Concussion is diagnosed when an athlete presents with typical symptoms, signs, behaviors, and difficulties with cognition and/or balance after direct or indirect trauma. Standard imaging modalities, such as computerized tomography (CT) and magnetic resonance imaging (MRI) scans, are typically normal, demonstrating that the injury is a functional problem more than a structural one. More sophisticated studies evaluating for structural injury, such as functional MRI, diffusion tensor imaging (DTI), along with neurochemical biomarkers and genetic markers may someday modify the methods by which the diagnosis of concussion is made. These tools remain research investigations, are not the emphasis of this article, and are reviewed elsewhere.

Most (80%–90%) sport-related concussions resolve within 7 to 10 days, although for some athletes, the time for complete recovery takes much longer. Why some athletes seem to recover quickly and others do not remains unclear. There do seem to be modifiers that may alter how concussion is managed and determine which athletes may have prolonged recovery patterns. Given these sometimes complex and unpredictable injuries, it is useful to consider a team approach to concussion management, with a variety of tools for evaluation and diagnosis, and consultants for treatment and management.
WHAT IS REPORTED?

Athletes often minimize and/or do not report their symptoms because they want to play and believe that their symptoms are mild enough to safely play through them. Younger athletes seek to emulate older athletes and show that they are tough enough to play despite their injuries and not to let their teammates down. It is common that athletes, at all levels, assume that “having their bell rung” is part of the game, and do not realize the significant consequences of playing with concussion. Many athletes do not realize that their symptoms indicate concussion. Most athletes do not want to be taken out of play, and will go to great lengths to minimize or trivialize their symptoms.

In a study of high-school football players, only 47.3% of players with a concussion reported their injury. Of those who did not report, 66.4% did think their injuries were serious enough to report, 41% did not want to be held out of play, and 36.1% did not realize their symptoms were consistent with concussion. In this study, when injuries were reported, they were most often reported to an athletic trainer. Given the serious nature of concussive injuries if untreated and/or repeated, it is important that the culture of sport change such that athletes, parents, coaches, and health care providers understand the significance of unreported, repetitive concussive injury. This is most important at the youth level where sports-trained medical providers, such as athletic trainers and team physicians, are often lacking.

GRADING SYSTEMS

The idea of grading a concussion at the time of injury with the intent of then determining when it will be safe to return to play led to a variety of different grading and classification systems. Although appealing, these grading scales have been abandoned, because they are not research based and assumed that loss of consciousness (LOC) denoted more severe injury. There is significant variability in injury and therefore a cookbook approach to managing concussion is ineffective.

The Zurich Guidelines represent the most recent, internationally agreed consensus statement on the management of sport-related concussion. They recommend: (1) athletes with symptoms should be removed from play; (2) no athlete with symptoms, at rest or with exertion, should continue to play; (3) young athletes need to be treated more conservatively; (4) there is no role for CT or MRI in concussion; and (5) a multidisciplinary approach to management is useful.

PREDICTORS OF SEVERITY

Based on the research on sport-related concussion that has occurred in the past decade, there are some recognized symptoms and/or signs that may predict more severe outcome as measured by the length of time that symptoms, neurocognitive deficits, or balance dysfunction occurs. Although brief LOC does not correlate with severity, the presence of prolonged LOC (>1 minute) has been shown to be associated with more severe injury. In addition, other studies have shown that amnesia, prolonged confusion, and persistent symptoms are associated with more severe injury. A recent study in Australian football players found that headache longer than 60 hours, self-reported fatigue/fogginess, and those with more than 4 symptoms were more likely to have delayed recovery based on cognitive testing. These symptoms should be evaluated during the sideline assessment of the concussed athlete. The severity of injury is likely best determined by the nature, burden, and duration of symptoms, as well as the time that cognitive and balance disturbances persist, and none of these can be determined at the time of injury.
SIDELINE MANAGEMENT OF CONCUSSION

For the athletic trainer and team physician taking care of athletes, the first step in sideline management is to have an emergency action plan (EAP) in place.22,23 Providers should be familiar with the EAP and for high-risk sports it should include a concussion protocol.24–26 The EAP is essential for all individuals involved in sport, including administrators, coaches, athletes, the team medical staff, and other health care providers. The concussion program may differ based on the resources available as well as the athletes being served, but should maintain basic principles of management including recognition of injury, assessment, disposition, follow-up, return to play (RTP), and education. Several sport and athletic organizations have developed programming and best practices that are useful in this regard.26–28 Education is an important aspect of the concussion protocol and should include athletes as well as coaches and parents as applicable.

