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National Athletic Trainers' Association Position Statement: Management of Sport-Related Concussion

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Sport in today's society is more popular than probably ever imagined. Large numbers of athletes participate in a variety of youth, high school, collegiate, professional, and recreational sports. As sport becomes more of a fixture in the lives of Americans, a burden of responsibility falls on the shoulders of the various organizations, coaches, parents, clinicians, officials, and researchers to provide an environment that minimizes the risk of injury in all sports. For example, the research-based recommendations made for football between 1976 and 1980 resulted in a significant reduction in the incidence of fatalities and nonfatal catastrophic injuries. In 1968, 36 brain and cervical spine fatalities occurred in high school and collegiate football. The number had dropped to zero in 1990 and has averaged about 5 per year since then.[1] This decrease was attributed to a variety of factors, including (1) rule changes, which have outlawed spearing and butt blocking, (2) player education about the rule changes and the consequences of not following the rules, (3) implementation of equipment standards, (4) availability of alternative assessment techniques, (5) a marked reduction in physical contact time during practice sessions, (6) a heightened awareness among clinicians of the dangers involved in returning an athlete to competition too early, and (7) the athlete's awareness of the risks associated with concussion.

Research in the area of sport-related concussion has provided the athletic training and medical professions with valuable new knowledge in recent years. Certified athletic trainers, who on average care for 7 concussive injuries per year,[2] have been forced to rethink how they manage sport-related concussion. Recurrent concussions to several high-profile athletes, some of whom were forced into retirement as a result, have increased awareness among sports medicine personnel and the general public. Bridging the gap between research and clinical practice is the key to reducing the incidence and severity of sport-related concussion and improving return-to-play decisions. This position statement should provide valuable information and recommendations for certified athletic trainers (ATCs), physicians, and other medical professionals caring for athletes at the youth, high school, collegiate, and elite levels. The following recommendations are derived from the most recent scientific and clinic-based literature on sport-related concussion. The justification for these recommendations is presented in the summary statement following the recommendations. The summary statement is organized into the following sections: ''Defining and Recognizing Concussion,'' ''Evaluating and Making the Return-to-Play Decision,'' ''Concussion Assessment Tools,'' ''When to Refer an Athlete to a Physician After Concussion,'' ''When to Disqualify an Athlete,'' ''Special Considerations for the Young Athlete,'' ''Home Care,'' and ''Equipment Issues.''

RECOMMENDATIONS

Defining and Recognizing Concussion

1. The ATC should develop a high sensitivity for the various mechanisms and presentations of traumatic brain injury (TBI), including mild, moderate, and severe cerebral concussion, as well as the more severe, but less common, head injuries that can cause damage to the brain stem and other vital centers of the brain.
2. The colloquial term ''ding'' should not be used to describe a sport-related concussion. This stunned confusional state is a concussion most often reflected by the athlete's initial confusion, which may disappear within minutes, leaving

no outwardly observable signs and symptoms. Use of the term ''ding'' generally carries a connotation that diminishes the seriousness of the injury. If an athlete shows concussion-like signs and reports symptoms after a contact to the head, the athlete has, *at the very least,* sustained a mild concussion and should be treated for a concussion.

3. To detect deteriorating signs and symptoms that may indicate a more serious head injury, the ATC should be able to recognize both the obvious signs (eg, fluctuating levels of consciousness, balance problems, and memory and concentration difficulties) and the more common, self-reported symptoms (eg, headache, ringing in the ears, and nausea).
4. The ATC should play an active role in educating athletes, coaches, and parents about the signs and symptoms associated with concussion, as well as the potential risks of playing while still symptomatic.
5. The ATC should document all pertinent information surrounding the concussive injury, including but not limited to (1) mechanism of injury; (2) initial signs and symptoms; (3) state of consciousness; (4) findings on serial testing of symptoms and neuropsychological function and postural-stability tests (noting any deficits compared with baseline); (5) instructions given to the athlete and/or parent; (6) recommendations provided by the physician; (7) date and time of the athlete's return to participation; and (8) relevant information on the player's history of prior concussion and associated recovery pattern(s).[3]

Evaluating and Making the Return-to-Play Decision

6. Working together, ATCs and team physicians should agree on a philosophy for managing sport-related concussion before the start of the athletic season. Currently 3 approaches are commonly used: (1) grading the concussion at the time of the injury, (2) deferring final grading until all symptoms have resolved, or (3) not using a grading scale but rather focusing attention on the athlete's recovery via symptoms, neurocognitive testing, and postural-stability testing. After deciding on an approach, the ATC-physician team should be consistent in its use regardless of the athlete, sport, or circumstances surrounding the injury.
7. For athletes playing sports with a high risk of concussion, baseline cognitive and postural-stability testing should be considered. In addition to the concussion injury assessment, the evaluation should also include an assessment of the cervical spine and cranial nerves to identify any cervical spine or vascular intracerebral injuries.
8. The ATC should record the time of the initial injury and document serial assessments of the injured athlete, noting the presence or absence of signs and symptoms of injury. The ATC should monitor vital signs and level of consciousness every 5 minutes after a concussion until the athlete's condition improves. The athlete should also be monitored over the next few days after the injury for the presence of delayed signs and symptoms and to assess recovery.
9. Concussion severity should be determined by paying close attention to the severity and persistence of *all* signs and symptoms, including the presence of amnesia (retrograde and anterograde) and loss of consciousness (LOC), as well as headache, concentration problems, dizziness, blurred vision, and so on. It is recommended that ATCs and physicians consistently use a symptom checklist similar to the one provided in Appendix A.
10. In addition to a thorough clinical evaluation, formal cognitive and postural-stability testing is recommended to assist in objectively determining injury severity and readiness to return to play (RTP). No one test should be used solely to determine recovery or RTP, as concussion presents in many different ways.
11. Once symptom free, the athlete should be reassessed to establish that cognition and postural stability have returned to normal for that player, preferably by comparison with preinjury baseline test results. The RTP decision should be made after an incremental increase in activity with an initial cardiovascular challenge, followed by sport-specific activities that do not place the athlete at risk for concussion. The athlete can be released to full participation as long as no recurrent signs or symptoms are present.

Concussion Assessment Tools

12. Baseline testing on concussion assessment measures is recommended to establish the individual athlete's ''normal'' preinjury performance and to provide the most reliable benchmark against which to measure postinjury recovery. Baseline testing also controls for extraneous variables (eg, attention deficit disorder, learning disabilities, age, and education) and for the effects of earlier concussion while also evaluating the possible cumulative effects of recurrent concussions.
13. The use of objective concussion assessment tools will help ATCs more accurately identify deficits caused by injury and postinjury recovery and protect players from the potential risks associated with prematurely returning to competition and sustaining a repeat concussion. The concussion assessment battery should include a combination of tests for cognition, postural stability, and self-reported symptoms known to be affected by concussion.
14. A combination of brief screening tools appropriate for use on the sideline (eg, Standardized Assessment of Concussion [SAC], Balance Error Scoring System [BESS], symptom checklist) and more extensive measures (eg, neuropsychological testing, computerized balance testing) to more precisely evaluate recovery later after injury is recommended.
15. Before instituting a concussion neuropsychological testing battery, the ATC should understand the test's user requirements, copyright restrictions, and standardized instructions for administration and scoring. All evaluators should be appropriately trained in the standardized instructions for test administration and scoring before embarking on testing or adopting an instrument for clinical use. Ideally, the sports medicine team should include a neuropsychologist, but in reality, many ATCs may not have access to a neuropsychologist for interpretation and consultation, nor the financial resources to support a neuropsychological testing program. In this case, it is recommended that the ATC use screening instruments (eg, SAC, BESS, symptom checklist) that have been developed specifically for use by sports medicine clinicians without extensive

training in psychometric or standardized testing and that do not require a special license to administer or interpret.

16. Athletic trainers should adopt for clinical use only those neuropsychological and postural stability measures with population-specific normative data, test-retest reliability, clinical validity, and sufficient sensitivity and specificity established in the peer-reviewed literature. These standards provide the basis for how well the test can distinguish between those with and without cerebral dysfunction in order to reduce the possibility of false-positive and false-negative errors, which could lead to clinical decision-making errors.
17. As is the case with all clinical instruments, results from assessment measures to evaluate concussion should be integrated with all aspects of the injury evaluation (eg, physical examination, neurologic evaluation, neuroimaging, and player's history) for the most effective approach to injury management and RTP decision making. Decisions about an athlete's RTP should never be based solely on the use of any one test.

