOE, APOE G-219T, tau exon 6 Hist47Tyr, and Tau exon 6 Ser53Pro and concussion risk, although Tau exon 6 Ser53Pro was trending towards significance (P = 0.09). A large prospective cohort study of a representative athletic population that controls for athletic exposure, prior concussion history, and other predisposing factors is necessary to determine if polymorphisms confer an increased risk for concussion, more severe concussions, or delayed neurocognitive recovery.

Mood Disorders

Mood disorders, either preexisting or as a result of a concussive episode, complicate both diagnosis and management of concussion. Symptoms of anxiety, depression, or irritability occur in 17% to 46% of high school and college athletes and affect the brain’s mood centers including the hippocampus, amygdala, and prefrontal brain regions, which are also affected in concussion. There is no evidence that the preexistence of a mood disorder predisposes athletes to concussion. However, when evaluating an athlete it is often difficult to determine which symptoms preceded the concussion, which have been caused by the concussion, and which symptoms are worsened after the concussion. An increased incidence of depression has been associated with a history of concussion among retired boxers and professional football players; however, these retrospective studies relied on a self-reported history and did not control for other factors that may cause depression. Anxiety, depression, and other psychological impairments may also affect neuropsychological testing, either at baseline or at repeat testing, complicating test interpretation. Knowing preinjury mood status may be beneficial to the evaluation of athletes with subsequent injury. (C)

Learning Disabilities and Attention Disorders

As with other conditions which share common symptomatology with concussion, it is important to take learning disabilities into account in both diagnosis and management of concussion. Preinjury learning disabilities and attention deficit disorders (ADD/ADHD) may be associated with increased cognitive dysfunction and prolonged recovery after concussion. Collins found that athletes with learning disabilities and a history of concussion did proportionally worse on selected paper and pencil neuropsychological testing than those without learning disabilities. In 108 athletes with concussion, Lau found there was no association between learning disability or attention deficit disorder and protracted recovery. Learning and attention disorders share common features of concussion, such as difficulty with memory, attention, and concentration, making the diagnosis and management in these individuals more challenging. Baseline neuropsychological testing scores are lower in those with learning and attention disabilities independent of concussion history making baseline testing more important in those with learning or attention disorders if neuropsychological testing is going to be used postinjury to assist in return-to-play decisions.

Migraines

A history of preexisting migraine headaches may be a risk factor for concussion and may be associated with prolonged recovery. 2.9% of NCAA college basketball athletes (0.9% of men and 4.4% of women) and 22% of Australian Rules football players report migraines meeting International Headache Society criteria for diagnosis compared to 10% of the general population. An association between concussion and preexisting migraine was shown in 1 retrospective population study, but no association between preexisting migraine and prolonged course of concussion has been demonstrated. Concussion can trigger a posttraumatic migraine, and athletes with post concussion migraine usually have more symptoms and poorer performance on neuropsychological tests than athletes with other types of headache or no headache at all. In addition, Lau found that athletes (without preexisting diagnosis of migraines) who developed symptoms in the “migraine symptoms complex”, which included headaches, visual problems, dizziness, noise/light sensitivity, nausea/vomiting, balance problems, and numbness/tingling, had a more protracted recovery. Similar to mood, learning, and attention disorders, it is important to understand preinjury cognitive or psychological disorders in order to optimize management.

Management of Concussion

Preseason

Preparation for the care of concussed athletes begins prior to any practice or competition with a preparticipation exam (PPE) and the development of an emergency action plan. The preparticipation exam should include concussion-related questions including a past history of concussion (number, frequency, severity, and recovery) and the presence of mood, learning, attention, or migraine disorders. This information can be used to assess risk and for historical reference in the case of injury.

The exact role and impact on concussion management of baseline testing remains unclear, as no study has shown that use of these tests provides better short- or long-term outcomes for athletes with concussion. The preseason evaluation may also include baseline symptom scores, baseline balance testing, a baseline sideline evaluation tool (Sport Concussion Assessment Tool 2 [SCAT2], NFL Sideline Concussion Assessment Tool), and/or baseline computerized neuropsychological (NP) testing. This baseline testing may be more important in high-risk athletes with a prior history of concussion, with confounding conditions (learning disability, mood and attention disorders, migraine headaches) and sports with a higher incidence of concussion. (C) This information can be used to assess risk and for historical reference in the case of injury.

The reliability of preseason testing as a dependable baseline assessment to compare with postinjury testing performed weeks or months later is also controversial and for many tests unknown. While baseline testing is increasingly used in practice and may have a role in the preseason evaluation of high risk athletes, the role of baseline tests in
other settings is unknown. More research is needed to define which baseline tests should be performed and in which athletes.

Preseason testing requires honest effort on the part of an athlete. Balance testing is time intensive, but can be done by nonphysician personnel. Computerized NP testing requires adequate resources and a quiet environment for best results, but can be done in large groups. Neuropsychological testing does require health professionals who are competent in test interpretation.