RECOGNITION

The first step in evaluating and managing concussion is recognition of injury. Although a big hit gathers the attention of medical staff and others present, it is important to realize that the mechanism of injury may be more subtle and not as obvious. In a study evaluating the relationship between the force of impact in college football and clinical outcome, magnitude of impact did not correlate with clinical injury.29 This study used accelerometers embedded into the football helmet and evaluated athletes with a clinical program involving preinjury baseline testing (symptoms, neuropsychological testing, postural balance testing) and repeat postinjury testing. The postinjury measures were compared with the baseline measures. The impact magnitude of the hits in concussed athletes ranged from 60.51 to 168.71 g, yet no significant relationships between these impacts (linear or rotational, location) and the change scores for symptom severity, postural stability or neuropsychological function were found. Additional research is needed to evaluate what other biomechanical issues play a role in the causation of injury.

Many symptoms of concussion are not specific to concussion. This creates a difficult dilemma in making the diagnosis. Headache, the most common symptom in concussion, has many causes, and is the most common symptom for individuals presenting to an emergency room facility.8,21 To diagnose a concussion, it is important that there is a history of trauma, either a blow to the head or a blow to the body that transmits an impulsive force to the head. The injury may have occurred several hours previously and can sometimes be difficult to discern. Teammates and/or coaches also often notice that an athlete is not acting normally, having difficulty remembering plays or assignments, or showing other signs of concussion. Education of coaches, athletes, parents, and health care providers regarding common signs and symptoms of concussion, as well as the importance of recognition and early management of these injuries is essential.

An athlete with signs or symptoms of concussion should be removed from play and evaluated by a health care provider.26–28,30 The athlete should not be allowed to RTP until an evaluation occurs. Coaches and administrators, as well as teammates and parents, should be familiar with how to engage the emergency medical services available to them and arrange for evaluation.

The symptoms of concussion are one component of diagnosis with the other components including a neurologic examination, cognitive assessment, and balance evaluation. The physical examination is important to exclude other critical diagnoses, as well as determine whether additional emergent evaluation is necessary. For
example, if any evidence of skull fracture or cervical spine injury is present, the athlete should be stabilized and emergently transferred to an emergency facility. Diagnoses such as skull fracture, cervical spine fracture, and/or intracranial injuries must be considered. The balance examination can indicate injury when other aspects of the examination are normal.

The first steps in evaluating the athlete on the sideline with possible concussive injury are to ensure that the athlete is stable from a cardiovascular standpoint, and exclude cervical spine injury. Emergency management principles should be followed and an EAP should be in place for all practices and competition. Part of this initial assessment includes evaluating the mental status of the athlete, including if necessary, the Glasgow Coma Scale. If the athlete is conscious, the athlete should be asked whether or not they have any neck pain. Signs and symptoms of cervical spine injury can include neck pain or neck tenderness, pain with neck movement, weakness, and/or numbness or tingling in the extremities. If the athlete is unconscious, then the assumption should be that a cervical spine injury is present; spine board immobilization and immediate transfer to an emergency facility should be arranged.

The following discussion pertains to the athlete who has been evaluated, acute cervical spine and/or neurologic emergency excluded, the athlete is stable, and concussion is the probable diagnosis.

