An overview of concussion consensus statements since 2000

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More refereed publications on sports-related concussion have appeared since 2000 than in all previous years combined. Three international consensus statements, documents from the National Athletic Trainers’ Association (NATA) and the American College of Sports Medicine (ACSM), and entire issues of the Clinical Journal of Sport Medicine and the Journal of Athletic Training have been devoted to this subject. The object of this article is to critique the consensus statements and NATA and ACSM documents, pointing out areas of controversy.

KEY WORDS  • brain concussion • postconcussion syndrome • sports-related concussion • neuropsychological assessment • sports medicine

It has been estimated by PubMed Central that more refereed publications on sports-related concussion have appeared since the year 2000 than in all the previous years combined. Since 2000, three international concussion-in-sport consensus statements have been published: 1) the Vienna statement of 2001; 2) the Prague statement of 2004; and, most recently, the St. Moritz conference of 2006. Extensive documents on concussion have also emerged from the NATA (the National Athletic Trainers’ Association position statement, published in 2004) and the ACSM (a consensus statement on concussion and the team physician, which appeared in 2006). In addition, entire issues of the Clinical Journal of Sport Medicine (July 2001) and the Journal of Athletic Training (July–September 2001) have been devoted to the subject.

A consensus statement obviously is just that, but the consensus is often not unanimous. Whenever writing groups are assembled from diverse organizations as well as from diverse personal and professional backgrounds, organizational or personal bias may be present, no matter how much expertise is brought to the table. The purpose of this paper, written by a member of the writing groups of all three international concussion consensus statements as well as the NATA and ACSM publications, is to give an overview as well as a personal critique of each of these documents.

Consensus Statements

Summary and Agreement Statement of the First International Conference on Concussion in Sport, Vienna 2001

This document was published concurrently in early 2002 in the British Journal of Sports Medicine, the Clinical Journal of Sport Medicine, and Physician and Sports Medicine. (See Appendix 1 for lists of authors and affiliations.) The conference was held in November 2001 and was supported and organized by the International Ice Hockey Federation, the FIFA Medical Assessment and Research Center, and the IOC Medical Commission, with a stated objective of providing recommendations for the improvement of the safety and health of athletes who suffer concussive injuries in ice hockey, soccer, and other sports. Experts were invited to address specific issues involving epidemiology, basic and clinical science, grading systems, cognitive assessment, new research methods, protective equipment, management, prevention, and long-term outcome from concussive injury. At the conclusion of the conference, a small group of the experts was given the mandate to draft the document that was subsequently published in the three journals previously mentioned.

The Vienna conference was, in my opinion, very successful, and the resulting publication is the most comprehensive of the three international consensus statements on concussion in sport. I recommend it as a valuable resource for all who are interested in sports-related concussion.

This document provided a revised definition of concussion as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.” The statement further qualified the definition by noting five conclusions about the nature of concussive head injury. First, “concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an ‘impulsive’ force transmitted to the head.” Second, a “concussion typically results in the rapid onset of short lived impairment of neurological function that resolves spontaneously.” Third, “concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.” Fourth, “concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive...
Posttraumatic Retrograde and Anterograde Amnesia: Pathophysiology and Implications in Grading and Safe Return to Play

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Robert C. Cantu, MA, MD, FACS, FACSM, provided conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

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Objective: The presence of posttraumatic amnesia (PTA) and loss of consciousness have been major factors used in a number of concussion guidelines. In this article, the focus is on using PTA (both retrograde and anterograde) as salient indicators of traumatic brain injury severity and the most reliable index of outcome prediction, even in mild cases.

Data Sources: A MEDLINE search for the years 1990–2000 using the key words posttraumatic retrograde and anterograde amnesia, concussion and mild traumatic brain injury was done.

Data Synthesis: On-the-field testing of PTA is a salient and integral component of the initial and follow-up neurologic assessments of the head-injured athlete.

Conclusions/Recommendations: Initial and follow-up assessments of PTA, anterograde and retrograde, are an essential part of the neurologic evaluation of the head-injured athlete. Increasingly, neuropsychological testing, including computer models, is being employed in this assessment. The importance of not just PTA but all concussive signs and symptoms being present at rest and exertion before allowing the athlete to return to play is emphasized.

Key Words: concussion, mild traumatic brain injury, athletic injury

Concussion is derived from the Latin word *concussus*, which means to shake violently. Initially, it was thought to produce only a temporary disturbance of brain function due to neuronal, chemical, or neuroelectrical changes without gross structural change. We now know that structural damage with loss of brain cells does occur with some concussions. In the last several years, the neurobiology of cerebral concussion has been advanced predominantly in animal studies but also in studies in man as well. It has become clear that, in the minutes to days after concussive brain injury, brain cells that are not irreversibly destroyed remain alive but in a vulnerable state. These cells are particularly vulnerable to minor changes in cerebral blood flow, increases in intracranial pressure, and especially anoxia. Animal studies have shown that, during this period of vulnerability, which may last as long as a week with a minor head injury such as a concussion, a minor reduction in cerebral blood flow that would normally be well tolerated now produces extensive neuronal cell loss.1–5 This vulnerability appears to be due to an uncoupling of the demand for glucose, which is increased after injury, with a relative reduction in cerebral blood flow. While the precise mechanisms of this dysfunction are still not fully understood, it is now clear that, although concussion in and of itself may not produce extensive neuronal damage, the surviving cells are in a state of vulnerability characterized by a metabolic dysfunction, which can be thought of as a breakdown between energy demand and production. Precisely how long this period of metabolic dysfunction lasts is not presently fully understood. Unfortunately, there are today no neuroanatomic or physiologic measurements that can be used to precisely determine the extent of injury in concussion or the severity of metabolic dysfunction or precisely when it has cleared. It is this fact that makes return-to-play decisions after a concussion a clinical judgment.

Team physicians, athletic trainers, and other medical personnel responsible for the medical care of athletes face no more challenging problem than the recognition and management of concussion. Indeed, such injuries have captured many headlines in recent years and have spurred studies within both the National Football League and the National Hockey League.

When discussing concussion, we must realize that there is no universal agreement on the definition and grading of concussion.1,6–8 Tables 1–8 present different attempts at grading concussion, all focusing on loss or nonloss of consciousness and posttraumatic amnesia (PTA) as hallmarks in the grading schemes. Furthermore, they may not give enough attention to the other signs and symptoms of concussion. As we all know, a patient with concussion may display any combination of the following signs and symptoms: a feeling of being stunned or seeing bright lights, brief loss of consciousness, lightheadedness, vertigo, loss of balance, headaches, cognitive and memory dysfunction, tinnitus, blurred vision, difficulty concentrating, lethargy, fatigue, personality changes, inability to perform daily activities, sleep disturbances, and motor or sensory symptoms.

Presently, there is no universal agreement that PTA is a better
Table 1. Cantu Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No loss of consciousness; posttraumatic amnesia less than 30 minutes</td>
</tr>
<tr>
<td>2</td>
<td>Loss of consciousness less than 5 minutes in duration or posttraumatic amnesia lasting longer than 30 minutes but less than 24 hours in duration</td>
</tr>
<tr>
<td>3</td>
<td>Loss of consciousness for more than 5 minutes or posttraumatic amnesia for more than 24 hours</td>
</tr>
</tbody>
</table>


Table 2. Colorado Medical Society Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Confusion without amnesia; no loss of consciousness</td>
</tr>
<tr>
<td>2</td>
<td>Confusion with amnesia; no loss of consciousness</td>
</tr>
<tr>
<td>3</td>
<td>Loss of consciousness</td>
</tr>
</tbody>
</table>

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Table 3. AAN Practice Parameter (Kelly and Rosenberg) Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transient confusion; no loss of consciousness; concussion symptoms or mental status abnormalities on examination resolve in less than 15 minutes</td>
</tr>
<tr>
<td>2</td>
<td>Transient confusion; no loss of consciousness; concussion symptoms or mental status abnormalities on examination last more than 15 minutes</td>
</tr>
<tr>
<td>3</td>
<td>Any loss of consciousness, either brief (seconds) or prolonged (minutes)</td>
</tr>
</tbody>
</table>