**On-Field Management**

The first step in assessing a collapsed athlete is the check for airway, breathing, and heart function, followed by a physical evaluation to exclude cervical spine injury and/or more serious brain injury. (C) If cervical spine injury cannot be eliminated, neck immobilization and immediate transfer emergency department capable of advanced neurological imaging and management of cervical trauma should follow. (C) Emergency transfer should also occur if there are signs of a more serious brain injury such as deteriorating mental status, focal neurological findings (abnormal or unequal pupil reactivity, abnormalities with extra-ocular movements, abnormalities on a screening motor/sensory exam), or worsening of symptoms. (C) If cervical spine and more serious brain injury can be excluded with history and physical exam, then a more detailed history of injury and an examination that includes symptoms, cognitive and balance assessment, and neurological examination to evaluate for concussion may be initiated. (C)

**Sideline Assessment of Concussion**

Any athlete suspected of having a concussion should be removed from play and assessed by a licensed healthcare provider trained in the evaluation and management of concussion. (C) It is useful to utilize a standardized approach in evaluating the athlete postinjury. Physical exam is primarily to rule out more serious brain injury and assess balance. History, cognitive testing, and balance testing comprise the majority of the evaluation. Previous medical history is important to understand confounding factors that may be present, such as mood or attention disorders, or orthopedic injury, which may affect the physical examination.

There have been several different sideline concussion assessment tools developed and in some settings the use of these tools is required. Standardized measures are designed to reduce the degree of subjectivity encountered by medical providers responsible for making a rapid and precise injury assessment and concussion diagnosis decision. When possible, sideline tests can be compared to a reliable preinjury baseline. (C) Baseline values of commonly used sideline tests can vary widely from athlete to athlete, and the results are dependent on age, sport, sex, and confounding medical conditions, making the use of sideline tests without baseline results difficult. In addition, baseline tests may change as part of the normal maturation and developmental process and can be dependent on current mood, fatigue, and other factors. Familiarity with an athlete is an important component in the sideline evaluation of concussion, given the variability in presentation. (C)

The most common sideline measures include the use of symptoms scores, the Maddocks Questions, the Standardized Assessment of Concussion (SAC), and the Balance Error Scoring System (BESS) or modified BESS. The SCAT2 and the NFL Sideline Concussion Assessment Tool combine various assessment measures to give one score. The sensitivity and specificity of the diagnosis of concussion may increase when combining multiple assessment tools.

The sensitivity (the likelihood that an athlete with concussion will be correctly identified), specificity (the likelihood that an athlete without a concussion will be correctly classified), and the false positive and false negative rates vary for the different sideline tests and are important to consider in the evaluation of an athlete (Table 4). The sensitivity and specificity of these tests may also change over the course of a concussion. A tool that is appropriate for sideline use may not be appropriate for office use. For example, balance testing typically returns to normal after 3 days, making it a potentially useful sideline test but not as useful for later follow-up. With our current sideline tests, as sensitivity goes up, the specificity goes down, so some athletes without a concussion may be held from return to play. Physicians evaluating concussion on the sideline are encouraged to err on the side of safety – “when in doubt sit them out.” More research is needed to validate and improve sideline testing.

**Balance Testing**

Over the past decade, balance testing has become increasingly utilized in the diagnosis and management of sports-related concussion particularly on the sideline. Studies have identified temporary or permanent deficits in static and/or dynamic balance in individuals with mild-moderate traumatic brain injury (TBI) and similar balance deficits have been reported in sports-related concussion.

**Balance Error Scoring System (BESS)**

The test is easy to administer in 5 to 7 minutes and is inexpensive. Three stances (narrow double leg stance; single leg stance; and tandem stance) and 2 footing surfaces (firm surface/ floor or medium density foam) are used for the complete test. Each stance is held, with hands on hips and eyes closed, for 20 seconds. “Error” point deductions are given for specific behaviors, including opening eyes, lifting hands off hips, stepping, stumbling, or falling. There is a maximum score of 60 points if both floor surfaces are used, or 30 if only 1 surface is used.

McCrea and colleagues reported that BESS scores in concussed college football players varied from baseline an average of -5.7 points when measured immediately following the game or practice in which the injury occurred. Changes in BESS performance and rapid recovery of static balance have been reported in other studies of concussed athletes. For most athletes, BESS performance returned to preseason baseline levels (average 12 errors) by 3 to 7 days postinjury. Sensitivity values for the BESS are reported as highest at the time of injury (sensitivity = 0.34). Specificity values for this instrument ranged from 0.91 to 0.96 across postinjury days 1 to 7. One study questioned the clinical utility of the BESS suggesting it has low interrater and intrarater reliability, and that the minimum detectible change for the total
Another study showed 42% of players with-... and its interconnective pathways to the cerebral cortex) may be disrupted postinjury and that the vestibular system is often affected following concussion."