BASELINE INFORMATION

An important feature of the concussion plan is to have a baseline evaluation for athletes participating in high-risk sports including a history of prior injuries as well as other modifiers, a baseline evaluation that includes symptoms, neurologic examination, cognitive evaluation, and balance testing. This can be incorporated into the preparticipation examination that athletes have before they participate in school sports. There are several symptom scales, cognitive evaluations, and balance-testing options that can be used. More important than which of these is used is the concept that a baseline evaluation is performed and is then repeated after injury to assess for changes reflective of concussive injury. This approach of combining a variety of tools for baseline and subsequent postinjury assessment has been found through a meta-analysis to be effective in managing sport-related concussion. A multifaceted approach is especially helpful in evaluating concussion as the symptoms vary, the presentations vary, and significant individual differences between athletes exist. There is significant benefit to having as many tools as possible to form the baseline and postinjury evaluation. This information provides the clinician with more data to consider.

Given the individualized nature of decision making in the management and RTP of concussed athletes, obtaining a history of modifiers is very important in those athletes at high risk for injury, and these are provided in Table 1. The concussion history should include prior history of injury, the symptoms that occurred, the duration of symptoms, and the length of time out of activity. It should also include any special testing obtained as well as the temporal relationship of injuries. Additional modifiers that should be included in the baseline evaluation are a history of learning disability (eg, attention deficit hyperactivity disorder), mental health issues (eg, depression, anxiety), migraine history, and/or sleep disorders.

THE SYMPTOM CHECKLIST: WHAT SYMPTOMS ARE IMPORTANT?

The symptoms of concussion listed earlier are not specific to concussion, which can contribute to the difficulty in making a diagnosis. If an athlete is confused or having
difficulties with memory, it may be easier to discern that a concussion is the diagnosis. However, if the athlete is simply dizzy or has a headache, the diagnosis can be more difficult. These symptoms are common yet can also occur in a variety of other sport-related issues such as dehydration, heat-related illness, or anemia. This underscores the importance of having a baseline score for each individual athlete and performing a complete evaluation. Headache is one of the most difficult symptoms given that there are athletes who have headache unrelated to trauma as well as defined headache disorders that are related to trauma, such as trauma-induced migraine, further complicating diagnostic decisions. In these situations, it is important to be conservative in management remembering the adage “when in doubt, sit them out.”

It is beneficial in both the preseason evaluation and the postinjury evaluation to use a symptom checklist. This is most important during the postinjury evaluation, when a standardized symptom checklist is preferable to open-ended questions such as “how are you,” or “are you ok,” which are likely to underdiagnose injury. Using a symptom checklist provides a systematic approach to the evaluation and management whereby the same scale can be used for every interaction that the athlete has with various health care providers during the time course of their injury. Many different symptom scales exist in the literature and most of these have been put together as lists without evaluating for their psychometric components. A recent systematic review of the literature on symptom scores in sport-related concussion identified 6 core scales and several derivative scales, but limited information about their psychometric properties as well as limited scientific data to support their use. Common symptom checklists include the Pittsburgh Steelers Post-concussion Scale and its derivatives (eg, Post-concussion Scale Revised, Head Injury Scale, McGill ACE Post-concussion Symptoms Scale, Concussion Resolution Index, Sports Concussion Assessment Tool (SCAT), Post Concussion Symptom Scale, and the Concussion Symptom Inventory. In addition,
derivative scales were also identified but with very limited scientific data to support their use. The most recent symptom checklist published as part of the 3rd International Consensus Conference on Concussion\textsuperscript{10} is called SCAT 2.\textsuperscript{41} Although more research is necessary to determine the ideal symptom checklist/scale, using a scale as part of a standardized evaluation, with a baseline set of symptoms for the individual athlete, is of benefit.

The symptom scale used in the SCAT was evaluated in a group of varsity university athletes. In addition to providing individual baseline information for each athlete, they also determined normative data for this group of athletes in terms of symptoms reported.\textsuperscript{42} They found that overall, 41.2\% of participants reported a symptom score of 0, the mean baseline score for all participants was 4.29, 3.52 for men and 6.39 for women. In addition, when they differentiated athletes with a prior history of concussion versus those without a history of concussion, they found that the symptom score was higher in those with a prior history of concussion (5.25 vs 3.75). In this study, the most common baseline symptoms reported included fatigue/low energy (37\%), drowsiness (23\%), and neck pain (20\%). A significant number of athletes also reported baseline symptoms of difficulty concentrating (18\%) and difficulty remembering (18\%). In addition to the gender differences seen between total baseline symptom scores, there were also gender differences for particular symptoms such as headache and emotional lability. The difference in baseline symptoms between genders as well as between athletes with or without a prior history of concussion has been noted in other studies.\textsuperscript{43,44}