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Table 4. Jordan Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Confusion without amnesia; no loss of consciousness</td>
</tr>
<tr>
<td>2</td>
<td>Confusion with amnesia lasting less than 24 hours; no loss of consciousness</td>
</tr>
<tr>
<td>3</td>
<td>Loss of consciousness with an altered level of consciousness not exceeding 2 to 3 minutes; posttraumatic amnesia lasting more than 24 hours</td>
</tr>
<tr>
<td>4</td>
<td>Loss of consciousness with an altered level of consciousness exceeding 2 to 3 minutes</td>
</tr>
</tbody>
</table>

Table 5. Ommaya Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Confusion without amnesia (stunned)</td>
</tr>
<tr>
<td>2</td>
<td>Amnesia without coma</td>
</tr>
<tr>
<td>3</td>
<td>Coma lasting less than 6 hours (includes classic cerebral concussion, minor and moderate head injuries)</td>
</tr>
<tr>
<td>4</td>
<td>Coma lasting 6 to 24 hours (severe head injuries)</td>
</tr>
<tr>
<td>5</td>
<td>Coma lasting more than 24 hours (severe head injuries)</td>
</tr>
<tr>
<td>6</td>
<td>Coma, death within 24 hours (fatal head injuries)</td>
</tr>
</tbody>
</table>


Table 6. Nelson Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Head struck or moved rapidly; not stunned or dazed initially; subsequently complains of headache and difficulty in concentrating</td>
</tr>
<tr>
<td>1</td>
<td>Stunned or dazed initially; no loss of consciousness or amnesia; sensorium clears in less than 1 minute</td>
</tr>
<tr>
<td>2</td>
<td>Headache; cloudy sensorium longer than 1 minute in duration; no loss of consciousness; may have tinnitus or amnesia; may be irritable, hyperexcitable, confused, or dizzy</td>
</tr>
<tr>
<td>3</td>
<td>Loss of consciousness less than 1 minute in duration; no coma (arousable with noxious stimuli); demonstrates grade 2 symptoms during recovery</td>
</tr>
<tr>
<td>4</td>
<td>Loss of consciousness for more than 1 minute; no coma; demonstrates grade 2 symptoms during recovery</td>
</tr>
</tbody>
</table>

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Table 7. Roberts Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell ringer</td>
<td>No loss of consciousness; no posttraumatic amnesia; symptoms less than 10 minutes</td>
</tr>
<tr>
<td>1</td>
<td>No loss of consciousness; posttraumatic amnesia less than 30 minutes; symptoms greater than 10 minutes</td>
</tr>
<tr>
<td>2</td>
<td>Loss of consciousness less than 5 minutes; posttraumatic amnesia greater than 30 minutes</td>
</tr>
<tr>
<td>3</td>
<td>Loss of consciousness greater than 5 minutes; posttraumatic amnesia greater than 24 hours</td>
</tr>
</tbody>
</table>

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Table 8. Torg Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Bell rung&quot;: short-term confusion; unsteady gait; dazed appearance; no amnesia</td>
</tr>
<tr>
<td>2</td>
<td>Posttraumatic amnesia only; vertigo; no loss of consciousness</td>
</tr>
<tr>
<td>3</td>
<td>Posttraumatic retrograde amnesia; vertigo; no loss of consciousness</td>
</tr>
<tr>
<td>4</td>
<td>Immediate transient loss of consciousness</td>
</tr>
<tr>
<td>5</td>
<td>Paralytic coma; cardiorespiratory arrest</td>
</tr>
<tr>
<td>6</td>
<td>Death</td>
</tr>
</tbody>
</table>

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some investigators have suggested that PTA might better be called posttraumatic confusional state.

Posttraumatic amnesia may be divided into 2 types. The first type of PTA is retrograde, defined by Cartlidge and Shaw as a "partial or total loss of the ability to recall events that have occurred during the period immediately preceding brain injury." The duration of retrograde amnesia usually progressively decreases. The second type of PTA is anterograde amnesia, a deficit in forming new memory after the accident, which may lead to decreased attention and inaccurate perception. Anterograde memory is frequently the last function to return after the recovery from loss of consciousness.

Memory and new learning are believed to involve the cerebral cortex, subcortical projections, hippocampal formation (gyrus dentatus, hippocampus, and parahippocampal gyri), and the diencephalons, especially the medial portions of the dorsomedial and adjacent midline nuclei of the thalamus. In addition, frontal lobe lesions may cause alterations in behavior, including irritability, aggressiveness, and loss of inhibition and judgment. Recently, evidence has been presented that the right frontal lobe plays a prominent role in sustained attention.

The lack of a universal definition or grading scheme for
Table 9. Evidence-Based Cantu Grading System for Concussion

| Grade 1 (mild) | No loss of consciousness; posttraumatic amnesia* or postconcussion signs or symptoms lasting less than 30 minutes |
| Grade 2 (moderate) | Loss of consciousness lasting less than 1 minute; posttraumatic amnesia* or postconcussion signs or symptoms lasting longer than 30 minutes but less than 24 hours |
| Grade 3 (severe) | Loss of consciousness lasting more than 1 minute or posttraumatic amnesia* lasting longer than 24 hours; postconcussion signs or symptoms lasting longer than 7 days |

*Retrograde and anterograde.

Concussion renders the evaluation of epidemiologic data extremely difficult. As a neurosurgeon and team physician, I have evaluated many football players who suffered a concussion. Most of these injuries were mild, not involving loss of consciousness, and were associated with PTA, which was helpful in making the diagnosis, especially in mild cases.

I developed a practical scheme for grading concussion severity based on the duration of unconsciousness or PTA (or both), which has worked well on the field and sideline (see Table 1). The most mild concussion (grade 1) occurs without loss of consciousness, and the only neurologic deficit is a brief period of posttraumatic confusion or PTA, which, by definition, lasts less than 30 minutes. The moderate (grade 2) concussion is usually associated with a brief period of unconsciousness, by definition, not exceeding 5 minutes. Less commonly, consciousness is not lost; the athlete instead experiences a protracted period of PTA lasting more than 30 minutes but less than 24 hours. A severe (grade 3) concussion occurs with a more protracted period of unconsciousness lasting longer than 5 minutes. Rarely, it may occur without a loss of consciousness or with a shorter period of unconsciousness but with a very protracted period of PTA lasting more than 24 hours. In reality, prospective studies over the last several years have shown that virtually all concussions are grade 3 by this guideline because of PTA lasting longer than 24 hours (D. Erlanger, unpublished data, 2000). A protracted period of unconsciousness lasting more than 5 minutes is almost never seen on athletic fields; most periods of unconsciousness last seconds to a minute. Prospective studies over the last 10 years have demonstrated a correlation between the duration of postconcussive symptoms and PTA and abnormal results on neuropsychological tests. Therefore, I present an evidence-based modification of the original Cantu guidelines* (Table 9).

When checking for orientation and retrograde amnesia on the field, asking the athlete the current quarter, the score, what happened, and the names of the current and last week’s opponents is useful. When checking for attention or anterograde amnesia deficits, useful tests are repeating 4 words immediately and 2 minutes later, repeating 5 numbers forward and especially backward, and repeating months of the year backward.

Recently, computer-administered minineuropsychological tests have been proposed as a more feasible way to conduct group baseline assessments,36,37 as well as a personal digital assistant version that can be connected to the Internet.38,39

Thus, while not yet the standard of care, neuropsychological tests (with a preseason baseline and serial postconcussion assessments) are assisting clinicians in concussion management, including return-to-play decisions.

Whether an athlete has been unconscious is, of course, important. It is generally believed that the degree of brain injury sustained is indicated by the depth and duration of coma.40–42 However, the coma referred to by these authors is not the seconds to minutes usually seen on the athletic field but rather hours’ or days’ duration. Thus, while diminishing the importance of being rendered unconscious, I find it illogical to grade a concussion that produces postconcussion symptoms lasting months or years without loss of consciousness as less severe than a concussion resulting in brief unconsciousness and resolution of all postconcussion symptoms within a few minutes or hours. Brett Lindros, Al Toon, Jim Miller, Steve Young, and Merrill Hodge are professional athletes whose careers were ended by concussions without loss of consciousness that produced sustained postconcussion symptoms. We know these athletes consider their concussions very severe.