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<table>
<thead>
<tr>
<th>Test</th>
<th>Time to Administer, mins</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>False Positives, %</th>
<th>False Negatives, %</th>
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<tr>
<td>Symptom Scores</td>
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<td>89</td>
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<tr>
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<td>6</td>
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<tr>
<td>Maddocks</td>
<td>5</td>
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<td>9</td>
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<tr>
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<tr>
<td>NFL Sideline Concussion Assessment Tool</td>
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<td>unknown</td>
<td>unknown</td>
<td>unknown</td>
</tr>
<tr>
<td>(SAC + modified BESS + Symptoms score)</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>SCAT2 (SAC + modified BESS + Glasgow coma scale + Physical signs score + Maddock’s score + coordination exam)</td>
<td>8-10</td>
<td>unknown</td>
<td>unknown</td>
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<td>unknown</td>
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</tbody>
</table>

BESS score is between 7 and 9 points making its clinical use questionable. Another study showed 42% of players without a clinically diagnosed concussion exceeded the reliable change on the BESS when tested after a game. Both the SCAT2 and the NFL Sideline Concussion Assessment Tool utilize a modified BESS. The modified BESS only includes testing on a firm surface and does not include testing on medium density foam. There are no reported intra- or interrater reliability studies using the modified BESS, no established minimal clinically meaningful change, no sensitivity and specificity values available. In addition, there are practical issues with using the BESS in a sideline setting. Baseline testing is typically done in a training room on a firm surface in sneakers without tape or ankle braces. Sideline testing is typically done in cleats with ankles taped or braced on grass or a turf field. Despite these limitations, balance is often affected by concussion and should be evaluated when concussion is suspected. Ideally, baseline BESS testing should be done in “game” conditions. More research to refine sideline balance testing is warranted.

The Sensory Organization Test (SOT) (NeuroCom International, Inc, Clackamas, Oregon) is a technical force plate system used to assess balance following concussion but is the gold standard in balance testing in research studies and clinical availability is limited. The SOT has proven to be a useful tool for detecting sensory interaction and balance deficits following concussion. Research utilizing the SOT has identified deficits lasting an average of 3 days postinjury, similar to the studies involving clinical balance tests. These studies indicate that the regions of the brain responsible for coordinating the sensory modalities (thalamus and its interconnective pathways to the cerebral cortex) may be disrupted postinjury and that the vestibular system is often affected following concussion.

**Sideline Management and Disposition**

When a player is being evaluated for, or has been diagnosed with, a concussion, it is a good safety strategy to sequester an essential piece of playing equipment to avoid an “inadvertent” return to the game. A concussed player should not be left alone if the decision is made to keep the player on site, and regular monitoring for deteriorating physical or mental status is essential. If after a full sideline assessment a concussion is not thought to have occurred and the player is allowed to continue play, serial evaluation should be performed after return to the game to ensure the decision was correct. (C)

Athletes diagnosed with a concussion should not return to play on the same day of practice or competition. (C) Athletes with concussion will need appropriate disposition to home, to remain on site until the end of the contest, or if needed, be transferred to an emergency facility. This is not always an easy or straightforward decision and regular reevaluation is desirable until a final disposition is determined. The medical provider should arrange or discuss the follow-up evaluation with a parent/guardian or in loco parentis representative for minor participants. The medical provider should also arrange for the athlete to be accompanied or monitored once allowed to leave the competition area. “Take home” information, ideally in written form, should be discussed with the athlete and any accompanying party, including signs or symptoms that should prompt an emergency room evaluation, avoiding any physical or cognitive exertion that can worsen or mimic signs of concussion, avoiding alcohol, and when to be seen in follow-up. (C)

Common advice previously given to those with concussion such as frequent awakening of the concussed athlete to “make sure they are okay” is no longer recommended. If level of consciousness is a concern, the athlete should be imaged and observed in a hospital setting; otherwise, sleep should not be interrupted, as it is likely restorative. Caretakers...
should be informed that it is desirable to let the athlete sleep. Likewise, no data support that postinjury use of anticoagulation increases morbidity or mortality in head trauma; however, because of the theoretical risk of bleeding, aspirin and nonsteroidal anti-inflammatory drugs (NSAIDs) are generally avoided postconcussion.

**Postsideline and Office Management of Concussion**

**Follow-up Evaluation and Treatment**

Athletes with concussion should have medical follow-up. (C) A detailed history of the event mechanism, course of symptoms, and previous history of concussion should be elicited. Serial monitoring of standardized symptoms scores can be helpful to more objectively assess resolution of symptoms or return to their preinjury baseline. In the vast majority of concussions balance disturbances are back to baseline by 3 days. Worsening symptoms, pronounced amnesia, progressive balance dysfunction, or focal neurological deficits on examination could be signs of intracranial pathology and should prompt neuroimaging. (C)

The treatment of concussion consists of relative physical and cognitive rest. In the early stages of concussion recovery, an athlete should not engage in physical or cognitive activities that result in an increase in symptoms. (B)

**Neuropsychological Testing**

Neuropsychological testing in athletes began in the 1980s, and its use has expanded in the last decade with the availability of computerized testing. Data suggest that cognitive impairment after concussion may last longer than subjective symptoms. Neuropsychological testing is a tool that can identify occult cognitive impairment and may also aid in documenting an athlete’s recovery from a concussion injury. Although variable by different test type, several domains of cognitive function are evaluated, focusing on those areas most affected by concussion such as memory, cognitive processing speed, and reaction time. It is currently unknown if the use of NP testing alters the short-term risks (recurrence or catastrophic injury) or potential long-term complications.