**COGNITIVE TESTING**

When an athlete exhibits signs and/or symptoms of concussion, it is important to perform a cognitive evaluation that determines how well the athlete’s brain is working; how they respond to questions, how well their short-term memory works, how they process information or perform simple tasks. For the team physician or athletic trainer who knows the athlete well, it may be very obvious during this cognitive evaluation that the athlete is struggling and may have a concussion. How accurately they answer simple questions as well as how quickly they respond and are able to process the information can be confirmative of a concussed athlete, once other possibilities are excluded.

The cognitive evaluations that are used as part of sideline management should also be standardized such that they are also used as part of the baseline evaluation. The evaluation should emphasize mental status and questions regarding orientation as well as simple tests of memory, recall, and new learning. Although a mental status examination is important in terms of orientation ("where are we?," “what day is it?,” “what is the date?,” “what is the month?,” “what is the year,” “what is the approximate time"), it is also important to recognize that these questions might be answered incorrectly without any injury. More useful are the questions by Maddocks and colleague,\textsuperscript{45} which ask "what venue are we at?," “what half is it?,” “who scored last in this match?,” “what team did we play last week/game?,” “did your team win the last game?,” “what was the score?” These questions are part of the SCAT2 sideline tool discussed previously.

Asking an athlete to remember 5 words, remember digit span backward (present the numbers in a series forward, and ask the athlete to say them back in reverse; ie, “if I say 5-3, you say 3-5” continuing with a longer series until the athlete fails twice) and asking them to quickly give the months in reverse order are examples of cognitive tests that are easy to perform on the sideline. These tests are part of the SCAT2, an abbreviated sideline test that includes a few cognitive tests.
Neuropsychological (NP) tests provide a reliable assessment and quantification of brain functioning by examining brain-behavior relationships. These include reaction time, attention, concentration, short-term and delayed memory, new learning, and problem solving. NP test batteries, either traditional paper/pencil tests, shorter abbreviated computerized batteries (eg, Headminder, CogSport, ImPACT) and/or a hybrid model have all been used in sport-related concussion. These tests are not appropriate for the sideline, but are useful in the postinjury setting when a more comprehensive evaluation can be considered. These tests are typically performed at least 24 to 48 hours after injury, when the athlete is symptom free, and when compared with preseason baseline tests, provide useful information to the team physician. There is typically no benefit to performing NP testing when the athlete is symptomatic, as the athlete should not RTP before being asymptomatic. However, for the very young athlete, or the athlete with prolonged symptomatology, NP testing before the resolution of symptoms may be considered. There is certainly value added by using NP testing. Often symptoms resolve completely before the resolution of cognitive deficits as measured by NP testing. However, it is essential that health care providers understand the limitations of the use of NP testing.

In 1 study evaluating the test-retest reliability of the available computerized NP batteries, individuals were found to test in the impaired range 20% to 40% of the time when the tests were performed and compared with their baseline test, even though they were not concussed. There are many test limitations and factors that affect NP testing, such as fatigue. In addition, there are subtleties that may be difficult to discern, underscoring the use of these tests as 1 component of the complete evaluation. Ideally, NP tests should be interpreted by a neuropsychologist. It is also important to remember that NP testing is just one tool in the toolbox; a multipronged approach to evaluation that includes symptoms, physical and cognitive examination, and balance testing is ideal.

POSTURAL STABILITY TESTING

Postural balance testing is a component of the physical examination that is important to include at baseline and during postinjury evaluations. Balance testing is sensitive to concussion and useful as 1 component of the evaluation. A variety of balance-testing options are available including the Sensory Organization Test on the NeuroCom Smart Balance Master System as well as the Balance Error Scoring System (BESS). More recently, the modified BESS was included as part of a sideline tool for concussion. Musculoskeletal instability issues affect the results of postural balance testing. These tests demonstrate learning/practice effects, again emphasizing the importance of baseline testing as well as using a variety of tools to measure injury.