RETURN TO COMPETITION AFTER CONCUSSION

A sobering realization is that the ability to process information may be reduced after a concussion, and the severity and duration of functional impairment may be greater with repeated concussions.43–45 Studies clearly suggest that the damaging effects of the shearing injury to nerve fibers and neurons are proportional to the degree to which the head is accelerated and that these changes may be cumulative.46–48 Once a player has incurred an initial cerebral concussion, his or her chances of incurring a second one are 3 to 6 times greater than for an athlete who has never sustained a concussion.49–51

Table 10 presents guidelines for return to play after a concussion, including termination of a season. Before an athlete returns to play, he or she must not only be free of PTA symptoms but also of all postconcussion symptoms at rest and exertion. All the guidelines agree on this salient point. Table 11 is a postconcussion signs and symptoms checklist I have found useful. Thus, while it is a clinical decision as to when to return an athlete to play after a concussion, to return an athlete with postconcussion symptoms risks not only cumulative brain in-

Table 10. Guidelines for Return to Play After Concussion*

<table>
<thead>
<tr>
<th>First Concussion</th>
<th>Second Concussion</th>
<th>Third Concussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1 (mild)</td>
<td>Return to play if asymptomatic for 1 week</td>
<td>Return to play in 2 weeks if asymptomatic for 1 week; terminate season; may return to play next season if asymptomatic</td>
</tr>
<tr>
<td>Grade 2 (moderate)</td>
<td>Return to play after asymptomatic for 1 week</td>
<td>Minimum of 1 month; may return to play then if asymptomatic for 1 week; consider terminating season</td>
</tr>
<tr>
<td>Grade 3 (severe)</td>
<td>Minimum of 1 month; may return to play if asymptomatic for 1 week</td>
<td>Terminate season; may return to play next season if asymptomatic</td>
</tr>
</tbody>
</table>

*Asymptomatic in all cases means no postconcussion symptoms, including retrograde or anterograde amnesia, at rest or with exertion.
Table 11. Postconcussion Signs and Symptoms Checklist

<table>
<thead>
<tr>
<th></th>
<th>Initial Symptoms</th>
<th>Symptoms Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drowsiness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess sleep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatigue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feel &quot;in fog&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feel &quot;slowed down&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nausea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nervousness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numbering/lightheaded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor balance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor concentration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringing in ears</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sadness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitive to light</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitive to noise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

jury but the second-impact syndrome and would be against the recommendations of all current guidelines.

CONCLUSION

There is no universal agreement on concussion grading and return-to-play criteria after a concussion. There is, however, unanimous agreement that an athlete still suffering postconcussion symptoms at rest and exertion should not return to contact or collision sports. In this article, I present the logic for using the duration of posttraumatic amnesia (retrograde and especially anterograde) as a criterion to be employed in the grading of concussion severity.

REFERENCES


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Multiple Concussions and Neuropsychological Functioning in Collegiate Football Players

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Objective: To document neurocognitive and neurobehavioral consequences of 1 versus 2 concussions.

Design and Setting: Nonequivalent, pretest-posttest cohort design with multiple dependent measures. Participants were selected from a large sample of athletes who participated in a comprehensive, multicenter study of football-related concussion.

Subjects: College football players who sustained 1 and 2 grade 1 concussive injuries were matched for age, education, and duration of competitive football.

Measurements: Neuropsychological tests and symptoms checklists.

Results: Multivariate analysis of variance did not show a statistically significant difference in test performance between players with 1 or 2 concussions. Chi square analyses revealed that concussions significantly increased the number of symptom complaints, but symptoms returned to baseline by 10 days post-injury. The effects of 2 injuries did not appear to be significantly greater than that of a single injury. Differences in response to concussion were observed.

Conclusions: Neurocognitive and neurobehavioral consequences of 2 concussions did not appear to be significantly different from those of 1 concussion, but methodologic issues place limitations on data interpretation. Additional studies are needed to clarify the neuropsychological consequences of multiple concussions.

Key Words: sports injuries, neuropsychological tests, symptoms

Over the past 15 years, research pertaining to concussive injuries sustained during athletic endeavors has increased substantially.1 Findings from these studies have been generally consistent and suggest that concussive injuries in competitive American football can cause time-limited neuropsychological and neurobehavioral problems.2-4 Although 1 concussion does not appear to result in significant morbidity, the effect of multiple concussions is less clear. In a recent study,4 a posttest-only control group design was used to compare athletes who had a history of 1 concussion with athletes who had a history of 2 or more concussions. The authors found that athletes who sustained 2 or more concussions reported more neurobehavioral symptoms and had more impairment on selected neuropsychological tests than athletes who had a history of a single concussion. Despite the differences on some neuropsychological measures, athletes with a history of 1 versus 2 or more concussions did not differ on tests of auditory attention, verbal fluency, verbal learning, verbal memory, or fine motor dexterity.4 In addition, players with 2 or more concussions were aggregated, and the effect of different numbers of concussions was not specified.4

Most studies investigating the effects of single or multiple concussions have been retrospective investigations using posttest-only designs.1 Accordingly, we designed our investigation to prospectively examine the neurobehavioral and neuropsychological consequences of 2 concussive injuries. Players who sustained 2 concussions were compared with players who sustained 1 concussion using a nonequivalent, pretest-posttest comparison design. Players who sustained 1 concussion were used as controls in order to contrast the effects of 1 versus 2 concussions. As mentioned previously, several studies have shown that a single concussion is associated with time-limited neurocognitive impairment. As such, identifying neurocognitive impairment was not the primary focus of our investigation. The primary goal was to determine if a second concussion produced identifiable cognitive deficits above and beyond those observed after a single injury. Based on prior investigations, we hypothesized that players who sustained 2 concussions would evidence significantly greater neurocognitive dysfunction and postconcussive symptoms compared with players who sustained a single injury.

METHODS

Subjects

Participants in this study (n = 24) were selected from a larger sample of athletes who participated in a comprehensive...
study of concussive injury in Division I-A collegiate football players. In the initial study, 2300 players were prospectively examined and followed for 4 years to determine the neuropsychological consequences of concussive injuries. During the study period, 195 players sustained grade 1 concussions based on classical classification guidelines. Six percent of all players with documented concussions sustained 2 injuries (n = 12). Five of these athletes sustained concussions in the same year (mean separation, 33 days; range, 14 to 70 days), while 7 players sustained concussions in consecutive years (mean separation, 532 days; range, 364 to 686 days). Players who sustained 2 concussions (T2) were compared with a selected cohort of players who sustained a single concussion (S). Players sustaining 1 concussion were selectively matched with players sustaining 2 concussions based on age, education, years in competitive football, and prior concussion history (none). Players with a single concussion (S) had a mean age of 19.5 years and a mean 8.4 years of experience in competitive football, and players with 2 concussions (T2) had a mean age of 19.1 years and a mean 9.1 years of experience in competitive football.

METHODS

All players (n = 24) were assessed preseason to establish baseline functioning. In addition to completing a physical examination, players completed several neuropsychological measures, including the Paced Auditory Serial Addition Task (Brainment Software, Marlton, NJ),

5 Trail-Making Tests A and B from the Halstead-Reitan Neuropsychological Test Battery (Reitan Neuropsychological Laboratory, Tucson, AZ),

4 and the Symbol Digit Test (Psychological Assessment Resources, Inc. Odessa FL). These tests were designed to measure various aspects of visual and auditory attention as well as information processing speed. Psychometrics of these instruments can be obtained from various sources. Players also completed a history questionnaire and a symptom checklist. Players who were suspected of sustaining head injuries during practices or games were examined by certified athletic trainers and physicians using standardized medical and mental status procedures. Players' temporal and spatial orientation and short-term memory were systematically assessed after injury. Players failing items were scored as inconclusive and were assessed until resolution of posttraumatic confusion. No players in our study experienced a documented loss of consciousness or posttraumatic confusion lasting longer than 30 minutes, which is consistent with a grade 1 concussion using the American Academy of Neurology and Virginia Neurologic Institute Standards. Players who failed the mental status examination were then assessed at 24 hours, 5 days, and 10 days postinjury using the neuropsychological measures administered during the baseline assessment. Neuropsychological tests were administered by research staff trained in test administration.

RESULTS

Neuropsychological test scores and self-reported symptoms of players who sustained 2 injuries (T2) were compared with test scores and symptoms of players who sustained a single injury (S) using a between-subjects multivariate analysis of variance (MANOVA). In addition, a within-subjects MANOVA was used to compare scores of players experiencing 2 injuries after their first (T1) and second (T2) injuries to determine if a second concussion produced a change in cognitive functioning. Additionally, players who were injured twice in close temporal proximity (mean separation, 33 days) were compared with players who sustained 2 injuries over 2 or more seasons (mean separation, 532 days). Finally, pre-season and postseason scores of players with 2 injuries were compared using a within-subjects MANOVA to examine changes over time.