There are 2 main types of testing employed: paper and pencil and computerized. Paper and pencil tests are typically administered and interpreted by a neuropsychologist. These tests are more comprehensive and have the advantage of testing additional domains, which may identify other conditions masquerading as a concussion or postconcussive syndrome. However, paper and pencil testing is more costly and requires significantly more time to administer. Computerized neuropsychological (CNP) testing has advantages in the athletic setting as it is less expensive, takes less time to administer, may be administered concurrently to groups of athletes, provides instant information to the provider, has more precise measures of reaction time, has multiple forms, and may be used for serial assessment. Both paper and pencil and computerized testing have significant individual variability in regards to domains measured and performance measures such as validity, sensitivity, specificity, reliable change index, and baseline variability.

Testing, particularly CNP, has been shown to have moderate sensitivity in the detection of postconcussive cognitive deficits. Neuropsychological testing has not been validated as a diagnostic tool but has the ability to show cognitive deficits longer than athletes are symptomatic. Because of this, testing has been promoted as a monitoring tool in the recovery from a concussive event. Intuitively, baseline testing appears to have advantages over comparative normal values, but no studies have looked at this issue with regard to outcomes, and there is limited data to suggest age-related norms may be adequate to assist with management decisions. No ideal interval for repeating baseline testing has been established for NP or CNP testing. Test-retest reliability studies of currently available NP tests show baseline testing may need to be repeated, but an ideal interval has not been established. Additionally, many intrinsic and extrinsic factors can affect performance on NP testing, particularly CNP testing. In 1 study of college football players without a diagnosis of concussion, CNP testing 48 hours postgame showed that 75% exceeded reliable change in 1 category and 25% exceeded reliable change in 2 categories. If testing is used, care should be taken to make the baseline and postinjury physiologic variables (ie, fatigue) and environmental variables (ie, distractions) as similar as possible. Other conditions such as age, effort, sex, cultural background, primary language, mood disorders, migraines, and history of concussion also can affect testing results. No optimum postconcussion monitoring interval has been established and reported intervals vary from every few days to only testing asymptomatic athletes prior to return to sports. No studies have evaluated these intervals in regard to long-term sequelae or recurrent concussive risk.

There are no universally agreed upon recommendations for use of NP testing, and existing recommendations are based on expert opinion. There are several potential reasons to consider testing. In high-risk athletes with prior concussion, testing adds additional information that may help with return-to-play decisions. In athletes who may deny symptoms in order to return to play sooner, testing may play a role to identify athletes with persistent deficits. It may also aid in the medico-legal or policy considerations in the management of these athletes.

Neuropsychological testing is only an adjunct to clinical assessment and judgment. In the majority of cases, concussions can be managed appropriately without the use of NP testing. However, testing may have added value in some settings, especially high-risk athletes. Neuropsychological testing should be interpreted by a healthcare professional trained and familiar with the type of test and the individual limitations of each test. Neuropsychological testing should be used only as part of a comprehensive concussion management strategy and should not be used in isolation.

**Symptom Management**

The appropriate management of concussion symptoms requires careful consideration of the timing and natural history of the injury. In the acute setting (0-10 hours postonset...
of injury), drugs that could alter mental status, such as benzodiazepines, should be avoided. (C) After this acute phase, medications may be considered for symptomatic relief, although those that affect the central nervous system, such as stimulants, certain anti-nausea medications, and anti-depressants, should be used with caution as they may cloud the neurological and cognitive examination and impair the physician’s ability to assess the injury. (C) When the patient is being considered for return to participation, medications that may mask symptoms of concussion must be avoided. During the entire course of the injury, activities and environmental conditions that exacerbate symptoms should be moderated appropriately.

There is no convincing evidence that any particular medication is effective in treating the acute symptoms of sports concussion specifically. Treatment should be based on common approaches to each specific symptom. (C) Symptoms such as headache, sleep difficulty, and depression may either be direct results of concussion or may represent exacerbations of preexisting conditions.

In the acute setting, treatment options for headache are limited. Acetaminophen offers possible benefit without significant increased bleeding risk. In general, aspirin (ASA) and NSAIDs are not recommended as discussed previously. Physical modalities (ie, massage, ice, contrast therapy, manual therapy) may be considered, especially if there is concurrent neck pain. A dim, quiet environment may moderate head pain, as well as symptoms of photophobia and phonophobia. If headache continues after 3 to 4 days, abortive treatment should be tailored to headache type (ie, migraine, tension, occipital neuralgia, etc). (C) Similarly, prophylactic treatment of a new or exacerbated chronic or recurrent headache syndrome should be tailored appropriately. Headaches that continue as part of a postconcussion syndrome (symptoms lasting longer than 6 weeks) often require a multidisciplinary approach.140

Sleep disturbance is a common and important symptom experienced throughout the course of concussion.141 Immediately after concussion, patients may experience either increased sleep latency and frequent wakening, or decreased latency and longer sleep times. In either case, sleep issues in the first few days following injury onset should be addressed conservatively, without medications, and with particular attention to good sleep hygiene. Excessive daytime somnolence is also common, regardless of absolute sleep times. There is no evidence to support a role for stimulant- or sleep-promoting medications in the acute setting. Sleep difficulties may continue as part of a postconcussion syndrome. In these cases, both medical and cognitive therapies may be considered.