SIDELINE TOOLS

Sideline tools that are useful for the athletic trainer and team physician for evaluating sports-related concussion include the Standardized Assessment of Concussion (SAC), the SCAT, and the SCAT 2. These tools remain an abbreviated sideline battery and are not designed to take the place of more comprehensive evaluation or NP testing. When using an abbreviated test, it is possible that an athlete with concussion will be able to perform well enough to be considered normal, despite having significant deficits on more rigorous testing. This has been demonstrated with the SAC. Although useful in differentiating concussed compared with nonconcussed athletes at the time of injury, the SAC no longer was able to differentiate these 2 groups when repeated a day later. In addition, concussed athletes scored 29% better on the SAC.
at the time of their injury compared with their baseline evaluation. This demonstrates that though the SAC and other tools may be useful in making the diagnosis of concussion, there is a practice effect (athletes can be expected to perform better on a test if they have taken it before) and a low ceiling (the score at which one is considered normal is easy to reach) for some of these tests that should be considered. The sensitivity and specificity of these tests may be limited. The SCAT was developed during the 2nd International Consensus Conference on Concussion and combined several other symptom scores, measures, and assessments, including the SAC, into 1 tool. The SCAT was further refined during the 3rd International Consensus Conference on Concussion in Sport and called the SCAT 2. Neither the SCAT nor the SCAT 2 have been validated, yet remain, for many, a sophisticated sideline tool.

DISPOSITION

Once an athlete has been diagnosed with concussion, they should be removed from play and evaluated by the appropriate health care provider. If an appropriate health care provider is not available immediately, the athlete should not be returned to play. Appropriate referral to a health care provider should be made. The immediacy of this referral depends on the situation and should be individualized. If an appropriate health care provider is available, then the appropriate disposition should be made. If the diagnosis is concussion, then the decision rests on whether the athlete is stable and can be observed, or whether the athlete needs emergency evacuation and evaluation. Situations in which an athlete should be sent for emergency evaluation include deteriorating mental status or worsening symptoms. Particular symptoms that raise concern include worsening headache, nausea or vomiting, or increased lethargy. In addition, for the athlete presenting with significant focal deficits or any deficits on physical examination, emergent transportation to a facility that can handle neurosurgical emergencies is essential.

TAKE-HOME INFORMATION

Most sport-related concussion injuries are mild injuries that do not necessitate emergency evacuation or treatment. It is important that all athletes are removed from play and evaluated in a complete and thorough manner. Athletes should be observed for the first few hours after their injury and should not be left alone in this timeframe. They should be monitored to ensure that no deterioration occurs. It is imperative that athletes are given take-home instructions regarding concussion; the symptoms and signs that should prompt referral to an emergency room, the importance of reporting symptoms as well as avoiding both physical and cognitive work in the immediate postinjury hours. They should be told to avoid alcohol and aspirin and other medications or drugs that may affect their brain, and to avoid video games, schoolwork, as well as the computer as these may aggravate their symptoms. Athletes need to understand the significance of concussive injury both in the short- and long-term as well as the importance of being honest regarding symptoms. A plan for follow-up evaluation should be made with the athlete.

FOLLOW-UP

When the athlete is seen in follow-up, it is important to review their symptoms (using a symptom checklist) and what other difficulties, if any, they have had. This is an opportunity to again review the important features of concussion as well as the importance of both physical and cognitive rest. For athletes who are in school, special
accommodations may be necessary such as extended time for tests, avoiding the computer, having someone take notes for them, and/or time away from school. Necessary accommodations are individualized and often difficult to predict.

RTP

The RTP decision is one of the most challenging decisions facing the team physician and is made more difficult given the individual nature of this injury. It is essential that the team physician takes into account the previous history of injury as well as the other modifiers for that individual in making the RTP decision. It is also important to take into account the other variables that play a role in making the RTP decision. In the past several years there has been a dramatic change in how clinicians approach the RTP decision. There has been a more conservative approach to RTP. In December 2009, the National Football League provided revised RTP guidelines that mandated that athletes diagnosed with concussion remain out of play for the remainder of the day. These modified RTP guidelines set an example that other sport organizations should consider. Whether independently arrived at or not, the National Collegiate Athletics Association (NCAA) and the National Federation of State High School Associations have subsequently put into practice modifications that will change RTP decisions for athletes with concussion. These include being removed from play once any signs or symptoms of concussion are present, as well as the need for immediate evaluation by a health care provider trained in concussion management. Both the NCAA and NHFS state that athletes diagnosed with concussion cannot RTP the same day, and require evaluation by a physician or their designee before return to play. These more stringent RTP policies are designed to protect the health and safety of participants in sport.