Mean test scores for each group are presented in Table 1. The MANOVA analysis revealed that the test results of players with a single injury (S) did not differ significantly from those of players who sustained 2 injuries, either at the time of their first injury (T1; F = 4.2, P < .06) or second injury (T2; F = 1.09, P < .386). Within-subjects comparison of players who sustained 2 injuries after their first injury (T1) and second injury (T2) revealed no significant differences in test performance (F = 0.858, P < .514). Comparison of players' preinjury test scores with postseason performance after their second injury revealed a trend toward improved performance (F = 3.27, P < .108). When the group sustaining 2 concussions was analyzed separately, no differences were noted in test performance between players who sustained injuries in close proximity or in successive seasons (F = 1.12, P < .351).

Players' self-reported symptoms (headache, dizziness, and memory loss) were summed before completing the analyses (Table 2). Statistical examination of the total number of symptoms using χ² analyses revealed a significant effect for time. Both groups (S and T1) had a statistically significant increase in the number of players with symptoms (headache, dizziness, and memory loss) at 24 hours postinjury (χ² = 22, P < .001) and 5 days postinjury (χ² = 40, P < .001). In contrast, the number of players with symptoms at 10 days postinjury was not significantly different from the number with symptoms preinjury (χ² = 0.30, P < .50). Analyses of symptoms with respect to groups revealed significant differences in symptom reports (headache, dizziness, and memory loss) between group S (single injury) and group T1 after their first injury (χ² = 10.6, P < .005). Players who sustained 2 injuries did not evidence statistically significant differences in symptom reports after first injuries (T1) or second injuries (T2) (χ² = 1.41, P < .50). The proportion of patients reporting symptoms also did not differ for players sustaining injuries in close proximity and players sustaining more remote injuries.

DISCUSSION

Our analyses suggest that 2 grade 1 concussive injuries sustained at least 2 weeks apart during competitive American football did not result in significantly more neurocognitive impairment than a single concussive injury. Compared with players who sustained a single injury, players who sustained 2 injuries performed as well or better on all neuropsychological tests after their first and second concussions. In addition, after a second concussion, there was no evidence of a decrement in test performance relative to the performance observed after players' first concussions. Furthermore, players who sustained 2 concussions performed better on postseason assessments than on preseason examinations.

Analyses of self-reported symptoms revealed a significant effect for time after injury. The number of players reporting symptoms increased significantly after 1 or 2 injuries, but
Table 1. Test Scores in Players With 1 versus 2 Mild Head Injuries*

<table>
<thead>
<tr>
<th>Test</th>
<th>Time</th>
<th>Preseason</th>
<th>24 h Postinjury</th>
<th>5 d Postinjury</th>
<th>10 d Postinjury</th>
<th>Postseason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trail-Making A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>21</td>
<td>22</td>
<td>17.9</td>
<td>17</td>
<td>NA†</td>
<td></td>
</tr>
<tr>
<td>T₁</td>
<td>22.8</td>
<td>21.7</td>
<td>18.8</td>
<td>18.6</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>T₂</td>
<td>22.8</td>
<td>17.6</td>
<td>16.9</td>
<td>15.9</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td>Trail-Making B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>46.8</td>
<td>39</td>
<td>39.8</td>
<td>34.5</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>T₁</td>
<td>50.5</td>
<td>40.1</td>
<td>35.2</td>
<td>36.1</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>T₂</td>
<td>50.5</td>
<td>37.4</td>
<td>30.3</td>
<td>29.9</td>
<td>32.9</td>
<td></td>
</tr>
<tr>
<td>Symbol Digit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>55.7</td>
<td>57.8</td>
<td>62.2</td>
<td>61.3</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>T₁</td>
<td>62.5</td>
<td>59.2</td>
<td>65.9</td>
<td>70.0</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>T₂</td>
<td>62.5</td>
<td>61.5</td>
<td>68.8</td>
<td>71.4</td>
<td>71.4</td>
<td></td>
</tr>
</tbody>
</table>
| Paced Auditory Serial Addition
Task 3 |                 |           |                 |                |                 |            |
| S                         | 77              | 81.9      | 96              | 88.4           | NA              |            |
| T₁                        | 82.5            | 86.7      | 94.4            | 93.8           | NA              |            |
| T₂                        | 82.5            | 92.1      | 96.0            | 94.6           | 94.3            |            |
| Paced Auditory Serial Addition
Task 4 |                 |           |                 |                |                 |            |
| S                         | 65              | 62        | 78.5            | 88.1           | NA              |            |
| T₁                        | 72.4            | 77.1      | 90.8            | 88.1           | NA              |            |
| T₂                        | 72.4            | 86.6      | 90.2            | 93             | 88.4            |            |

*S indicates 1 concussion (control); T₁, 2 concussions (first injury); and T₂, 2 concussions (second injury).
†Not available.

Table 2. Number of Players Reporting Postconcussive Symptoms*

<table>
<thead>
<tr>
<th>Time</th>
<th>No. Reporting Headache</th>
<th>No. Reporting Dizziness</th>
<th>No. Reporting Memory Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>T₁</td>
<td>T₂</td>
</tr>
<tr>
<td>Preseason</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>24 h postinjury</td>
<td>8</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5 d postinjury</td>
<td>4</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>10 d postinjury</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*S indicates 1 concussion (control); T₁, 2 concussions (first injury); and T₂, 2 concussions (second injury).

Symptom reports essentially returned to baseline by 10 days postinjury in both groups. The most commonly reported symptom in both groups was headache, but players who sustained 2 concussions reported more symptoms after their first and second concussions when compared with players who sustained a single concussion. Despite the presence of a differential response to the first injury, the frequency of players' symptoms after first and second injuries revealed no statistically significant increase in symptoms after a second injury, whether this injury occurred in close proximity to the first injury or at a more remote time. In other words, even though one group of players experienced more symptoms after their first injury, the responses to their first and second concussions were remarkably similar. Although interesting, the significance of these findings is not entirely clear. Differences in symptom reports could be due to normal variations in injury response accentuated by selective matching. In the future, variability in symptom reports after injury can be examined to assess whether players who experience prominent self-reported symptoms after a concussion are at greater risk for a second concussion.

Despite our findings, several methodologic issues merit discussion. First, the base rate of documented multiple injuries in our sample was quite low (6%). As such, our data are based on a small sample of players who may not adequately represent the population of players who typically sustain multiple injuries. Second, all of our players sustained grade 1 concussions by contemporary classification standards. Although the effect of injury severity is generally consistent across players, the cumulative effects of more severe injuries are unknown. Third, the timing of injuries in our study was variable. For example, only 2 players experienced a second injury within 2 weeks of their first injury. In fact, 7 players did not even sustain both injuries in the same year but rather within 12 to 24 months. Because neurocognitive impairment and neurobehavioral symptoms after 1 concussion resolve rather rapidly, the extended time between injuries may have limited the in-
teraction between the first and second injuries. Most importantly, even though we observed no differences between players with proximal versus remote injuries, our sample was too small to definitively answer questions about injury proximity. Finally, none of our players sustained more than 2 concussions, which limits direct comparison with studies assessing players with as many as 10 concussions.4

In addition to sample size, injury frequency, and the timing of injuries, test sensitivity issues require comment. For example, a number of neuropsychological tests are susceptible to practice effects.10 In our study, players who were injured twice were exposed to all tests on at least 7 occasions. Actually, despite being injured, players evidenced improved performance over time regardless of testing time (24 hours, 5 days, 10 days) or injury status (1 or 2 concussions). As such, the genuine neurocognitive consequences of concussions may be obscured by considerable exposure to tests. Of course, an injury with serious neuropsychological consequences would most likely reduce the influence of practice effects, but there was no evidence of a significant decline in neuropsychological test performance for any player in our sample.