When to Refer an Athlete to a Physician After Concussion

18. The ATC or team physician should monitor an athlete with a concussion at 5-minute intervals from the time of the injury until the athlete's condition completely clears or the athlete is referred for further care. Coaches should be informed that in situations when a concussion is suspected but an ATC or physician is not available, their primary role is to ensure that the athlete is immediately seen by an ATC or physician.
19. An athlete with a concussion should be referred to a physician on the day of injury if he or she lost consciousness, experienced amnesia lasting longer than 15 minutes, or meets any of the criteria outlined in Appendix B.
20. A team approach to the assessment of concussion should be taken and include a variety of medical specialists. In addition to family practice or general medicine physician referrals, the ATC should secure other specialist referral sources within the community. For example, neurologists are trained to assist in the management of patients experiencing persistent signs and symptoms, including sleep disturbances. Similarly, a neuropsychologist should be identified as part of the sports medicine team for assisting athletes who require more extensive neuropsychological testing and for interpreting the results of neuropsychological tests.
21. A team approach should be used in making RTP decisions after concussion. This approach should involve input from the ATC, physician, athlete, and any referral sources. The assessment of all information, including the physical examination, imaging studies, objective tests, and exertional tests, should be considered prior to making an RTP decision.

When to Disqualify an Athlete

22. Athletes who are symptomatic at rest and after exertion for at least 20 minutes should be disqualified from returning to participation on the day of the injury. Exertional exercises should include sideline jogging followed by sprinting, sit-ups, push-ups, and any sport-specific, noncontact activities (or positions or stances) the athlete might need to perform on returning to participation. Athletes who return on the same day because symptoms resolved quickly ($<$20 minutes) should be monitored closely after they return to play. They should be repeatedly reevaluated on the sideline after the practice or game and again at 24 and 48 hours postinjury to identify any delayed onset of symptoms.
23. Athletes who experience LOC or amnesia should be disqualified from participating on the day of the injury.
24. The decision to disqualify from further participation on the day of a concussion should be based on a comprehensive physical examination; assessment of self-reported postconcussion signs and symptoms; functional impairments, and the athlete's past history of concussions. If assessment tools such as the SAC, BESS, neuropsychological test battery, and symptom checklist are not used, a 7-day symptom-free waiting period before returning to participation is recommended. Some circumstances, however, will warrant even more conservative treatment (see recommendation 25).
25. Athletic trainers should be more conservative with athletes who have a history of concussion. Athletes with a history of concussion are at increased risk for sustaining subsequent injuries as well as for slowed recovery of self-reported postconcussion signs and symptoms, cognitive dysfunction, and postural instability after subsequent injuries. In athletes with a history of 3 or more concussions and experiencing slowed recovery, temporary or permanent disqualification from contact sports may be indicated.

Special Considerations for the Young Athlete

26. Athletic trainers working with younger (pediatric) athletes should be aware that recovery may take longer than in older athletes. Additionally, these younger athletes are maturing at a relatively fast rate and will likely require more frequent updates of baseline measures compared with older athletes.
27. Many young athletes experience sport-related concussion. Athletic trainers should play an active role in helping to educate young athletes, their parents, and coaches about the dangers of repeated concussions. Continued research into the epidemiology of sport-related concussion in young athletes and prospective investigations to determine the acute and long-term effects of recurrent concussions in younger athletes are warranted.
28. Because damage to the maturing brain of a young athlete can be catastrophic (ie, almost all reported cases of second-impact syndrome are in young athletes), athletes under age 18 years should be managed more conservatively, using stricter RTP guidelines than those used to manage concussion in the more mature athlete.

Home Care

29. An athlete with a concussion should be instructed to avoid taking medications except acetaminophen after the injury. Acetaminophen and other medications should be given

only at the recommendation of a physician. Additionally, the athlete should be instructed to avoid ingesting alcohol, illicit drugs, or other substances that might interfere with cognitive function and neurologic recovery.

30. Any athlete with a concussion should be instructed to rest, but complete bed rest is not recommended. The athlete should resume normal activities of daily living as tolerated while avoiding activities that potentially increase symptoms. Once he or she is symptom free, the athlete may resume a graded program of physical and mental exertion, without contact or risk of concussion, up to the point at which postconcussion signs and symptoms recur. If symptoms appear, the exertion level should be scaled back to allow maximal activity without triggering symptoms.
31. An athlete with a concussion should be instructed to eat a well-balanced diet that is nutritious in both quality and quantity.
32. An athlete should be awakened during the night to check on deteriorating signs and symptoms only if he or she experienced LOC, had prolonged periods of amnesia, or was still experiencing significant symptoms at bedtime. The purpose of the wake-ups is to check for deteriorating signs and symptoms, such as decreased levels of consciousness or increasing headache, which could indicate a more serious head injury or a late-onset complication, such as an intracranial bleed.
33. Oral and written instructions for home care should be given to the athlete and to a responsible adult (eg, parent or roommate) who will observe and supervise the athlete during the acute phase of the concussion while at home or in the dormitory. The ATC and physician should agree on a standard concussion home-instruction form similar to the one presented in Appendix C, and it should be used consistently for all concussions.

Equipment Issues

34. The ATC should enforce the standard use of helmets for protecting against catastrophic head injuries and reducing the severity of cerebral concussions. In sports that require helmet protection (football, lacrosse, ice hockey, baseball/softball, etc), the ATC should ensure that all equipment meets either the National Operating Committee on Standards for Athletic Equipment (NOCSAE) or American Society for Testing and Materials (ASTM) standards.
35. The ATC should enforce the standard use of mouth guards for protection against dental injuries; however, there is no scientific evidence supporting their use for reducing concussive injury.
36. At this time, the ATC should neither endorse nor discourage the use of soccer headgear for protecting against concussion or the consequences of cumulative, subconcussive impacts to the head. Currently no scientific evidence supports the use of headgear in soccer for reducing concussive injury to the head.

DEFINING AND RECOGNIZING CONCUSSION

Perhaps the most challenging aspect of managing sport-related concussion is recognizing the injury, especially in athletes with no obvious signs that a concussion has actually occurred. The immediate management of the head-injured athlete depends on the nature and severity of the injury. Several terms are used to describe this injury, the most global being TBI, which can be classified into 2 types: focal and diffuse. Focal or posttraumatic intracranial mass lesions include subdural hematomas, epidural hematomas, cerebral contusions, and intracerebral hemorrhages and hematomas. These are considered uncommon in sport but are serious injuries; the ATC must be able to detect signs of clinical deterioration or worsening symptoms during serial assessments. Signs and symptoms of these focal vascular emergencies can include LOC, cranial nerve deficits, mental status deterioration, and worsening symptoms. Concern for a significant focal injury should also be raised if these signs or symptoms occur after an initial lucid period in which the athlete seemed normal.

Diffuse brain injuries can result in widespread or global disruption of neurologic function and are not usually associated with macroscopically visible brain lesions except in the most severe cases. Most diffuse injuries involve an acceleration-deceleration motion, either within a linear plane or in a rotational direction or both. In these cases, lesions are caused by the brain being shaken within the skull.[4,5] The brain is suspended within the skull in cerebrospinal fluid (CSF) and has several dural attachments to bony ridges that make up the inner contours of the skull. With a linear acceleration-deceleration mechanism (side to side or front to back), the brain experiences a sudden momentum change that can result in tissue damage. The key elements of injury mechanism are the velocity of the head before impact, the time over which the force is applied, and the magnitude of the force.[4,5] Rotational acceleration-deceleration injuries are believed to be the primary injury mechanism for the most severe diffuse brain injuries. Structural diffuse brain injury (diffuse axonal injury [DAI]) is the most severe type of diffuse injury because axonal disruption occurs, typically resulting in disturbance of cognitive functions, such as concentration and memory. In its most severe form, DAI can disrupt the brain-stem centers responsible for breathing, heart rate, and wakefulness.[4,5]

Cerebral concussion, which is the focus of this position statement, can best be classified as a mild diffuse injury and is often referred to as mild TBI (MTBI). The injury involves an acceleration-deceleration mechanism in which a blow to the head or the head striking an object results in 1 or more of the following conditions: headache, nausea, vomiting, dizziness, balance problems, feeling "slowed down," fatigue, trouble sleeping, drowsiness, sensitivity to light or noise, LOC, blurred vision, difficulty remembering, or difficulty concentrating.[6] In 1966, the Congress of Neurological Surgeons proposed the following consensus definition of concussion, subsequently endorsed by a variety of medical associations: "Concussion is a clinical syndrome characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision, equilibrium, etc, due to mechanical forces."[7] Although the definition received widespread consensus in 1966, more contemporary opinion (as concluded at the First International Conference on Concussion in Sport, Vienna, 2001[8]) was that this definition fails to include many of the predominant clinical features of concussion, such as headache and nausea. It is often reported that there is no universal agreement on the standard definition or nature of concussion; however, agreement does exist on several features that incorporate clinical, pathologic, and biomechanical injury constructs associated with head injury:

1. Concussion may be caused by a direct blow to the head or elsewhere on the body from an ''impulsive'' force transmitted to the head.
2. Concussion may cause an immediate and short-lived impairment of neurologic function.
3. Concussion may cause neuropathologic changes; however, the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
4. Concussion may cause a gradient of clinical syndromes that may or may not involve LOC. Resolution of the clinical and cognitive symptoms typically follows a sequential course.
5. Concussion is most often associated with normal results on conventional neuroimaging studies.[8]

Occasionally, players sustain a blow to the head resulting in a stunned confusional state that resolves within minutes. The colloquial term ''ding'' is often used to describe this initial state. However, the use of this term is not recommended because this stunned confusional state is still considered a concussion resulting in symptoms, although only very short in duration, that should not be dismissed in a cavalier fashion. It is essential that this injury be reevaluated frequently to determine if a more serious injury has occurred, because often the evolving signs and symptoms of a concussion are not evident until several minutes to hours later.