It is essential that the athlete is asymptomatic both at rest and with exertion, before initiating an RTP progression. The first step in an RTP progression is to initiate cardiovascular demand without the risk for contact. This is often a trial of cardiovascular activity, lasting 15 to 20 minutes, during which the athlete increases their heart rate and work load without increasing the risk for contact. The athlete should break a sweat and an increase in their heart rate should be recognized. If the athlete is able to tolerate this load, then the intent would be to gradually increase the load as well as the risk for contact gradually. This RTP process (Table 2) was outlined in the 1st International Agreement Statement and is endorsed by several other more recent publications.

The RTP process is a complex one that requires an individual approach. An injury in an athlete without any significant modifiers may take only a few days to start the RTP progression, whereas for the same injury in an athlete with several modifiers the team physician might decide that a longer symptom-free interval is necessary. In addition, for the athlete who recently sustained a concussion, it may be important to take a slower approach to progressing activity, whereby instead of a day for each stage, a longer period of time is taken for each stage. This decision is an individualized one that should factor in the specific modifiers that each athlete has.

The sideline evaluation of the concussed athlete represents one of the most difficult evaluations facing the team physician. Having an EAP that includes a concussion protocol for high-risk sports is useful in practicing the approach to this injury, although realizing that several individual factors/modifiers will need to be considered. Using a standardized sideline tool for evaluation of injury and the preseason evaluation against which to compare is useful for the clinician on the sideline. This should include a symptom checklist, a directed physical examination, a cognitive evaluation, and balance testing. The decision to remove an athlete from play when suspected signs or
symptoms of concussion are present is important. Given the long-term consequences of unreported and/or recurrent injury, it is imperative that a conservative approach is used. It is important to evaluate for and exclude more emergent medical issues such as intracranial bleed, skull fracture, and/or cervical spine injury. It is important that appropriate disposition and follow-up is discussed with the athlete including specific take-home instructions. Further management may include more comprehensive neuropsychological and balance testing, and basic principles regarding an RTP progression should be considered. It is the optimistic view of this author that if these basic principles are followed, participating in sport, no matter the activity or risk for concussive injury, remains a safe activity. Although the risk for concussion exists in sport, the assertion is that if treated promptly and appropriately, significant long-term risks are avoided and the overall the benefits of participation far outweigh the risks of participation.

REFERENCES


<table>
<thead>
<tr>
<th>Rehabilitation Stage</th>
<th>Functional Exercise at Each Stage of Rehabilitation</th>
<th>Objective of Each Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No activity</td>
<td>Complete physical and cognitive rest</td>
<td>Recovery</td>
</tr>
<tr>
<td>2. Light aerobic exercise</td>
<td>Walking, swimming, or stationary cycling keeping intensity &lt;70% maximum predicted heart rate \No resistance training</td>
<td>Increase heat rate</td>
</tr>
<tr>
<td>3. Sport-specific exercise</td>
<td>Skating drills in ice hockey, running drills in soccer. \No head impact activities</td>
<td>Add movement</td>
</tr>
<tr>
<td>4. Noncontact training drills</td>
<td>Progression to more complex training drills, eg passing drills in football and ice hockey \May start progressive resistance training</td>
<td>Exercise, coordination, and cognitive load</td>
</tr>
<tr>
<td>5. Full contact practice</td>
<td>After medical clearance, participate in normal trailing activities</td>
<td>Restore confidence and assess functional skills by coaching staff</td>
</tr>
<tr>
<td>6. Return to play</td>
<td>Normal game play</td>
<td></td>
</tr>
</tbody>
</table>