Alteration in mood is also a common manifestation of concussion, particularly in the acute setting.142 While depression is perhaps the most common, any mood disturbance is possible. There is no established role for medications in the treatment of a concussion-induced mood disturbance. If mood issues persist beyond 6 to 12 weeks, either as part of a postconcussion syndrome, or as manifestations of an exacerbated mood disorder, treatment with medications and/or cognitive therapy should be considered. (C)

Cognitive symptoms, especially decreased attention, may also produce significant morbidity. There is no established role for stimulant medications in the treatment of acute attention difficulties following concussion. (C) Decreasing academic responsibilities and other cognitive demands should be considered for any significant decrease in cognitive performance.143

Symptoms of balance dysfunction and vertigo should be carefully evaluated prior to treatment. Medications such as meclizine or diazepam may be helpful for acute attacks of vertigo, but should be used cautiously early in concussion management as they may affect cognitive function, cause fatigue, and obscure the evaluation of concussion resolution.144 Although only limited evidence exists, vestibular therapy may be considered for the treatment of dizziness or vertigo.145

Return to School

There are no standardized guidelines for returning the athlete to school. If the athlete develops increased symptoms with cognitive stress, student-athletes may require academic accommodations such as a reduced workload, extended test taking time, days off, or a shortened school day.146 Some athletes have persistent neurocognitive deficits following concussion, despite being symptom free. Consideration should be made to withhold an athlete from contact sports if they have not returned to their ‘academic baseline’ following their concussion.126 (C) The CDC developed educational materials for educators and school administrators that are available at no cost and can be obtained via the CDC Web site. Additional resources for academic accommodations should be developed for both clinicians and educators.147 (C)

Return to Play

Return to play after concussion should be individualized, gradual, and progressive and should consider factors that may affect individual risk and outcome.4,15,29,43,58,95,148 (C) The athlete should be free of concussion symptoms at rest as well as during and after exertion before returning to full participation. (C) The athlete should also have a normal neurologic exam including a normal cognitive and balance evaluation, ideally compared to a preinjury baseline. (C) Once the athlete is asymptomatic and has returned to their baseline measures (if available), a gradual and medically supervised incremental return to activity should be initiated and includes a step-wise increase in physical demands, sports-specific activities, and physical contact. This progression may take days to weeks depending on the individual responses and modifying circumstances. It is important to consider individual factors that are suspected to increase susceptibility and/or prolong recovery after concussive injury. The severity of a concussion is based on the nature, burden, and duration of symptoms, the frequency and past history of concussions, and the presence of prolonged symptoms. All should all be considered when determining the symptom-free interval required prior to starting the return-to-play progression. (C)

The return-to-play progression should be individualized, with symptoms and cognitive and balance exams used to track recovery. (C) A typical return-to-play progression for an uncomplicated concussion is shown in Table 5. If the athlete develops symptoms with an increase in activity level, the progression should be stopped and the athlete returned to the previous phase when symptom free again. (C) The return-to-play decision is individualized for the specific
TABLE 5. Graduated Return-to-Play Protocol

<table>
<thead>
<tr>
<th>Rehabilitation Stage</th>
<th>Objective of Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No activity</td>
<td>Recovery</td>
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<tr>
<td>Light aerobic exercise</td>
<td>Increase heart rate</td>
</tr>
<tr>
<td>Sport specific exercise</td>
<td>Add movement</td>
</tr>
<tr>
<td>Non-contact training drills</td>
<td>Exercise, coordination, and cognitive load</td>
</tr>
<tr>
<td>Full-contact practice</td>
<td>Restore athlete’s confidence; coaching staff assesses functional skills</td>
</tr>
<tr>
<td>Return to play</td>
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</tr>
</tbody>
</table>

circumstances of each concussion. A final return-to-practice/play determination should occur with documented medical clearance from a licensed healthcare provider trained in the evaluation and management of concussion. (C)

**Neuroimaging**

The vast majority of athletes with sports-related concussion do not require neuroimaging. Standard neuroimaging with computed tomography (CT) or magnetic resonance imaging (MRI) is negative in concussion but are used to evaluate for more serious brain injury. Computer tomography is best used acutely for evaluating for bony fracture and for intracranial bleeding, contusion, mass effects, and/or brain stem herniation, whereas MRI is more sensitive for evaluating persistent or worsening symptoms or concern for underlying pathology (eg, headache or seizure disorder, arteriovenous malformation, Chiari malformation, etc). Computed tomography exposes the brain to radiation and should be used judiciously. Magnetic resonance imaging technology has improved with stronger magnets and different techniques that can detect minor abnormalities after concussion, although the clinical relevance of the findings are unclear.

Other imaging techniques used primarily in concussion research include positron emission tomography (PET) and single-photon emission computed tomography (SPECT) imaging which measure cerebral glucose uptake and regional cerebral blood flow, respectively. Both PET and SPECT incorporate injected radioisotope, are time consuming, and have undetermined predictive value, which limits their clinical use. Recent research is evaluating new neuroimaging techniques after sports-related concussion including functional MRI (fMRI), diffusion tensor imaging (DTI) and MR spectroscopy (MRS). Functional MRI demonstrates neuronal dysfunction by measuring regional changes in blood oxidation patterns measured in response to a specific task that the individual performs while in the scanner. The information obtained is totally dependent on the tasks being performed (eg, working memory, sensorimotor coordination, or visuospatial memory). Abnormal patterns of activation have been noted in several studies of sports-related concussion.