Although it is important for the ATC to recognize and eventually classify the concussive injury, it is equally important for the athlete to understand the signs and symptoms of a concussion as well as the potential negative consequences (eg, second-impact syndrome and predisposition to future concussions) of not reporting a concussive injury. Once the athlete has a better understanding of the injury, he or she can provide a more accurate report of the concussion history.

Mechanisms of Injury

A forceful blow to the resting, movable head usually produces maximum brain injury beneath the point of cranial impact (coup injury). A moving head hitting an unyielding object usually produces maximum brain injury opposite the site of cranial impact (contrecoup injury) as the brain shifts within the cranium. When the head is accelerated before impact, the brain lags toward the trailing surface, thus squeezing away the CSF and creating maximal shearing forces at this site. This brain lag actually thickens the layer of CSF under the point of impact, which explains the lack of coup injury in the moving head. Alternatively, when the head is stationary before impact, neither brain lag nor disproportionate distribution of CSF occurs, accounting for the absence of contrecoup injury and the presence of coup injury.[4,5]

No scientific evidence suggests that one type of injury (coup or contrecoup) is more serious than the other or that symptoms present any differently. Many sport-related concussions are the result of a combined coup-contrecoup mechanism, involving damage to the brain on both the side of initial impact and the opposite side of the brain due to brain lag. Regardless of whether the athlete has sustained a coup, contrecoup, or combined coup-contrecoup injury, the ATC should manage the injury the same.

Three types of stresses can be generated by an applied force to injure the brain: compressive, tensile, and shearing. Compression involves a crushing force in which the tissue cannot absorb any additional force or load. Tension involves pulling or stretching of tissue, whereas shearing involves a force that moves across the parallel organization of the tissue. Brief, uniform compressive stresses are fairly well tolerated by neural tissue, but tension and shearing stresses are very poorly tolerated.[4,9]

Neuroimaging of Cerebral Concussion

Traditionally, computed tomography (CT) and magnetic resonance imaging (MRI) have been considered useful in identifying certain types of brain lesions; however, they have been of little value in assessing less severe head injuries, such as cerebral concussion, and contributing to the RTP decision. A CT scan is often indicated emergently if a focal injury such as an acute subdural or epidural bleed is suspected; this study easily demonstrates acute blood collection and skull fracture, but an MRI is superior at demonstrating an isodense subacute or chronic subdural hematoma that may be weeks old.[10,11] Newer structural MRI modalities, including gradient echo, perfusion, and diffusion-weighted imaging, are more sensitive for structural abnormalities (eg, vascular shearing) compared with other diagnostic imaging techniques.[10] Functional imaging technologies (eg, positron emission tomography [PET], single-photon emission computerized tomography [SPECT], and functional MRI [fMRI]) are also yielding promising early results and may help define concussion recovery.[12] Presently, no neuroanatomic or physiologic measurements can be used to determine the severity of a concussion or when complete recovery has occurred in an individual athlete after a concussion.

EVALUATING AND MAKING THE RETURN-TO-PLAY DECISION

Clinical Evaluation

Results from a thorough clinical examination conducted by both the ATC and the physician cannot be overlooked and should be considered very important pieces of the concussion puzzle. These evaluations should include a thorough *history* (including number and severity of previous head injuries), *observation* (including pupil responses), *palpation*, and *special tests* (including simple tests of memory, concentration, and coordination and a cranial nerve assessment). In many situations, a physician will not be present at the time of the concussion, and the ATC will be forced to act on behalf of the sports medicine team. More formal neuropsychological testing and postural-stability testing should be viewed as adjuncts to the initial clinical and repeat evaluations (see ''Concussion Assessment Tools''). The ATC-physician team must also consider referral options to specialists such as neurologists, neurosurgeons, neuropsychologists, and neuro-otologists, depending on the injury severity and situation. Referrals for imaging tests such as CT, MRI, or electronystagmography are also options that sometimes can aid in the diagnosis and/or management of sport-related concussion but are typically used only in cases involving LOC, severe amnesia, abnormal physical or neurologic findings, or increasing or intensified symptoms.

Determining Injury Severity

The definition of concussion is often expanded to include mild, moderate, and severe injuries. Several early grading scales and RTP guidelines early were proposed for classifying and managing cerebral concussions.[6,13–20] None of the scales have been universally accepted or followed with much consistency by the sports medicine community. In addition, most of these classification systems denote the most severe injuries as associated with LOC, which we now know is not always predictive of recovery after a brain injury.[21,22] It is important for the ATC and other health care providers to recognize the importance of identifying retrograde amnesia and anterograde amnesia, LOC, and other signs and symptoms present and to manage each episode independently.

The ATC must recognize that no 2 concussions are identical and that the resulting symptoms can be very different, depending on the force of the blow to the head, the degree of metabolic dysfunction, the tissue damage and duration of time needed to recover, the number of previous concussions, and the time between injuries. All these factors must be considered when managing an athlete suffering from cerebral concussion.[3] The 2 most recognizable signs of a concussion are LOC and amnesia; yet, as previously mentioned, neither is required for an injury to be classified as a concussion. A 2000 study of 1003 concussions sustained by high school and collegiate football players revealed that LOC and amnesia presented infrequently, 9% and 27% of all cases, respectively, whereas other signs and symptoms, such as headache, dizziness, confusion, disorientation, and blurred vision, were much more common.[23] After the initial concussion evaluation, the ATC should determine whether the athlete requires more advanced medical intervention on an emergent basis or whether the team physician should be contacted for an RTP decision (Appendix B). It may be helpful if the injury is graded throughout the process, but this grading is likely to be more important for treating subsequent injuries than the current injury.

Most grading systems rely heavily on LOC and amnesia as indicators of injury severity. Recent research, however, suggests that these 2 factors, either alone or in combination, are not good predictors of injury severity. A number of authors have documented no association between brief (<1 minute) LOC and abnormalities on neuropsychological testing at 48 hours, raising concern for brief LOC as a predictor of recovery after concussion.[8,22,24–27] Studies involving high school and collegiate athletes with concussion revealed no association between (1) LOC and duration of symptoms or (2) LOC and neuropsychological and balance tests at 3, 24, 48, 72, and 96 hours postinjury.[21,28,29] In other words, athletes experiencing LOC were similar to athletes without LOC on these same injury-severity markers.

With respect to amnesia, the issue is more clouded because findings have been inconsistent. Several studies of nonathletes[30–37] suggest that the duration of posttraumatic amnesia correlates with the severity and outcome of severe TBI but not with mild TBI or concussion.[38–40] More contemporary studies of athletes with concussion are also clouded. Two unrelated, prospective studies of concussion suggest that the presence of amnesia best correlates with abnormal neuropsychological testing at 48 hours and with the duration and number of other postconcussion signs and symptoms.[24,41] However, more recently, investigations of high school and collegiate athletes with concussion revealed no association between (1) amnesia and duration of symptoms or (2) amnesia and neuropsychological and balance tests at 3, 24, 48, 72, and 96 hours postinjury.[21,28,29] Of importance in these studies is the significant association between symptom-severity score (within the initial 3 hours postinjury) and the total duration of symptoms (measured until asymptomatic). Although these findings suggest that initial symptom severity is probably a better indicator than either LOC or amnesia in predicting length of recovery, amnesia was recently found to predict symptom and neurocognitive deficits at 2 days postinjury.[42] More research is needed in this area to help improve clinical decision making.

Table 1. American Academy of Neurology Concussion Grading Scale[6]

Grade 1 (mild)	Transient confusion; no LOC*; symptoms and mental status abnormalities resolve <15 min
Grade 2 (moderate)	Transient confusion; no LOC; symptoms and mental status abnormalities last >15 min
Grade 3 (severe)	Any LOC

*LOC indicates loss of consciousness.