A final issue deserving attention is the effect of group research on individual responses to concussion. For example, neurocognitive test data and symptom reports document variability in response to concussions with apparently equivalent clinical features such as duration of posttraumatic amnesia. In other words, the group that experienced 2 concussions did report more symptoms after their first injury, and this reporting continued after their second concussion. Consequently, group studies using aggregated data may obscure differential responses to and recovery from injury. In order to address this issue, investigators have recently recommended using reliable change indices (RCIs) when conducting research.11 RCIs are calculated using preinjury and postinjury scores, with mathematical consideration given to the standard error measurement and test reliability. In essence, RCI is a type of effect size. Calculating effect sizes of injuries for individual players may yield information that would be lost when summing group data. For example, players with large injury effects can be examined independently for relationships among injury severity, neurocognitive functioning, and neurobehavioral symptoms.

In spite of the study's limitations, our data suggest that 2 concussions do not result in a statistically or clinically significant increase in neurocognitive deficits relative to a single concussion. There is also no compelling evidence that self-reported symptoms are more common or severe after a second injury. Unfortunately, methodologic limitations do not permit generalization of these data to populations in whom injuries may be more frequent, may occur in closer temporal proximity, or may be more severe. Nonetheless, as documented by other studies, our data do suggest that self-reported symptoms may be sensitive indicators of postinjury neuropsychological impairment.2 As such, the presence of symptoms should be given serious consideration in return-to-play decisions, regardless of neuropsychological test performance.1 In any case, further research is needed to more closely examine the effect of multiple concussions on neuropsychological function. Until then, we can have modest confidence in the fact that, although undesirable, 2 grade 1 concussions occurring at least 2 weeks apart did not appear to produce significantly greater impairment than a single injury, at least in this population of collegiate football players.

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REFERENCES

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. 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, 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).  

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’s 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, non-contact 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 (e.g., 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. 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. Rotation 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.

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 "slopped down," fatigue, trouble sleeping, drowsiness, sensitivity to light or noise, LOC, blurred vision, difficulty remembering, or difficulty concentrating. 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." Although the definition received widespread consensus in 1966, more contemporary opinion (as concluded at the First International Conference on Concussion in Sport, Vienna, 2001) 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. 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.

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.

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. 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. Functional imaging technologies (eg, positron emission tomography [PET], single-photon emission computed tomography [SPECT], and functional MRI [fMRI]) are also yielding promising early results and may help define concussion recovery. 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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.

Table 1. American Academy of Neurology Concussion Grading Scale\textsuperscript{4}

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (mild)</td>
<td>Transient confusion; no LOC; symptoms and mental status abnormalities resolve (&lt;15 \text{ min})</td>
</tr>
<tr>
<td>2 (moderate)</td>
<td>Transient confusion; no LOC; symptoms and mental status abnormalities last (&gt;15 \text{ min})</td>
</tr>
<tr>
<td>3 (severe)</td>
<td>Any LOC</td>
</tr>
</tbody>
</table>

\*LOC indicates loss of consciousness.

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.\textsuperscript{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.\textsuperscript{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\textsuperscript{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.\textsuperscript{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.\textsuperscript{34,41} However, more recent, 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.\textsuperscript{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.\textsuperscript{42} More research is needed in this area to help improve clinical decision making.

It has been suggested that LOC and amnesia, especially when prolonged, should not be ignored,\textsuperscript{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)\textsuperscript{4} 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 Gradings Scale (Table 2),\textsuperscript{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*

<table>
<thead>
<tr>
<th>Grade 1 (mild)</th>
<th>Grade 2 (moderate)</th>
<th>Grade 3 (severe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No LOC, PTAT &lt;30 min, PCSS&lt;24 h</td>
<td>LOC &lt;1 min or PTAT =30 min &lt;24 h or PCSS =24 h &lt;7 d</td>
<td>LOC ≥1 min or PTAT ≥24 h or PCSS ≥7 d</td>
</tr>
</tbody>
</table>

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

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. 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. Although many clinicians deviate from these recommendations and are more liberal in making RTP decisions, recent studies by Guskiewicz and McCrea et al 12,29 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 to 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 sports 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. 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. Ide-
ally, preseason baseline testing is conducted before athletes are exposed to the risk of concussion during sport participation (e.g., 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 (e.g., 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 ensure adequate planning time (e.g., 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 (e.g., 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 longer 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 “slow down”; trouble falling asleep; sleeping more than usual; fatigue; drowsiness; sensitivity to light or noise; unsteadiness or loss of balance; feeling “dinger,” dazed, or stunned; seeing stars or flashing lights; ringing in the ears; and double vision. Self-reported symptoms are referenced by many of the concussion grading scales. 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.

A number of concussion symptom checklists and scales 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 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. Obtaining a baseline symptom score is helpful to establish any preexisting symptoms attributable to factors other than the head injury (e.g., 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 (e.g., sport sideline, locker room, and clinic). The SAC includes measures of orientation, immediate memory, concentration, and delayed recall that sum to 30 points. 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 and validity 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. The SAC is also sensitive to detecting more severe neurocognitive changes in injured athletes with LOC or amnesia associated with their concussions. 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. As with neuropsychological testing, sensitivity and specificity of the SAC in concussion assessment are maximized when individual baseline test data are available.
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.61-62 The BESS has established good test-retest reliability and good concurrent validity when compared with laboratory forceplate measures52,62 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 concussive literature.20,21,25,29,48,52,58,59,65-69 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.24,28,29,41,50-52,57,65,66,71-75 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.24,28,29,41,50-52,57,59,66,69,71-75 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. Barr76 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 functioning41 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).24,41,51,53,66,71,75,78-84 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
practice effects. Collie et al.\(^7\) 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.\(^7\) 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.\(^24,41,50,73,75,83\) 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 3. Common Neuropsychological Tests Used in Sport Concussion Assessment

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

### Table 4. Computerized Neuropsychological Tests

<table>
<thead>
<tr>
<th>Neuropsychological Test</th>
<th>Developer (Contact Information)</th>
<th>Cognitive Domains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated Neuropsychological Assessment Metrics (ANAM)</td>
<td>National Rehabilitation Hospital and Assistive Technology and Neuroscience Center, Washington, DC (<a href="mailto:jsb2@mgh.edu">jsb2@mgh.edu</a>)</td>
<td>Simple Reaction Metrics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sternberg Memory</td>
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<tr>
<td></td>
<td></td>
<td>Math Processing</td>
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<tr>
<td></td>
<td></td>
<td>Continuous Performance</td>
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<tr>
<td></td>
<td></td>
<td>Matching to Sample</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spatial Processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Code Substitution</td>
</tr>
<tr>
<td>CogSport</td>
<td>CogState Ltd, Victoria, Australia (<a href="http://www.cogsport.com">www.cogsport.com</a>)</td>
<td>Simple Reaction Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complex Reaction Time</td>
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<tr>
<td></td>
<td></td>
<td>One-Back</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuous Learning</td>
</tr>
<tr>
<td>Concussion Resolution Index</td>
<td>HeadMinder Inc, New York, NY (<a href="http://www.headminder.com">www.headminder.com</a>)</td>
<td>Reaction Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cued Reaction Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual Recognition 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual Recognition 2</td>
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<td></td>
<td></td>
<td>Animal Decoding</td>
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<tr>
<td></td>
<td></td>
<td>Symbol Scanning</td>
</tr>
<tr>
<td>Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)</td>
<td>University of Pittsburgh Medical Center, Pittsburgh, PA (<a href="http://www.impacttest.com">www.impacttest.com</a>)</td>
<td>Verbal Memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual Memory</td>
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<tr>
<td></td>
<td></td>
<td>Information Processing Speed</td>
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<tr>
<td></td>
<td></td>
<td>Reaction Time</td>
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<tr>
<td></td>
<td></td>
<td>Impulse Control</td>
</tr>
</tbody>
</table>
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. Balance testing may provide additional information to assist the clinician in the decision-making process of whether to disqualify an individual after a concussion. 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. 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. 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 neuropsychological levels. Lovell et al found significant memory deficits 36 hours postinjury in athletes who were symptom free within 15 minutes of a mild concussion. Guskiewicz et al 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 & the American Academy of Neurology 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. Merrill 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.

Once an athlete has suffered a concussion, he or she is at increased risk for subsequent head injuries. Gusiewicz et al 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. Players also had a 3-fold greater risk for subsequent concussions in the same season, whereas recurrent, in-season injuries occurred within 10 days of the initial injury 92% of the time. In a similar study of high school athletes, Collins et al 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. 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 sub-

ttle 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.