Diffusion tensor imaging provides structural images of white matter fiber tracts of the brain by measuring the movement of water within the brain. Fractional anisotropy is a measure of the relative directionality of water diffusion in axons, and in healthy individuals the direction is organized and in a specific direction (anisotropy). Both fractional anisotropy and mean diffusivity have been shown to change after sports-related concussion, though how these correlate with clinical measures of injury and recovery have not yet been elucidated.

MR spectroscopy measures neurometabolites via proton magnetic resonance spectroscopy that are important in the neuropathology of concussive injury. MR spectroscopy typically evaluates N-acetylaspartate, creatinine, choline, myoinositol, and lactate, and preliminary research in sports-related concussions show changes in the ratio of these neurometabolites in different areas of the brain. The research involving the use of MRS as well as other advanced neuroimaging techniques is evolving rapidly, but currently there are no definitive clinical correlations to make them applicable to patient care.

**Short-term Risks Associated with Premature Return to Play**

There are potential health risks of returning an athlete with persistent symptoms to play including the possibility of second impact syndrome (SIS) or diffuse cerebral swelling, and increased susceptibility to a recurrent or more severe concussion and prolonged duration of symptoms. Second impact syndrome is described as occurring when an individual sustains a second head injury before the symptoms associated with the initial injury have fully cleared. The pathophysiology of SIS is thought to involve a loss of autoregulation of the brain’s blood supply, leading to vascular engorgement, marked increase in intracranial pressure, brain herniation, and ultimately coma or death. There is significant debate as to whether SIS is related to a prior head injury or if it represents a separate pathophysiologic malignant brain edema, a form of diffuse cerebral swelling described in children. The pathophysiology of diffuse cerebral swelling after first impact is described in laboratory animal models. There are also limited cases of SIS reported in the literature, and while rare, SIS is reported as more common in boxers and athletes under the age of 18. The history and pathophysiology of death in some reported cases of SIS do not support the diagnosis. Whether or not a discrete entity of SIS exists, the association with concussion is a compelling reason why an athlete should not return to play before symptoms of their concussion have completely resolved.

Returning an athlete to play with persistent symptoms may predispose an athlete to a worse concussion. Concussion decreases cognitive ability and reaction time, which theoretically diminishes an athlete’s ability to respond to the demands of the sport, increasing the risk of a second brain impact and injury to other body parts. In addition, early activity after concussion can prolong symptoms and neurocognitive recovery on a pathophysiological basis; studies suggest there is an increased window of brain vulnerability after concussion secondary to impairment of cellular energy metabolism. A second injury before the brain has recovered results in worsening cellular metabolic changes and more significant cognitive deficits in animal laboratory models. In humans this may translate to increased susceptibility to concussion, increased morbidity from relatively lower forces, or prolonged symptom duration and neurocognitive recovery.
Prolonged Concussive Symptoms/Postconcussion Syndrome

While the majority of concussions resolve within 7 to 10 days, in some cases symptoms will persist for weeks, months, or years beyond the initial injury. The evolution of concussion injury to postconcussion syndrome is ill defined and poorly understood. It is difficult to define where concussion ends and postconcussion syndrome begins. The syndrome is simply defined as symptoms and signs of concussion that persist for weeks to months after the incident.\(^{95,185-187}\) Symptoms of postconcussion syndrome can be subjective or objective and are often vague and nonspecific making the diagnosis difficult. Although any symptom of concussion can be involved, commonly reported symptoms include headache; dizziness; insomnia; exercise intolerance; cognitive intolerance; psychological symptoms such as depressed mood, irritability, and anxiety; cognitive problems involving memory loss, poor concentration, and problem solving; fatigue; or noise and light sensitivity.\(^{81}\)

While there are many potential causes of postconcussion syndrome, none have been proven or accepted. There is, however, no proven correlation between the severity of the concussion injury and 1) the likelihood of developing persistent postconcussion symptoms, 2) any structural damage to the brain or disruption of neurotransmitter systems, or 3) the presence of psychological factors like depression, anxiety, or posttraumatic stress disorder.\(^{88,143-145}\) Risk factors for postconcussion syndrome include increasing age, female sex (possibly because women are more likely to seek medical care when they have symptoms), or non–sports-related concussion (car collision, fall, or assault). Compared to other forms of concussion, sports-related concussions seem less likely to result in postconcussion syndrome.\(^{58,143-145}\)

The foundation of postconcussion syndrome management is time. Recovery from postconcussive syndrome can be a long and slow process that is often frustrating for patients and requires them from their normal endeavors in school and sport. Management of postconcussion syndrome is ideally done by a team of providers who work with concussion on a regular basis. (C) Comprehensive neuropsychological evaluation by a trained neuropsychologist utilizing standardized paper and pencil testing can be helpful to define cognitive deficits and areas of potential neurocognitive rehabilitation. (C) Cognitive therapy,\(^ {188}\) integrated neuoro rehabilitation programs,\(^ {187}\) and supervised progressive exercise programs may improve recovery.\(^ {189}\)