It has been suggested that LOC and amnesia, especially when prolonged, should not be ignored,[43,44] but evidence for their usefulness in establishing RTP guidelines is scarce. Loss of consciousness, whether it occurs immediately or after an initially lucid interval, is important in that it may signify a more serious vascular brain injury. Other postconcussion signs and symptoms should be specifically addressed for presence and duration when the ATC is evaluating the athlete. Determining whether a cervical spine injury has occurred is also of major importance because it is often associated with head injury and should not be missed. If the athlete complains of neck pain or has cervical spine tenderness, cervical spine immobilization should be considered. If a cervical spine injury is ruled out and the athlete is taken to the sideline, a thorough clinical examination should follow, including a complete neurologic examination and cognitive evaluation. The ATC must note the time of the injury and then maintain a timed assessment form to follow the athlete's symptoms and examinations serially. It is often difficult to pay attention to the time that has passed after an injury. Therefore, it is important for one member of the medical team to track time during the evaluation process and record all pertinent information. After an initial evaluation, the clinician must determine whether the injured athlete requires more advanced medical intervention and eventually grade the injury and make an RTP decision that can occur within minutes, hours, days, or weeks of the injury.

There are currently 3 approaches to grading sport-related concussion. One approach is to grade the concussion at the time of the injury on the basis of the signs and symptoms present at the time of the concussion and within the first 15 minutes after injury. The American Academy of Neurology Concussion Grading Scale (Table 1)[6] has been widely used with this approach. It permits the ATC to grade the injury primarily on the basis of LOC and to provide the athlete, coach, and parent with an estimation of injury severity. A disadvantage to this approach is that many injuries behave differently than expected on initial evaluation, potentially creating more difficulties with the athlete, coach, or parent and making the RTP decision more challenging. Another approach is to grade the concussion on the basis of the presence and overall duration of symptoms. This approach is best addressed using the Cantu Evidence-Based Grading Scale (Table 2),[43] which guides the ATC to grade the injury only after all concussion signs and symptoms have resolved. This scale places less emphasis on LOC as a potential predictor of subsequent impairment and additional weight on overall symptom dura-

Table 2. Cantu Evidence-Based Grading System for Concussion[43]

Grade 1 (mild)	No LOC*, PTA† <30 min, PCSS‡ <24 h
Grade 2 (moderate)	LOC <1 min **or** PTA ≥30 min <24 h **or** PCSS ≥24 h <7 d
Grade 3 (severe)	LOC ≥1 min **or** PTA ≥24 h **or** PCSS ≥7 d

*LOC indicates loss of consciousness.
†PTA indicates posttraumatic amnesia (anterograde/retrograde).
‡PCSS indicates postconcussion signs and symptoms other than amnesia.

tion.[3,43] Finally, a third approach to the grading-scale dilemma is to not use a grading scale but rather focus attention on the athlete's recovery via symptoms, neuropsychological tests, and postural-stability tests. This line of thinking is that the ATC should not place too much emphasis on the grading system or grade but should instead focus on whether the athlete is symptomatic or symptom free. Once the athlete is asymptomatic, a stepwise progression should be implemented that increases demands over several days. This progression will be different for athletes who are withheld for several weeks compared with those athletes withheld for just a few days. This multitiered approach was summarized and supported by consensus at the 2001 Vienna Conference on Concussion in Sport.[8]

Making the Return-to-Play Decision

The question raised most often regarding the concussion grading and RTP systems is one of practicality in the sport setting. Many clinicians believe that the RTP guidelines are too conservative and, therefore, choose to base decisions on clinical judgment of individual cases rather than on a general recommendation. It has been reported that 30% of all high school and collegiate football players sustaining concussions return to competition on the same day of injury; the remaining 70% average 4 days of rest before returning to participation.[23] Many RTP guidelines call for the athlete to be symptom free for at least 7 days before returning to participation after a grade 1 or 2 concussion.[6,13,15,17,43,44] Although many clinicians deviate from these recommendations and are more liberal in making RTP decisions, recent studies by Guskiewicz and McCrea et al[21,29] suggest that perhaps the 7-day waiting period can minimize the risk of recurrent injury. On average, athletes required 7 days to fully recover after concussion. Same-season repeat injuries typically take place within a short window of time, 7 to 10 days after the first concussion,[21] supporting the concept that there may be increased neuronal vulnerability or blood-flow changes during that time, similar to those reported by Giza, Hovda, et al[45–47] in animal models.

Returning an athlete to participation should follow a progression that begins once the athlete is completely symptom free. All signs and symptoms should be evaluated using a graded symptom scale or checklist (described in ''Concussion Assessment Tools'') when performing follow-up assessments and should be evaluated both at rest and after exertional maneuvers such as biking, jogging, sit-ups, and push-ups. Baseline measurements of neuropsychological and postural stability are strongly recommended for comparing with postinjury measurements. If these exertional tests do not produce symptoms, either acutely or in delayed fashion, the athlete can then participate in sport-specific skills that allow return to practice but should remain out of any activities that put him or her at risk for recurrent head injury. For the basketball player, this may include shooting baskets or participating in walk-throughs, and for the soccer player, this may include dribbling or shooting drills or other sport-specific activities. These restricted and monitored activities should be continued for the first few days after becoming symptom free. The athlete should be monitored periodically throughout and after these sessions to determine if any symptoms develop or increase in intensity. Before returning to full contact participation, the athlete should be reassessed using neuropsychological and postural-stability tests if available. If all scores have returned to baseline or better, return to full participation can be considered after further clinical evaluation. It is strongly recommended that after recurrent injury, especially within-season repeat injuries, the athlete be withheld for an extended period of time (approximately 7 days) after symptoms have resolved.

CONCUSSION ASSESSMENT TOOLS

Sports medicine clinicians are increasingly using standardized methods to obtain a more objective measurement of postconcussion signs and symptoms, cognitive dysfunction, and postural instability. These methods allow the clinician to quantify the severity of injury and measure the player's progress over the course of postinjury recovery. An emerging model of sport concussion assessment involves the use of brief screening tools to evaluate postconcussion signs and symptoms, cognitive functioning, and postural stability on the sideline immediately after a concussion and neuropsychological testing to track recovery further out from the time of injury. Ultimately, these tests, when interpreted with the physical examination and other aspects of the injury evaluation, assist the ATC and other sports medicine professionals in the RTP decision-making process.

Data from objective measures of cognitive functioning, postural stability, and postconcussion signs and symptoms are most helpful in making a determination about severity of injury and postinjury recovery when preinjury baseline data for an individual athlete are available.[3,8,24,29,41] Baseline testing provides an indicator of what is ''normal'' for that particular athlete while also establishing the most accurate and reliable benchmark against which postinjury results can be compared. It is important to obtain a baseline symptom assessment in addition to baseline cognitive and other ability testing. Without baseline measures, the athlete's postinjury performance on neuropsychological testing and other concussion assessment measures must be interpreted by comparison with available population normative values, which ideally are based on a large sample of the representative population. Normative data for competitive athletes on conventional (ie, paper-and-pencil) and computerized neuropsychological tests and other concussion assessment measures are now more readily available from large-scale research studies, but baseline data on an individual athlete still provide the greatest clinical accuracy in interpreting postinjury test results. When performing baseline testing, a suitable testing environment eliminates all distractions that could alter the baseline performance and enhances the likelihood that all athletes are providing maximal effort. Most important, all evaluators should be aware of a test's user requirements and be appropriately trained in the standardized instructions for test administration and scoring before embarking on baseline testing or adopting a concussion testing paradigm for clinical use.

Several models exist for implementing baseline testing. Ideally, preseason baseline testing is conducted before athletes are exposed to the risk of concussion during sport participation (eg, before contact drills during football). Some programs choose to conduct baseline testing as part of the preparticipation physical examination process. In this model, stations are established for various testing methods (eg, history collection, symptom assessment, neuropsychological testing, and balance testing), and athletes complete the evaluation sequence after being seen by the attending physician or ATC. This approach has the advantage of testing large groups of athletes in 1 session, while they are already in the mindset of undergoing a preseason physical examination. When preseason examinations are not conducted in a systematic group arrangement, alternative approaches can be considered. In any case, it is helpful to conduct all modules of baseline testing on players in 1 session to limit the complications of scheduling multiple testing times and to keep testing conditions constant for the athletes. One should allow adequate planning time (eg, 3 months) to implement a baseline testing module. Often this equates to conducting baseline testing for fall sports during the spring semester, before school is recessed for the summer. The benefits of interpreting postinjury data for an athlete after a concussion far outweigh the considerable time and human resources dedicated to baseline testing.

Collecting histories on individual athletes is also a vital part of baseline testing, especially in establishing whether the athlete has any history of concussion, neurologic disorder, or other remarkable medical conditions. Specifically with respect to concussion, it is important to establish (1) whether the player has any history of concussions and, if so, how many and (2) injury characteristics of previous concussions (eg, LOC, amnesia, symptoms, recovery time, time lost from participation, and medical treatment). For athletes with a history of multiple concussions, it is also important to clarify any apparent pattern of (1) concussions occurring as a result of lighter impacts, (2) concussions occurring closer together in time, (3) a lengthier recovery time with successive concussions, and (4) a less complete recovery with each injury. Documenting a history of attentional disorders, learning disability, or other cognitive development disorders is also critical, especially in interpreting an individual player's baseline and postinjury performance on neuropsychological testing. If resources do not allow for preseason examinations in all athletes, at least a concerted effort to evaluate those athletes with a previous history of concussion should be made because of the awareness of increased risk for subsequent concussions in this group.