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. Gusiewicz et al prospecively 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 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 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 reported that 15% of the children (mean = 8.34 ± 5.31 years) who were admitted to hospitals after MTBI suffered from a sport-related mechanism of injury. Another group 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. 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 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. 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. 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. 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 concussion 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. 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. The athlete should avoid activities that may increase symptoms (e.g., 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. 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. 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 (e.g., 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.

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 athlete 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 sequela 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.

ACKNOWLEDGMENTS

We gratefully acknowledge the efforts of Kent Scriber, PhD, ATC; Scott Anderson, MS, ATC; Michael Collins, PhD; Vito A. Perriello, Jr, MD, PhD; Karen Johnston, MD, PhD; and the Pronouncements Committee in the preparation of this document.

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## Graded Symptom Checklist (GSC)

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

**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)

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

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 (e.g., sleep disturbances or cognitive difficulties)

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: ____________
Summary and Agreement Statement of the 2nd International Conference on Concussion in Sport, Prague 2004

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Preamble
This paper is a revision and update of the Vienna consensus recommendations developed following the 1st International Symposium on Concussion in Sport. The Prague agreement statement is designed to build on the principles outlined in the original Vienna document and to develop further conceptual understanding of this problem. This document is developed for use by doctors, therapists, health professionals, coaches and other people involved in the care of injured athletes, whether at the recreational, elite or professional level.

Background Perspective
In November 2001, the 1st International Symposium on Concussion in Sport was held in Vienna, Austria. This meeting was organized by the International Ice Hockey Federation (IIHF) in partnership with the Federation Internationale de Football (FIFA) and the International Olympic Committee Medical Commission (IOC). As part of the resulting mandate for the future, the need for leadership and updates was identified. To meet that mandate the 2nd International Symposium on Concussion in Sport was organized by the same group and held in Prague, Czech Republic in November 2004.

The original aims of the symposia were to provide recommendations for the improvement of safety and health of athletes who suffer concussive injuries in ice hockey, football (soccer) as well as other sports. To this end a range of experts were invited to both meetings to address specific issues of epidemiology, basic and clinical science, injury grading systems, cognitive assessment, new research methods, protective equipment, management, prevention and long term outcome. At the conclusion of the initial conference, a small group of experts were given a mandate by the conference delegates and organizing bodies to draft a document describing the agreement position reached by those in attendance at that meeting. This document was co-published in the British Journal of Sports Medicine, Clinical Journal of Sport Medicine and Physician and Sportsmedicine.

The wider interest base resulting from the first meeting and document was reflected by the expanded representation. New groups at the second meeting included trauma surgeons, sport psychologists and others. This same group has produced the current document as an update of the original Vienna consensus document and includes a sideline assessment form with a pocket sized summary card for use by clinicians.

This protocol represents a work in progress and, as with all other recommendations or proposals, it must be updated as new information is added to the current state of the literature and understanding of this injury.

BACKGROUND ISSUES

Definition of Concussion
Over 35 years ago, the Committee on Head Injury nomenclature of the Congress of Neurologic Surgeons proposed a 'consensus' definition of concussion. This definition was recognized as having a number of limitations in accounting for the common symptoms of concussion. In the Vienna document, a revised consensus definition was proposed as follows:

Sports concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic

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biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously.
3. Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.
4. Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.
5. Concussion is typically associated with grossly normal structural neuroimaging studies.

No changes were made to the definition by the Prague Group beyond noting that in some cases post-concussive symptoms may be prolonged or persistent.

**Pathophysiological Basis of Concussion**

At this time, there is no existing animal or other experimental model that accurately reflects a sporting concussive injury. It is noted that in experimental models of more severe injury a complex cascade of biochemical, metabolic and gene expression changes occur. Whether similar metabolic changes occur in sports concussion however, remains speculative at this time.

**Concussion Grading Scales**

The Vienna recommendation that injury grading scales be abandoned in favor of combined measures of recovery to determine injury severity (and/or prognosis) and hence individually guide return to play decisions received continued support.

It was also noted that concussion severity could only be determined in retrospect after all concussion symptoms have cleared, the neurologic examination is normal, and cognitive function has returned to baseline. There is limited published evidence that concussion injury severity correlates with the number and duration of acute concussion signs and symptoms and/or degree of impairment on neuropsychological testing. The ongoing development of validated injury severity scales continues in the published literature.

**Subtypes of Concussion**

One of the issues that was speculated upon at the Vienna conference was whether concussion represents a unitary phenomenon with a linear spectrum of injury severity or whether different concussion sub-types exist. These sub-types may represent differences in clinical manifestations (confusion, memory problems, loss of consciousness), anatomic localization (eg, cerebral versus brainstem), biomechanical impact (rotational versus linear force), genetic phenotype (ApoE4 positive versus ApoE4 negative), neuropathological change (structural injury versus no structural injury) or an as yet undefined difference. These factors may operate independently or interact with each other. It is clear that the variations in clinical outcome with the same impact force require a more sophisticated approach to the understanding of this phenomenon than currently available.

**The Significance of Loss of Consciousness**

The traditional approach to severe traumatic brain injury utilizing loss of consciousness (LOC) as the primary measure of injury severity has acknowledged limitations in assessing the severity of sporting concussive injury. Findings in this field describe LOC association with specific early deficits but does not necessarily imply severity. As such the presence of LOC as a symptom would not necessarily classify the concussion as complex (see below).

**The Significance of Amnesia**

There is renewed interest in the role of post-traumatic amnesia and its role as a surrogate measure of injury severity. Published evidence suggests that the nature, burden and duration of the clinical post-concussive symptoms may be more important than the presence or duration of amnesia alone. Further it must be noted that retrograde amnesia varies with the time of measurement post-injury and hence is poorly reflective of injury severity.

**Pediatric Concussive Injury**

The general recommendations outlined in the Vienna document were originally designed for the management of adult sporting concussion. Agreement was reached however, that identified those recommendations as relevant and useful to management of children as well. In broad terms it was felt that the recommendations should be applicable to children (defined as 5–18 years of age) whereby children should not be returned to playing or training until clinically completely symptom free. In addition the concept of "cognitive rest" was introduced with special reference to a child's need to limit exertion with activities of daily living and to limit scholastic activities while symptomatic. There was also a recognition by the group that additional research is needed to better clarify the potential differences between adults and children with regard to recovery from injury and to develop cognitive assessment tools that better evaluate the younger athlete.

Formal cognitive assessment is currently problematic until late teen years due to the ongoing cognitive maturation that occurs during this period which, in turn, makes the utility of comparison to either the person's own baseline performance or to population norms limited.

Because of the different physiological response during childhood to head trauma a conservative return to play approach is recommended. It may be appropriate to extend the amount of time of asymptomatic rest and/or the length of the graded exertion in children and adolescents. Future research is needed in this area.

**A NEW CLASSIFICATION OF CONCUSSION IN SPORT**

Historically, concussions have been classified with a number of different grading systems. In the Vienna Statement,
this approach was abandoned. One of the key developments by the Prague Group is the understanding that concussion may be categorized for management purposes as either simple or complex.

Simple Concussion

In simple concussion, an athlete suffers an injury that progressively resolves without complication over 7–10 days. In such cases, apart from limiting playing or training while symptomatic, no further intervention is required during the period of recovery and the athlete typically resumes sport without further problem. Formal neuropsychological screening does not play a role in these circumstances although mental status screening should be a part of the assessment of all concussed athletes. Simple concussion represents the most common form of this injury and can be appropriately managed by primary care physicians or by certified athletic trainers working under medical supervision. The cornerstone of management is rest until all symptoms resolve and then a graded program of exertion before return to sport. All concussions mandate evaluation by a medical doctor.

Complex Concussion

Complex concussion encompasses cases where athletes suffer persistent symptoms (including persistent symptom recurrence with exertion), specific sequelae (e.g. convulsions, prolonged loss of consciousness (>1 minute) or prolonged cognitive impairment following the injury. This group may also include athletes who suffer multiple concussions over time or where repeated concussions occur with progressively less impact force. In this group, there may be additional management considerations beyond simple return to play advice. Formal neuropsychological testing and other investigations should be considered in complex concussions. It is envisaged that such athletes would be managed in a multidisciplinary manner by physicians with specific expertise in the management of concussive injury such as a sport medicine doctor with experience in concussion, sports neurologist or neurosurgeon.