(B) Progressive exercise programs involve exercising to the onset of symptoms, then every other day exercise at 80% of the symptom threshold, with retesting and progression of activity as tolerated. The general return-to-exercise recommendation is to advance slowly as symptoms permit. Similar to the management of concussion, athletes with postconcussion syndrome will need academic and workplace accommodations to restrict or modify cognitive loads until learning processes have recovered. Treatment of coexistent or new mood and sleep disturbances may also be beneficial. (C)

Disqualification from Sport

There are no evidence-based guidelines for disqualifying or retiring an athlete from their sport after concussion. Several authors have proposed that a clinician consider disqualifying an athlete if any of the following are present: structural abnormality on neuroimaging; multiple lifetime concussions; persistent diminished academic or workplace performance; persistent postconcussive symptoms; prolonged recovery courses; and perceived reduced threshold of sustaining recurrent concussions.\(^ {90-195}\) There have been no agreed upon absolute number of concussions an individual can sustain before disqualification from contact sports is necessary. Each case should be carefully deliberated with all parties involved with an understanding of risks and unknowns. An individualized approach to determining disqualification is essential. (C)

Long-term Sequelae of Sports-related Concussion

There is increasing concern that head impact exposure and recurrent concussions contribute to long-term neurological sequelae including chronic traumatic encephalopathy (CTE) and chronic neurocognitive impairment (CNI). There is no known relationship between CNI and CTE.

Chronic traumatic encephalopathy is a neurodegenerative disease associated with repetitive brain trauma and characterized pathologically by the accumulation of tau protein in specific areas of the brain. Chronic traumatic encephalopathy results in executive dysfunction, memory impairment, depression, and poor impulse control.\(^ {190}\) Chronic traumatic encephalopathy is a diagnosis made only after death with confirmatory histopathology, and the prevalence of this condition is unknown. Recent studies have described the histopathological findings of CTE in the postmortem analysis of athletes’ brain tissue.\(^ {197-201}\) The typical symptoms and behaviors preceding death in athletes with CTE suggest a link between neurobehavioral patterns and the neuroanatomical areas of the brain affected. Chronic traumatic encephalopathy is not a continuation of postconcussive syndrome or symptoms from an acute concussion, but rather develops decades after exposure. Not all athletes diagnosed with CTE postmortem reported concussions during play, raising the question if subconcussive blows may contribute to the development of CTE. Given the large number of athletes participating in contact or collision sports and the small number of cases described, it is likely that other factors such as genetic predisposition play a role in its development.\(^ {198,199}\)

Chronic neurocognitive impairment after head injury can present in postconcussive syndrome, but can also occur years after a symptom-free interval, and CNI symptoms and behaviors can be demonstrated by neuropsychological testing. Some studies have identified an association between prior concussions and chronic cognitive dysfunction,\(^ {37,85,202,203}\) but others have found no association.\(^ {204-207}\) Studies involving former American football players\(^ {204,208}\) and soccer players who were active at the time of the study\(^ {209-211}\) suggest an increased risk of CNI with increased exposure to concussions and subconcussive insults to the head. Guskiewicz showed a higher incidence of mild cognitive impairment and depression in former National Football League athletes with a history of concussion compared to those who did not have a history of concussion.\(^ {42,208}\) Matser showed decreased performance on neuropsychological testing in athletes who had a higher incidence of concussion and head injury.\(^ {209-211}\) However, a community-based study of high school football players in Minnesota with long-term follow-up...
(median 50.2 years) showed no increase in dementia, Parkinson’s
disease, or amyotrophic lateral sclerosis in football players
compared to the general population.212 While the potential
for CNI and CTE is concerning, large-scale, epidemiological
studies will be required to more clearly understand the causes
and develop prevention strategies.

Education

Studies demonstrate that athletes, parents, and coaches
lack the knowledge needed to make informed decisions about concussion.213–215 Misconceptions and lack of understanding
about symptoms of concussion, as well as the recommended
treatment and return-to-play guidelines, still exist.213,215
Administrators and coaches play a big part in the health and
safety of the athlete and they are often the first source of knowl-
edge for the athlete and parents on topics like concussion.213
Education of medical personnel, coaches, athletes, and
parents can enhance the identification of concussions and
improve treatment and prevention. (C) Preseason education,
including symptoms and signs of concussion, proper fit and
use of equipment, player respect, sport rules, sport-specific
technique, symptom reporting and assessment, treatment and
testing options, and return-to-play guidelines, will help all to
better understand the significance and importance of this
injury. The education method and medium should be tailored
to the group to optimize the learning method.216

Currently, there are a variety of concussion educational
materials available through governmental agencies, educa-
tional institutions, and private companies. Table 6 below lists
some recommended concussion education resources.

Prevention of Sports-related Concussion

All sports-related concussion cannot be prevented, but
several efforts may reduce the incidence and severity. (B)
These changes will require a shift in attitude and expectation
on the part of players, coaches, officials, administrators,
parents, and fans, especially with respect to contact and
collision sports.