Postconcussion Symptom Assessment

Self-reported symptoms are among the more obvious and recognizable ways to assess the effects of concussion. Typical self-reported symptoms after a concussion include but are not limited to headache; dizziness; nausea; vomiting; feeling ''in a fog''; feeling ''slowed down''; trouble falling asleep; sleeping more than usual; fatigue; drowsiness; sensitivity to light or noise; unsteadiness or loss of balance; feeling ''dinged,'' dazed, or stunned; seeing stars or flashing lights; ringing in the ears; and double vision.[8,26,48] Self-reported symptoms are referenced by many of the concussion grading scales.[10,43,44,49] The presence of self-reported symptoms serves as a major contraindication for RTP, and, based on current recommendations, the athlete should be fully symptom free for at least 7 days at rest and during exertion before returning to play.[43,44]

A number of concussion symptom checklists[43,50–52] and scales[26,41,48,53] have been used in both research and clinical settings. A symptom checklist that provides a list of concussion-related symptoms allows the athlete to report whether the symptom is present by responding either ''yes'' (experiencing the symptom) or ''no'' (not experiencing the symptom). A symptom scale is a summative measure that allows the athlete to describe the extent to which he or she is experiencing the symptom. These instruments commonly incorporate a Likert-type scale that allows the player to rate the severity or frequency of postconcussion symptoms. These scores are then summed to form a composite score that yields a quantitative measure of overall injury severity and a benchmark against which to track postinjury symptom recovery. Initial evidence has been provided for the structural validity of a self-report concussion symptom scale.[48] Obtaining a baseline symptom score is helpful to establish any preexisting symptoms attributable to factors other than the head injury (eg, illness, fatigue, or somatization). Serial administration of the symptom checklist is the recommended method of tracking symptom resolution over time (see Appendix A).

Mental Status Screening

Cognitive screening instruments similar to the physician's mini mental status examination objectify what is often a subjective impression of cognitive abnormalities. Various methods have been suggested for a systematic survey of mental status and cognitive function in the athlete with a concussion. The SAC was developed to provide sports medicine clinicians with a brief, objective tool for assessing the injured athlete's mental status during the acute period after concussion (eg, sport sideline, locker room, and clinic).[54] The SAC includes measures of orientation, immediate memory, concentration, and delayed recall that sum to 30 points.[55] Lower scores on the SAC indicate more severe cognitive impairment. The SAC also includes assessments of strength, sensation, and coordination and a standard neurologic examination but should not replace the clinician's thorough physical examination or referral for more extensive neuropsychological evaluation when indicated. Information about the occurrence and duration of LOC and amnesia is also recorded on the SAC. Alternate forms of the SAC are available to minimize the practice effects during retesting. The SAC takes about 5 minutes to administer and should be used only after the clinician's thorough review of the training manual and instructional video on the administration, scoring, and interpretation of the instrument.

The SAC has demonstrated reliability[29,55,56] and validity[29,56,57] in detecting mental status changes after a concussion. Recent evidence suggests that a decline of 1 point or more from baseline classified injured and uninjured players with a level of 94% sensitivity and 76% specificity.[56] The SAC is also sensitive to detecting more severe neurocognitive changes in injured athletes with LOC or amnesia associated with their concussions.[57] The SAC is most useful in the assessment of acute cognitive dysfunction resulting from concussion, with sensitivity and specificity comparable with extensive neuropsychological testing batteries during the initial 2 to 3 days after concussion.[29,58,59] As with neuropsychological testing, sensitivity and specificity of the SAC in concussion assessment are maximized when individual baseline test data are available.[29,55,56,60]

Postural-Stability Assessment

A number of postural-stability tests have been used to assess the effects of concussion in the clinical and laboratory settings. The Romberg and stork stand were basic tests used to assess balance and coordination. Riemann et al[61–62] developed the Balance Error Scoring System (BESS) based on existing theories of posturography. The BESS uses 3 stance positions and tests on both a firm and a foam surface with the eyes closed (for a total of 6 trials). The administration and scoring procedures are found in several publications.[61–63] The BESS has established good test-retest reliability and good concurrent validity when compared with laboratory forceplate measures[52,62] and significant group differences, with an increased number of errors for days 1, 3, and 5 postinjury when compared with controls.[52] Thus, the BESS can be used as a clinical measure in identifying balance impairment that could indicate a neurologic deficit.

The NeuroCom Smart Balance Master System (NeuroCom International, Clackamas, OR) is a forceplate system that measures vertical ground reaction forces produced by the body's center of gravity moving around a fixed base of support. The Sensory Organization Test (SOT, NeuroCom International) is designed to disrupt various sensory systems, including the visual, somatosensory, and vestibular systems. The SOT consists of 6 conditions with 3 trials per condition, for a total of 18 trials, with each trial lasting 20 seconds. The complete administration has been described previously.[52,64] The SOT has produced significant findings related to the assessment of concussion recovery. In a sample of 36 athletes with concussion, the mean stability (composite score) and vestibular and visual ratios demonstrated deficits for up to 5 days postinjury.[52] The greatest deficits were seen 24 hours postinjury, and the athletes with concussion demonstrated a gradual recovery during the 5-day period to within 6% of baseline scores. These results were confirmed by Peterson et al,[65] who found that these deficits continued for up to 10 days after concussion. These findings reveal a sensory interaction problem from the effects of concussion with measurable changes in overall postural stability.

Neuropsychological Testing

Neuropsychological testing has historically been used to evaluate various cognitive domains known to be preferentially susceptible to the effects of concussion and TBI. In recent years, neuropsychological testing to evaluate the effects of sport-related concussion has gained much attention in the sport concussion literature.[20,21,26,29,48,52,58,59,65–69] The work of Barth et al,[70] who studied more than 2000 collegiate football players from 10 universities, was the first project to institute baseline neuropsychological testing. Similar programs are now commonplace among many collegiate and professional teams, and interest is growing at the high school level. Several recent studies have supported the use of neuropsychological testing as a valuable tool to evaluate the cognitive effects and recovery after sport-related concussion,[24,28,29,41,42,50–52,57,65,66,71–75] but its feasibility for sideline use is not likely realistic. As is the case with other concussion assessment tools, baseline neuropsychological testing is recommended, when possible, to establish a normative level of neurocognitive functioning for individual athletes.[24,28,29,41,50–52,57–59,66,69,73–75] Baseline neuropsychological testing typically takes 20 to 30 minutes per athlete.

Before implementing a neuropsychological testing program, the ATC must consider several issues, including test-specific training requirements and methodologic issues, the practicality of baseline testing, the reliability and validity of individual tests comprising the test battery, and the protocol for interpretation of the postinjury test results. Barr[76] provided an excellent review on the methodologic and professional issues associated with neuropsychological testing in sport concussion assessment. Most states require advanced training and licensure to purchase and use neuropsychological tests for clinical purposes. Neuropsychological tests are also copyright protected to prevent inappropriate distribution or use by unqualified professionals. At present, these requirements necessitate that a licensed psychologist, preferably one Board certified in clinical neuropsychology or with clinical experience in the evaluation of sport-related concussion, oversee and supervise the clinical application of neuropsychological testing for sport concussion assessment. These factors likely restrict how widely neuropsychological testing can be used to assess sport-related concussion, especially at the high school level and in rural areas where neuropsychologists are not readily available for consultation.

Neuropsychologists, ATCs, and sports medicine clinicians are faced with the challenge of designing a model that jointly upholds the testing standards of neuropsychology and meets the clinical needs of the sports medicine community without undue burden. The cost of neuropsychological testing, either conventional or computerized, is also a factor in how widely this method can be implemented, especially at the high school level. Consultation fees for the neuropsychologist can be considerable if work is not done on a pro bono basis, and some computerized testing companies charge a consulting fee for interpreting postinjury test results by telephone.