Clinical Issues

Pre-participation Physical Examination

Recognizing the importance of concussion history, and appreciating the fact that many athletes will not recognize all the concussions they may have suffered in the past, a detailed concussion history is of value. Such a history may pre-identify athletes that fit into the “complex” category outlined above and provides an opportunity for the physician to educate the athlete in regard to the significance of concussive injury.

A structured concussion history should include specific questions as to previous symptoms of a concussion not just perceived number of past concussions. It is also worth noting that dependence upon the recall of concussive injuries by teammates or coaches has been demonstrated to be unreliable. The clinical history should also include information about all previous head, face or neck injuries as these may have clinical relevance to the present injury. It is worth emphasizing that in the setting of maxillofacial injuries and neck, co-

existent concussive injuries may be missed unless specifically assessed. Specific questions pertaining to disproportionate impact versus symptom severity matching may alert the clinician to a progressively increasing vulnerability to injury.

As part of the clinical history it is advised that details regarding protective equipment employed at time of injury be sought, both for recent and remote injuries. The benefit of this approach allows for modification and optimization of protective behavior and an opportunity for education.

It is specifically recommended that:

1. Both a baseline cognitive assessment (such as the Prague SCAT test in the absence of computerized neuropsychological testing) and symptom score is performed as part of the preparticipation evaluation.

2. Although formal baseline neuropsychological screening may be beyond the resources of many sports or individuals, it is recommended that in organized high risk sports consideration be given to having cognitive evaluation regardless of the age or level of performance.

Signs and Symptoms of Acute Concussion

The suspected diagnosis of sports concussion made on the sideline is applicable to both medical and non-medical personnel and can include clinical symptoms, physical signs, cognitive impairment and/or loss of consciousness.

If any one of the following symptoms or problems is present, a head injury should be suspected and appropriate management instituted. These will be summarized on the Sideline Concussion Assessment Tool (SCAT) that accompanies this document.

a) Cognitive Features

Unaware of period, opposition, score of game
Confusion
Amnesia
Loss of consciousness

b) Typical Symptoms (see SCAT for standard symptom scale)

Headache or pressure in the head
Balance problems or dizziness
Nausea
Feeling “dinged”, “foggy”, stunned or “dazed”
Visual problems (e.g. Seeing stars or flashing lights, double vision)
Hearing problems (e.g. Ringing in the ears)
Irritability or emotional changes

Other symptoms such as a subjective feeling of slowness and fatigue in the setting of an impact may indicate that a concussion has occurred or has not fully resolved.

c) Physical Signs

Loss of consciousness/impaired conscious state
Poor coordination or balance
Concussive convolution/impact seizure
Gait unsteadiness/loss of balance
Slow to answer questions or follow directions
Easily distracted, poor concentration
Displaying inappropriate emotions (e.g., laughing, crying)
Vomiting
Vacant stare/glassy eyed
Slurred speech
Personality changes
Inappropriate playing behavior (e.g., running the wrong direction)
Significantly decreased playing ability

Sideline evaluation of cognitive function is an essential component in the assessment of this injury. Brief neuropsychological test batteries that assess attention and memory function have been shown to be practical and effective. Such tests include the Maddocks questions and the Standardised Assessment of Concussion (SAC). It is worth noting that standard orientation questions (e.g., time, place, person) have been shown to be unreliable in the sporting situation when compared with memory assessment.

It is recognized however that abbreviated testing paradigms are designed for rapid concussion evaluation on the sidelines and are not meant to replace comprehensive neuropsychological testing which is sensitive to detect subtle deficits that may exist beyond the acute episode; nor should they be used as a stand alone tool for the ongoing management of sports concussions. It should also be recognized that the appearance of symptoms may be delayed several hours following a concussive episode.

**Convulsive and Motor Phenomena**

A variety of acute motor phenomena (e.g., tonic posturing) or convulsive movements may accompany a concussion. Although dramatic, these clinical features are generally benign and require no specific management beyond the standard treatment of the underlying concussive injury.

**Development of the Sport Concussion Assessment Tool (SCAT)**

In appendix 1, the SCAT is outlined. The intent was to create a standardized tool that could be used for patient education as well as for physician assessment of sports concussions. The SCAT was developed by combining the following existing tools into a new standardized tool:

3. Standardized Assessment of Concussion–SAC
4. Sideline Concussion Check–UPMC, Thinksafe, Sports Medicine New Zealand Inc and the Brain Injury Association
7. The UK Jockey Club Assessment of Concussion
8. Maddocks questions

The authors gave input through a process of collaboration and iterative review. The SCAT was evaluated for face content validity on the basis of scientific literature and clinical experience of the authors. The memory questions, specifically, were modified from the validated Maddocks questions to make these questions less football-specific.

**INVESTIGATIONAL ISSUES**

**Neuropsychological Assessment Post Concussion**

The application of neuropsychological testing in concussion has been shown to be of value and continues to contribute significant information in concussion evaluation. It has been demonstrated that cognitive recovery may precede or follow clinical symptom resolution suggesting that the assessment of cognitive function should be an important component in any return to play protocol. It must be emphasized however, that neuropsychological assessment should not be the sole basis of a return to play decision but rather be seen as an aid to the clinical decision making. Although neuropsychological screening may be performed or interpreted by other health care professionals, the final return to play decision should remain a medical one in which a multidisciplinary approach has been taken.

Neuropsychological testing should not be done while the athlete is symptomatic since it adds nothing to return-to-play decisions and it may contaminate the testing process by allowing for practice effects to confound the results. In certain cases however, serial post-injury follow up is valuable both as a means to encourage athlete compliance as well as for comparison purposes.

Overriding principles common to all neuropsychological test batteries is the need for and benefit of baseline pre-injury testing and serial follow-up. Recent work with computerized platforms however, suggests that performance variability may be a key measure for acute concussion diagnosis even in the absence of a baseline test. This strategy is currently the subject of ongoing research. Inherent problems with most neuropsychological tests include the normal ranges, sensitivity and specificity of tests and practice or learning effect as well as the observation that players may return to baseline while still symptomatic. Computerized testing utilizing infinitely variable test paradigms may overcome some of these concerns. Computerized testing also has the logistical advantage that the tests may be administered by the team physician (or be web-based) rather than requiring a neuropsychologist for a formal assessment. The strengths and weaknesses of such testing have been recently reviewed.

It is recommended that neuropsychological testing remain one of the cornerstones of concussion evaluation in complex concussion. It is not currently regarded as important in the evaluation of simple concussion. While this modality contributes significantly to both understanding of the injury and management of the individual, neuropsychological testing should not be the sole basis of management decisions, rather for continued time out or return to play decisions.

**Objective Balance Assessment**

Balance testing, either with computerized platforms or clinical assessment, may offer additional information in
concussed athletes and may be used as a part of the overall concussion management strategy, particularly where symptoms or signs indicate a balance component.\textsuperscript{58}

**Neuroimaging**

It was recognized in the Vienna agreement document that conventional structural neuroimaging is usually normal in concussive injury. Given that caveat, the following suggestions are made: Brain CT (or where available MR brain scan) contributes little to concussion evaluation but should be employed whenever suspicion of an intra-cerebral structural lesion exists. Examples of such situations may include prolonged disturbance of conscious state, focal neurologic deficit or worsening symptoms.

Newer structural MRI modalities including gradient echo, perfusion and diffusion weighted imaging have greater sensitivity for structural abnormalities however the lack of published studies as well as absent pre-injury neuroimaging data limits the usefulness of this approach in clinical management at the present time.

In addition, the predictive value of various MR abnormalities that may be incidentally discovered is not established at the present time. Promising new functional imaging (eg, PET/SPECT/fMRI) technologies, while demonstrating some compelling findings, are still at early stages of development.\textsuperscript{39-41}

Although neuroimaging may play a part in the assessment of complex sports concussions or more severe brain injury, it is not essential for simple concussive injury.

**Genetic Testing**

Genetic genotyping has been demonstrated to be of benefit in traumatic brain injury. Published studies have demonstrated that ApoE4 is a risk factor for adverse outcome following all levels of brain injury.\textsuperscript{42-48} Similarly ApoE4 has been shown to be a risk factor for the development of chronic traumatic encephalopathy on boxers.\textsuperscript{49} The significance of ApoE4 in sports concussion risk or injury outcome is unclear. Other published studies have noted the association of a particular calcium subunit gene abnormality with brain swelling following minor head trauma.\textsuperscript{50} Although still in the early stages of understanding, routine genetic screening cannot be recommended at the present time and furthermore physicians are urged to be mindful of the ethical implications of such testing.