The rules of play form the basis of safe conduct for the
game. Stringent enforcement of the rules by coaches and
officials217 and strict adherence to the rules by players will
reduce the incidence of concussion. The rules of the game
set expectations for behavior on the field of play and define
infractions for collisions with increased risk to the aggrieved
player. Rigorous education and consistent modeling of the
rules by coaches and officials reinforce the importance of clean
play. Fair play rules were shown to reduce concussion injury in
hockey tournaments218 and may have similar benefits for other
sports. Promoting fair play encourages respect for opponents
and emphasizes safety precautions for athletes. Coaches,
parents, and managers must role model fair play values for
effectiveness. Rule changes based on epidemiologic data also
have reduced concussion and neck injury in some sports: 1)
banning “spear tackling” in American football, 2) enforcing no
“checking from behind” in ice hockey,219 and 3) limiting “elbow to head” contact in soccer.217

Limiting the number of contact practices will reduce
exposures and subsequently the number of concussions. This
concept is being tested in American college football, college
lacrosse, and college soccer in some conferences, and if
proven effective may also be beneficial in other sports such as
ice hockey and rugby.220,221 Similar restrictions in contact-
collision for different age groups, such as prohibiting body
checking in boys’ lacrosse and ice hockey below the age of
13 to 15, also has the potential for preventing injury.

Player behavior plays an integral part in injury reduction. Athletes must be taught correct playing techniques
and appropriate behavior by trained and qualified coaches.
Any behavior that increases concussion risk should be
eliminated, and this may require a culture change in players,
coaches, officials, administrators, and fans. Sports-specific
techniques like tackling, body checking, and heading the ball
must be properly taught and demonstrated before they are
used in game situations.

Protective equipment has not yet shown a role in concussion reduction.30,222,223 Helmets have played a signifi-
cant role in reducing scalp lacerations, skull fractures, and
intracranial bleeds, and their use in sports such as cycling,
skiing, and snowboarding should be strongly supported.
While headgear and helmets can reduce biomechanical forces
associated with a blow to the head and could possibly reduce
concussion severity, helmet use has not been shown to pre-
vent or reduce concussion.222 There is potential for improved
helmet design and for sport-specific helmets to decrease con-
cussion in sport. Mouth guards prevent peri-oral and dental
injury, but there is little evidence that mouth guards reduce
concussion rates.95,131 Often overlooked is the possibility that
use of protective equipment may change player behavior and
secondarily contribute to an increase in concussion risk.

Neck strengthening may limit transmitted forces to the
head and dampen impact to the brain. Differences in head-neck
segment mass and girth have been demonstrated between
women and men and may underlie the differences seen in
reported concussion incidence between sexes.60,224 From a theo-
retical standpoint, increasing the strength and rigidity of the
head-neck segment could decrease the acceleration forces seen
by the head when struck. However, neck strengthening programs
have not yet, to date, been published that demonstrate a signifi-
cant intervention effect. In addition, the benefits of stronger neck
muscles are not effective when the athlete has no opportunity to
‘prepare’ for impact as often occurs in rule infractions.

Educating athletes, parents, coaches, administrators,
athletic trainers, and physicians involved in contact and
collision sports is important for athlete safety. (C) An
understanding of the risks, detection and assessment tech-
niques, and the principles of safe return to play should help
improve concussion safety.

Legislation

Concussion-related legislation in many states requires
education of athletes, parents or guardians, and coaches,
removal from play or practice at the time of a suspected concussion, and written clearance for return to practice or play by a licensed healthcare provider trained in the evaluation and management of concussion. Such laws provide a uniform standard for scholastic and nonscholastic sports organizations regarding concussion safety and management.225 These efforts have arisen as safety measures to improve the care of this injury by standardizing the roles and responsibilities of athletes, parents or guardians, coaches, and healthcare providers.225 Healthcare providers should be aware of the laws in the state where they practice. Over 80% of states have laws in place, and there are ongoing efforts to establish legislation in all 50 states.226 These laws should be viewed as living documents to be modified as the best educational policies and practices are developed, the most effective strategies for implementing and measuring compliance of the laws are determined, and as new knowledge about sports concussions develops.

CONCLUSIONS

Concussion is a concerning and complicated problem in sport requiring a multifaceted approach to diagnosis and management. Athletes, coaches, officials, and parents need to be educated regarding signs and symptoms of concussion to recognize the injury on the field of play and to seek appropriate evaluation. It is critical that athletes are forthcoming regarding their symptoms as this is often the only detectable indication of concussion. A physician or other health professional trained in the evaluation and management of concussion who knows the athlete well is in the best position to correctly diagnose a concussed athlete. Standardized sideline tests provide a helpful, uniform approach for examination, but further studies are needed to delineate their accuracy. No athlete diagnosed with a concussion should return to play on the same day or while symptomatic. The return-to-play decision is a medical one. Additional research is needed to validate current assessment tools, further delineate the role of NP and balance testing, validate return-to-play guidelines, and improve identification of those at risk for prolonged concussive symptoms or other short- or long-term complications.

REFERENCES


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