Although no clear indications exist as to which are the best individual neuropsychological tests to evaluate sport concussion, the use of multiple instruments as a ''test battery'' offers clinicians greater potential for recognizing any cognitive deficits incurred from the injury. A number of neuropsychological tests and test batteries have been used to assess sport-related concussion. Table 3 provides a brief description of the paper-and-pencil neuropsychological tests commonly used by neuropsychologists in the assessment of sport concussion. Sport concussion batteries should include measures of cognitive abilities most susceptible to change after concussion, including attention and concentration, cognitive processing (speed and efficiency), learning and memory, working memory, executive functioning, and verbal fluency. Tests of attention and concentration[50,52,74,77] and memory functioning[41] have been reported as the most sensitive to the acute effects of concussion. The athlete's age, sex, primary language, and level of education should be considered when selecting a test battery.[68]

Computerized Neuropsychological Tests. Recently, a number of computerized neuropsychological testing programs have been designed for the assessment of athletes after concussion. The Automated Neuropsychological Assessment Metrics (ANAM), CogSport, Concussion Resolution Index, and Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) are all currently available and have shown promise for reliable and valid concussion assessment (Table 4).[24,41,51,53,66,71,72,75,78–84] The primary advantages to computerized testing are the ease of administration, ability to baseline test a large number of athletes in a short period of time, and multiple forms used within the testing paradigm to reduce the

Table 3. Common Neuropsychological Tests Used in Sport Concussion Assessment

Neuropsychological Test	Cognitive Domain
Controlled Oral Word Association Test	Verbal fluency
Hopkins Verbal Learning Test	Verbal learning, immediate and delayed memory
Trail Making: Parts A and B	Visual scanning, attention, information processing speed, psychomotor speed
Wechsler Letter Number Sequencing Test	Verbal working memory
Wechsler Digit Span: Digits Forward and Digits Backward	Attention, concentration
Wechsler Digit Symbol Test	Psychomotor speed, attention, concentration
Symbol Digit Modalities Test	Psychomotor speed, attention, concentration
Paced Auditory Serial Addition Test	Attention, concentration
Stroop Color Word Test	Attention, information processing speed

practice effects. Collie et al[71] summarized the advantage and disadvantages of computerized versus traditional paper-and-pencil testing.

As outlined, in the case of conventional neuropsychological testing, several of the same challenges must be addressed before computerized testing becomes a widely used method of sport concussion assessment. Issues requiring further consideration include demonstrated test reliability; validity, sensitivity, and specificity in the peer-reviewed literature; required user training and qualifications; the necessary role of the licensed psychologist for clinical interpretation of postinjury test results; hardware and software issues inherent to computerized testing; and user costs.[71] Progress is being made on many of these issues, but further clinical research is required to provide clinicians with the most effective neuropsychological assessment tools and maintain the testing standards of neuropsychology.

Neuropsychological Testing Methods. Neuropsychological testing is not a tool that should be used to diagnose the injury (ie, concussion); however, it can be very useful in measuring recovery once it has been determined that a concussion has occurred. The point(s) at which postinjury neuropsychological testing should occur has been a topic of debate. A variety of testing formats has been used to evaluate short-term recovery from concussion.[24,41,50,73,75,82] Two approaches are most common. The first incorporates neuropsychological testing only after the injured player reports that his or her symptoms are completely gone. This approach is based on the conceptual foundation that an athlete should not participate while symptomatic, regardless of neuropsychological test performance. Unnecessary serial neuropsychological testing, in addition to being burdensome and costly to the athlete and medical staff, also introduces practice effects that may confound the interpretation of performance in subsequent postinjury testing sessions.[85] The second approach incorporates neuropsychological testing at fixed time points (eg, postinjury day 1, day 7, and so on) to track postinjury recovery. This approach is often appropriate for prospective research protocols but is unnecessary in a clinical setting when the player is still symptomatic and will be withheld from competition regardless of the neuropsychological test results. In this model, serial testing can be used until neuropsychological testing returns to normal, preinjury levels and the player is completely symptom free.

Measuring ''recovery'' on neuropsychological tests and other clinical instruments is often a complex statistical matter, further complicated by practice effects and other psychometric dynamics affected by serial testing, even when preinjury baseline data are available for individual athletes. The use of statistical models that empirically identify meaningful change while controlling for practice effects on serial testing may provide the clinician with the most precise benchmark in deter-

Table 4. Computerized Neuropsychological Tests

Neuropsychological Test	Developer (Contact Information)	Cognitive Domains
Automated Neuropsychological Assessment Metrics (ANAM)	National Rehabilitation Hospital Assistive Technology and Neuroscience Center, Washington, DC[84] (jsb2@mhg.edu)	Simple Reaction Metrics Sternberg Memory Math Processing Continuous Performance Matching to Sample Spatial Processing Code Substitution
CogSport	CogState Ltd, Victoria, Australia (www.cogsport.com)	Simple Reaction Time Complex Reaction Time One-Back Continuous Learning
Concussion Resolution Index	HeadMinder Inc, New York, NY (www.headminder.com)	Reaction Time Cued Reaction Time Visual Recognition 1 Visual Recognition 2 Animal Decoding Symbol Scanning
Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)	University of Pittsburgh Medical Center, Pittsburgh, PA (www.impacttest.com)	Verbal Memory Visual Memory Information Processing Speed Reaction Time Impulse Control

Table 5. Factors Influencing Neuropsychological Test Performance[68]*

Previous concussions
Educational background
Preinjury level of cognitive functioning
Cultural background
Age
Test anxiety
Distractions
Sleep deprivation
Medications, alcohol, or drugs
Psychiatric disorders
Learning disability
Attention deficit/hyperactivity
Certain medical conditions
Primary language other than English
Previous neuropsychological testing

*Reprinted with permission of Grindel SH, Lovell MR, Collins MW. The assessment of sport-related concussion: the evidence behind neuropsychological testing and management. *Clin J Sport Med.* 2001; 11: 134–143.

mining postinjury recovery, above and beyond the simple conclusion that the player is ‘‘back to baseline.’’ The complexity of this analysis is the basis for the neuropsychologist overseeing the clinical interpretation of test data to determine injury severity and recovery. Further research is required to clarify the guidelines for determining and tracking recovery on specific measures after concussion. The clinician should also be aware that any concussion assessment tool, either brief screening instruments or more extensive neuropsychological testing, comes with some degree of risk for false negatives (eg, a player performs within what would be considered the normal range on the measure before actually reaching a complete clinical recovery after concussion). Therefore, test results should always be interpreted in the context of all clinical information, including the player's medical history. Also, caution should be exercised in neuropsychological test interpretation when preinjury baseline data do not exist. Numerous factors apart from the direct effects of concussion can influence test performance (Table 5).

WHEN TO REFER AN ATHLETE TO A PHYSICIAN AFTER CONCUSSION

Although most sport-related concussions are considered mild head injuries, the potential exists for complications and life-threatening injuries. Each ATC should be concerned about the potential for the condition of an athlete with a concussion to deteriorate. This downward trend can occur immediately (minutes to hours) or over several days after the injury. As discussed earlier, the spectrum of sport-related head injuries includes more threatening injuries, such as epidural and subdural hematomas and second-impact syndrome. Postconcussion syndrome, however, is a more likely consequence of a sport-related concussion. Not every sport-related concussion warrants immediate physician referral, but ATCs must be able to recognize those injuries that require further attention and provide an appropriate referral for advanced care, which may include neuroimaging. Serial assessments and physician follow-up are important parts of the evaluation of the athlete with a concussion. Referrals should be made to medical personnel with experience managing sport-related concussion. The ATC should monitor vital signs and level of consciousness every 5 minutes after a concussion until the athlete's condition stabilizes and improves. The athlete should also be monitored over the next few hours and days after the injury for delayed signs and symptoms and to assess recovery. Appendix B outlines scenarios that warrant physician referral or, in many cases, transport to the nearest hospital emergency department.

WHEN TO DISQUALIFY AN ATHLETE

Return to participation after severe or repetitive concussive injury should be considered only if the athlete is completely symptom free and has a normal neurologic examination, normal neuropsychological and postural-stability examinations, and, if obtained, normal neuroimaging studies (ie, MRI with gradient echo). It may not be practical or even possible to use all these assessments in all athletes or young children, but a cautious clinical judgment should take into account all evaluation options. Each injured athlete should be considered individually, with consideration for factors including age, level of participation, nature of the sport (high risk versus low risk), and concussion history.

Standardized neuropsychological testing, which typically assesses orientation, immediate and delayed memory recall, and concentration may assist the ATC and physician in determining when to disqualify an athlete from further participation.[60] Balance testing may provide additional information to assist the clinician in the decision-making process of whether to disqualify an individual after a concussion.[52] When to disqualify the athlete is one of the most important decisions facing the ATC and team physician when dealing with an athlete suffering from a concussion. This includes not only when to disqualify for a single practice or event but also when to disqualify for the season or for a career.

Disqualifying for the Game or Practice

The decision to disqualify an individual from further participation on the day of the concussive episode is based on the sideline evaluation, the symptoms the athlete is experiencing, the severity of the apparent symptoms, and the patient's past history.[86] The literature is clear: any episode involving LOC or persistent symptoms related to concussion (headache, dizziness, amnesia, and so on), regardless of how mild and transient, warrants disqualification for the remainder of that day's activities.[8,9,13,19,43,60,87] More recent studies of high school and collegiate athletes underscore the importance of ensuring that the athlete is symptom free before returning to participation on the same day; even when the player is symptom free within 15 to 20 minutes after the concussive episode, he or she may still demonstrate delayed symptoms or depressed neurocognitive levels. Lovell et al[88] found significant memory deficits 36 hours postinjury in athletes who were symptom free within 15 minutes of a mild concussion. Guskiewicz et al[21] found that 33% (10/30) of the players with concussion who returned on the same day of injury experienced delayed onset of symptoms at 3 hours postinjury, as compared with only 12.6% (20/158) of those who did not return to play on the same day of injury. Although more prospective work is needed in this area, these studies raise questions as to whether the RTP criteria for grade 1 (mild) concussions are conservative enough.

Disqualifying for the Season

Guidelines from Cantu[43] and the American Academy of Neurology[6] both recommend termination of the season after the third concussion within the same season. The decision is more difficult if one of the injuries was more severe or was a severe injury resulting from a minimal blow, suggesting that the athlete's brain may be at particular risk for recurrent injury. In addition, because many athletes participate in year-round activities, once they are disqualified for the ''season,'' it may be difficult to determine at what point they can resume contact play. Other issues without clear-cut answers in the literature are when to disqualify an athlete who has not been rendered unconscious and whose symptoms cleared rapidly or one who suffered multiple mild to moderate concussions throughout the career and whether youth athletes should be treated differently for initial and recurrent concussive injuries.

Disqualifying for the Career

When to disqualify an athlete for a career is a more difficult question to answer. The duration of symptoms may be a better criterion as to when to disqualify an athlete for the season or longer. Merril Hoge, Eric Lindros, Chris Miller, Al Toon, and Steve Young provide highly publicized cases of athletes sustaining multiple concussions with recurrent or postconcussion signs and symptoms that lasted for lengthy periods of time.[43]

Once an athlete has suffered a concussion, he or she is at increased risk for subsequent head injuries.[21,43,86] Guskiewicz et al[21,23] found that collegiate athletes had a 3-fold greater risk of suffering a concussion if they had sustained 3 or more previous concussions in a 7-year period and that players with 2 or more previous concussions required a longer time for total symptom resolution after subsequent injuries.[21] Players also had a 3-fold greater risk for subsequent concussions in the same season,[23] whereas recurrent, in-season injuries occurred within 10 days of the initial injury 92% of the time.[21] In a similar study of high school athletes, Collins et al[82] found that athletes with 3 or more prior concussions were at an increased risk of experiencing LOC (8-fold greater risk), anterograde amnesia (5.5-fold greater risk), and confusion (5.1-fold greater risk) after subsequent concussion. Despite the increasing body of literature on this topic, debate still surrounds the question of how many concussions are enough to recommend ending the player's career. Some research suggests that the magic number may be 3 concussions in a career.[21,23,82] Although these findings are important, they should be carefully interpreted because concussions present in varying degrees of severity, and all athletes do not respond in the same way to concussive insults. Most important is that these data provide evidence for exercising caution when managing younger athletes with concussion and athletes with a history of previous concussions.

SPECIAL CONSIDERATIONS FOR THE YOUNG ATHLETE

Many epidemiologic studies on concussion have focused on professional or collegiate athletes. However, this focus seems to now be shifting to the high school level and even to youth sports. Special consideration must be given to the young athlete. The fact that the brain of the young athlete is still developing cannot be ignored, and the effect of concussion on the developing brain is still not entirely understood. Even subtle damage may lead to deficits in learning that adversely influence development. Therefore, it has been suggested that pediatric athletes suffering a concussion should be restricted from further participation for the day and that additional consideration should be given as to when to return these individuals to activity.[46]

Recent epidemiologic investigations of head-injury rates in high school athletes have shown that 13.3% of all reported injuries in high school football affect the head and neck, whereas the numbers in other sports range from 1.9% to 9.5% in baseball and wrestling, respectively.[89] Guskiewicz et al[23] prospectively examined concussion incidence in high school and collegiate football players and found that the greatest incidence was at the high school level (5.6%), compared with the National Collegiate Athletic Association Division I (4.4%), Division II (4.5%), and Division III (5.5%).

Authors who have tracked symptoms and neuropsychological function after concussion suggest that age-related differences exist between high school and collegiate athletes with regard to recovery. Lovell et al[41] reported that the duration of on-field mental status changes in high school athletes, such as retrograde amnesia and posttraumatic confusion, was related to the presence of memory impairment at 36 hours, 4 days, and 7 days postinjury as well as slower resolution of self-reported symptoms. These findings further emphasize the need to collect these on-field measures after concussion and to use the information wisely in making RTP decisions, especially when dealing with younger athletes. Field et al[90] found that high school athletes who sustained a concussion demonstrated prolonged memory dysfunction compared with collegiate athletes who sustained a concussion. The high school athletes performed significantly worse on select tests of memory than age-matched control subjects at 7 days postinjury when compared with collegiate athletes and their age-matched control subjects. We hope these important studies and others will eventually lead to more specific guidelines for managing concussions in high school athletes.

Very few investigators have studied sport-related injuries in the youth population, and even fewer focused specifically on sport-related concussion. One group[91] reported that 15% of the children (mean $= 8.34 \pm 5.31$ years) who were admitted to hospitals after MTBI suffered from a sport-related mechanism of injury. Another group[92] found that sport-related head injury accounted for 3% of all sport-related injuries and 24% of all serious head injuries treated in an emergency department. Additionally, sport-related concussion represented a substantial percentage of all head injuries in children under the age of 10 years (18.2%) and 10- to 14-year-old (53.4%) and 15- to 19-year-old (42.9%) populations.[92] Thus, sport-related head injury has a relatively high incidence rate and is a significant public health concern in youth athletes, not just participants at higher competitive levels.

Although no prospective investigations in younger athletes (younger than 15 years old) have been undertaken regarding symptom resolution and cognitive or postural-stability recovery, Valovich McLeod et al[93] recently determined the reliability and validity of brief concussion assessment tools in a group of healthy young athletes (9–14 years old). The SAC is valid within 48 hours of injury and reliable for testing of youths above age 5 years, but younger athletes score slightly below high school and collegiate athletes.[55] This issue is remedied, however, if preseason baseline testing is conducted for all players and a preinjury baseline score established for each athlete against which changes resulting from concussion can be detected and other factors that affect test performance can be controlled. Users of standardized clinical tools should be aware of the effects of age and education on cognitive test performance and make certain to select the appropriate normative group for comparison when testing an injured athlete at a specific competitive level. Uncertainties about the effects of concussion on young children warrant further study.

HOME CARE

Once the athlete has been thoroughly evaluated and determined to have sustained a concussion, a comprehensive medical management plan should be implemented. This plan should include frequent medical evaluations and observations, continued monitoring of postconcussion signs and symptoms, and postinjury cognitive and balance testing. If symptoms persist or worsen or the level of consciousness deteriorates at all after a concussion, neuroimaging should be performed. Although scientific evidence for the evaluation and resolution of the concussion is ample, specific management advice to be given to the athlete on leaving the athletic training room is lacking.[94] Athletic trainers and hospital emergency rooms have created various home instruction forms, but minimal scientific evidence supports these instructions. However, despite these limitations, a concussion instruction form (Appendix C) should be given to the athlete and a responsible adult who will have direct contact with the athlete for the initial 24 hours after the injury. This form helps the companion to know what signs and symptoms to watch for and provides useful recommendations on follow-up care.

Medications

At this time, the clinician has no evidence-based pharmacologic treatment options for an athlete with a concussion.[95] Most pharmacologic studies have been performed in severely head-injured patients. It has been suggested that athletes with concussion avoid medications containing aspirin or nonsteroidal anti-inflammatories, which decrease platelet function and potentially increase intracranial bleeding, mask the severity and duration of symptoms, and possibly lead to a more severe injury. It is also recommended that acetaminophen (Tylenol, McNeil Consumer & Specialty Pharmaceuticals, Fort Washington, PA) be used sparingly in the treatment of headache-like symptoms in the athlete with a concussion. Other substances to avoid during the acute postconcussion period include those that adversely affect central nervous function, in particular alcohol and narcotics.

Wake-Ups and Rest

Once it has been determined that a concussion has been sustained, a decision must be made as to whether the athlete can return home or should be considered for overnight observation or admission to the hospital. For more severe injuries, the athlete should be evaluated by the team physician or emergency room physician if the team physician is not available. If the athlete is allowed to return home or to the dormitory room, the ATC should counsel a friend, teammate, or parent to closely monitor the athlete. Traditionally, part of these instructions included a recommendation to wake up the athlete every 3 to 4 hours during the night to evaluate changes in symptoms and rule out the possibility of an intracranial bleed, such as a subdural hematoma. This recommendation has raised some debate about unnecessary wake-ups that disrupt the athlete's sleep pattern and may increase symptoms the next day because of the combined effects of the injury and sleep deprivation. It is further suggested that the concussed athlete have a teammate or friend stay during the night and that the athlete not be left alone. No documented evidence suggests what severity of injury requires this treatment. However, a good rule to use is if the athlete experienced LOC, had prolonged periods of amnesia, or is still experiencing significant symptoms, he or she should be awakened during the night. Both oral and written instructions should be given to both the athlete and the caregiver regarding waking.[96] The use of written and oral instructions increases the compliance to 55% for purposeful waking in the middle of the night. In the treatment of concussion, complete bed rest was ineffective in decreasing postconcussion signs and symptoms.[97] The athlete should avoid activities that may increase symptoms (eg, staying up late studying and physical education class) and should resume normal activities of daily living, such as attending class and driving, once symptoms begin to resolve or decrease in severity. As previously discussed, a graded test of exertion should be used to determine the athlete's ability to safely return to full activity.

Diet

Evidence is limited to support the best type of diet for aiding in the recovery process after a concussion. A cascade of neurochemical, ionic, and metabolic changes occur after brain injury.[47] Furthermore, some areas of the brain demonstrate glycolytic increases and go into a state of metabolic depression as a result of decreases in both glucose and oxidative metabolism with a reduction in cerebral blood flow. Severely brain-injured subjects ate larger meals and increased their daily caloric intake when compared with controls.[98] Although limited information is available regarding the recommended diet for the management of concussion, it is well accepted that athletes should be instructed to avoid alcohol, illicit drugs, and central nervous system medications that may interfere with cognitive function. A normal, well-balanced diet should be maintained to provide the needed nutrients to aid in the recovery process from the injury.

EQUIPMENT ISSUES

Helmets and Headgear

Although wearing a helmet will not prevent all head injuries, a properly fitted helmet for certain sports reduces the risk of such injuries. A poorly fitted helmet is limited in the amount of protection it can provide, and the ATC must play a role in enforcing the proper fitting and use of the helmet. Protective sport helmets are designed primarily to prevent catastrophic injuries (ie, skull fractures and intracranial hematomas) and are not designed to prevent concussions. A helmet that protects the head from a skull fracture does not adequately prevent the rotational and shearing forces that lead to many concussions.[99]

The National Collegiate Athletic Association requires helmets be worn for the following sports: baseball, field hockey (goalkeepers only), football, ice hockey, women's lacrosse (goalkeepers only), men's lacrosse, and skiing. Helmets are also recommended for recreational sports such as bicycling, skiing, mountain biking, roller and inline skating, and speed skating. Headgear standards are established and tested by the National Operating Committee on Standards for Athletic Equipment and the American Society for Testing and Materials.[99]

Efforts to establish and verify standards continue to be tested and refined, but rarely are the forces and conditions experienced on the field by the athletes duplicated. In addition to direction, speed, and amount of the forces delivered and received by the athlete, conditions not controlled in the testing process include weather conditions, changes in external temperatures and temperatures inside the helmet, humidity levels, coefficient of friction for the surfaces of the equipment and ground, and density of the equipment and ground. However, equipment that does meet the standards is effective in reducing head injuries.[99]

More recently, the issue of headgear for soccer players has received much attention. Although several soccer organizations and governing bodies have approved the use of protective headbands in soccer, no published, peer-reviewed studies support their use. Recommendations supporting the use and performance of headgear for soccer are limited by a critical gap in biomechanical information about head impacts in the sport of soccer. Without data linking the severity and type of impacts and the clinical sequelae of single and repeated impacts, specifications for soccer headgear cannot be established scientifically. These types of headgear may reduce the ''sting'' of a head impact, yet they likely do not meet other sports headgear performance standards. This type of headgear may actually increase the incidence of injury. Players wearing headgear may have the false impression that the headgear will protect them during more aggressive play and thereby subject themselves to even more severe impacts that may not be attenuated by the headgear.

Mouth Guards

The wearing of a mouth guard is thought by some to provide additional protection for the athlete against concussion by either reducing the risk of injury or reducing the severity of the injury itself.[100] Mouth guards aid in the separation between the head of the condyle of the mandible and the base of the skull. It is thought that wearing an improperly fitted mouth guard or none at all increases this contact point. This theory, which is based on Newtonian laws of physics, suggests that the increased separation between 2 adjacent structures increases the time to contact, thus decreasing the amount of contact and decreasing the trauma done to the brain.[100] However, no biomechanical studies support the theory that the increased separation results in less force being delivered to the brain.

High school football and National Collegiate Athletic Association football rules mandate the wearing of a mouth guard, but the National Football League rulebook does not require players to wear a mouth guard. The National Collegiate Athletic Association requires mouth guards to be worn by all athletes in football, field hockey, ice hockey, and lacrosse. Researchers[101,102] have found no advantage in wearing a custom-made mouth guard over a boil-and-bite mouth guard to reduce the rise of cerebral concussion in athletes. However, ATCs and coaches should mandate the regular use of mouth guards because a properly fitted mouth guard, with no alterations such as cutting off the back part, is of great value in protecting the teeth and preventing fractures and avulsions that could require many years of expensive dental care.

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Graded Symptom Checklist (GSC)

Symptom	Time of injury	2-3 Hours postinjury	24 Hours postinjury	48 Hours postinjury	72 Hours postinjury
Blurred vision					
Dizziness					
Drowsiness					
Excess sleep					
Easily distracted					
Fatigue					
Feel "in a fog"					
Feel "slowed down"					
Headache					
Inappropriate emotions					
Irritability					
Loss of consciousness					
Loss or orientation					
Memory problems					
Nausea					
Nervousness					
Personality change					
Poor balance/coordination					
Poor concentration					
Ringing in ears					
Sadness					
Seeing stars					
Sensitivity to light					
Sensitivity to noise					
Sleep disturbance					
Vacant stare/glassy eyed					
Vomiting					

NOTE: The GSC should be used not only for the initial evaluation but for each subsequent follow-up assessment until all signs and symptoms have cleared at rest and during physical exertion. In lieu of simply checking each symptom present, the ATC can ask the athlete to grade or score the severity of the symptom on a scale of 0-6, where 0=not present, 1=mild, 3=moderate, and 6=most severe.

Appendix B. Physician Referral Checklist

Day-of-injury referral

1. Loss of consciousness on the field
2. Amnesia lasting longer than 15 min
3. Deterioration of neurologic function*
4. Decreasing level of consciousness*
5. Decrease or irregularity in respirations*
6. Decrease or irregularity in pulse*
7. Increase in blood pressure
8. Unequal, dilated, or unreactive pupils*
9. Cranial nerve deficits
10. Any signs or symptoms of associated injuries, spine or skull fracture, or bleeding*
11. Mental status changes: lethargy, difficulty maintaining arousal, confusion, or agitation*
12. Seizure activity*
13. Vomiting
14. Motor deficits subsequent to initial on-field assessment
15. Sensory deficits subsequent to initial on-field assessment
16. Balance deficits subsequent to initial on-field assessment
17. Cranial nerve deficits subsequent to initial on-field assessment
18. Postconcussion symptoms that worsen
19. Additional postconcussion symptoms as compared with those on the field
20. Athlete is still symptomatic at the end of the game (especially at high school level)

Delayed referral (after the day of injury)

1. Any of the findings in the day-of-injury referral category
2. Postconcussion symptoms worsen or do not improve over time
3. Increase in the number of postconcussion symptoms reported
4. Postconcussion symptoms begin to interfere with the athlete's daily activities (ie, sleep disturbances or cognitive difficulties)

*Requires that the athlete be transported immediately to the nearest emergency department.

Appendix C. Concussion Home Instructions

I believe that ______________________ sustained a concussion on ______________________. To make sure he/she recovers, please follow the following important recommendations:

1. Please **remind** ______________________ to report to the athletic training room tomorrow at __________ for a follow-up evaluation.

2. Please **review** the items outlined on the enclosed **Physician Referral Checklist.** If any of these problems develop prior to his/her visit, please call ________________ at ________________ or contact the local emergency medical system or your family physician. Otherwise, you can follow the instructions outlined below.

It is OK to:

- Use acetaminophen (Tylenol) for headaches
- Use ice pack on head and neck as needed for comfort
- Eat a light diet
- Return to school
- Go to sleep
- Rest (no strenuous activity or sports)

There is NO need to:

- Check eyes with flashlight
- Wake up every hour
- Test reflexes
- Stay in bed

Do NOT:

- Drink alcohol
- Eat spicy foods

Specific recommendations:

Recommendations provided to: ____

Recommendations provided by: ______________________ Date: ____________ Time: ____________

Please feel free to contact me if you have any questions. I can be reached at: ______________________

Signature: ______________________________________ Date:____________________