**Experimental Concussion Assessment Modalities**

Different electrophysiological recording techniques such as, evoked response potential (ERP) and electroencephalogram (EEG) have demonstrated reproducible abnormalities in the post concussive state.\textsuperscript{51-53} However, not all studies reliably differentiated concussed athletes from controls.\textsuperscript{54-57} The clinical significance of these changes remains to be established.

In addition, biochemical serum markers of brain injury (including S-100b, NSE, MBP, GvAP) have been proposed as means by which cellular damage may be detected if present.\textsuperscript{58,59} However, there is currently not sufficient evidence to justify the use of these markers clinically.

**CONCUSSION MANAGEMENT**

**Acute Injury**

When a player shows ANY symptoms or signs of a concussion:

1. The player should not be allowed to return to play in the current game or practice.
2. The player should not be left alone; and regular monitoring for deterioration is essential over the initial few hours following injury.
3. The player should be medically evaluated following the injury.
4. Return to play must follow a medically supervised stepwise process.

A player should never return to play while symptomatic. "When in doubt, sit them out!"

**Return to Play Protocol**

As described above, the majority of injuries will be simple concussions and such injuries recover spontaneously over several days. In these situations, it is expected that an athlete will proceed rapidly through the stepwise return to play strategy.\textsuperscript{50}

During this period of recovery in the first few days following an injury, it is important to emphasize to the athlete that physical AND cognitive rest is required. Activities that require concentration and attention may exacerbate the symptoms and as a result delay recovery.

The return to play following a concussion follows a stepwise process:

1. No activity, complete rest. Once asymptomatic, proceed to level 2.
2. Light aerobic exercise such as walking or stationary cycling. No resistance training.
3. Sport specific exercise (eg, skating in hockey, running in soccer), progressive addition of resistance training at steps 3 or 4.
4. Non-contact training drills.
5. Full contact training after medical clearance.
6. Game play.

With this stepwise progression, the athlete should continue to proceed to the next level if asymptomatic at the current level. If any post concussion symptoms occur, the patient should drop back to the previous asymptomatic level and try to progress again after 24 hours.

In cases of complex concussion, the rehabilitation will be more prolonged and return to play advice will be more circumspect. It is envisaged that complex cases should be managed by physicians with a specific expertise in the management of such injuries.

An additional consideration in return to play is that concussed athletes should not only be symptom free but also should not be taking any pharmacological agents/medications that may effect or modify the symptoms of concussion. Where antidepressant therapy may be commenced during the
management of a complex concussion, the decision to return to play while still on such medication must be considered carefully by the clinician concerned (see below). In professional sport, where there are team physicians experienced in concussion management as well as access to immediate (ie, sideline) neuro-cognitive assessment, return to play management is often more rapid however must still follow the same basic principles: namely full clinical and cognitive recovery before consideration of return to play.

The Role of Pharmacological Therapy

Pharmacological therapy in sports concussion may be applied in two distinct situations. The first of these is the management of specific symptoms (eg, sleep disturbance, anxiety) in complex concussion and the second situation is where drug therapy is used to modify the underlying pathophysiology of the condition with the aim of shortening the duration of the concussion symptoms.61

In broad terms, this approach to management should be only considered in complex sports concussions and by clinicians experienced in concussion management.

Sports Psychology

In addition sport psychology approaches may have potential application in this injury, particularly in complex concussion.62 Care givers are also encouraged to evaluate the concussed athlete for affective symptoms such as depression as these may be common in concussion.60

OTHER ISSUES

Prevention

There is no clinical evidence that currently available protective equipment will prevent concussion. In certain sports, protective equipment may prevent other forms of head injury which may be an important issue for those sports.

Consideration of rule changes (ie, no head checking in ice hockey) to reduce the head injury rate may be appropriate where a clear-cut mechanism is implicated in a particular sport. Similarly, rule enforcement is a critical aspect of such approaches and referees play an important role.

An important consideration in the use of protective equipment is the concept of risk compensation.63 This is where the use of protective equipment results in behavioral change such as the adoption of more dangerous playing techniques, which can result in paradoxical increase in injury rates. This may be a particular concern in child and adolescent athletes where head injury rates are often higher than in adult athletes.64

Medical Legal Considerations

While agreement exists pertaining to principal messages conveyed within this document, the authors acknowledge that the science of concussion is at early stages and therefore management and return to play decisions remain largely in the realm of clinical judgment on an individualized basis.

Education

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues and the general public is a mainstay of progress in this field. Athletes and their health care providers must be educated regarding the detection of concussion, its clinical features, assessment techniques and principles of safe return to play. Methods to improve education including web-based resources, educational videos and international outreach programs such as Think First (www.thinkfirst.ca) are important in delivering the message. In addition, concussion working groups plus the support and endorsement of enlightened sport groups such as FIFA, IOC and IIHF who initiated this endeavor have enormous value and must be pursued vigorously.

The promotion of fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly coaches, parents and managers play an important part in ensuring these values are implemented on the field of play.

Research Methods

A number of research protocols and data evaluating concussion injury assessment, injury susceptibility and brain function post injury were presented at both the Vienna and Prague conferences. All of these techniques, while offering great potential for injury assessment, must be considered experimental at this time. Elite and professional teams are well placed to contribute to these efforts through athlete recruitment for studies demonstrating the scientific value of such approaches.

Such research is essential in contributing to the science of concussion and will potentially provide valuable information for such important issues as clinical management, return to play guidelines and long term outcome. Therefore, research should be continued and encouraged, both by academics and by sporting organizations.

Future

The issue of sports concussion management is continually evolving and the usefulness of expert consensus in establishing a standard of care has been demonstrated by the Vienna agreement. The consensus group established at that meeting has provided ongoing leadership in this field based on the initial mandate established at that time.1 We expect that this Prague agreement will be revised and updated at future meetings.

APPENDIX

Sport Concussion Assessment Tool (SCAT)

REFERENCES


**Sport Concussion Assessment Tool (SCAT)**

This tool represents a standardized method of evaluating people after concussion in sport. This Tool has been produced as part of the Summary and Agreement Statement of the Second International Symposium on Concussion in Sport, Prague 2004.

**Sports concussion** is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body, with an "impulsive" force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.
3. Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.
4. Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.
5. Concussion is typically associated with grossly normal structural neuroimaging studies.

**Post Concussion Symptoms**

Ask the athlete to score themselves based on how they feel now. It is recognized that a low score may be normal for some athletes, but clinical judgment should be exercised to determine if a change in symptoms has occurred following the suspected concussion event.

It should be recognized that the reporting of symptoms may not be entirely reliable. This may be due to the effects of a concussion or because the athlete's passionate desire to return to competition outweighs their natural inclination to give an honest response.

If possible, ask someone who knows the athlete well about changes in affect, personality, behavior, etc.

**Remember:** concussion should be suspected in the presence of ANY ONE or more of the following:
- Symptoms (such as headache), or
- Signs (such as loss of consciousness), or
- Memory problems

Any athlete with a suspected concussion should be monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

For more information see the "Summary and Agreement Statement of the Second International Symposium on Concussion in Sport" in the April, 2005 edition of the Clinical Journal of Sport Medicine (vol 15), British Journal of Sports Medicine (vol 39), Neurosurgery (vol 59) and the Physician and Sportsmedicine (vol 33). This tool may be copied for distribution to teams, groups and organizations. ©2005 Concussion in Sport Group

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**The SCAT Card**

(Sport Concussion Assessment Tool)

**Athlete Information**

**What is a concussion?** A concussion is a disturbance in the function of the brain caused by a direct or indirect force to the head. It results in a variety of symptoms (like those listed below) and may, or may not, involve memory problems or loss of consciousness.

**How do you feel?** You should score yourself on the following symptoms, based on how you feel now.

<table>
<thead>
<tr>
<th>Post Concussion Symptom Scale</th>
<th>None</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>&quot;Pressure in head&quot;</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Neck Pain</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Balance problems or dizzy</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Nausea or vomiting</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Vision problems</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Hearing problems / ringing</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>&quot;Don't feel right&quot;</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Feeling &quot;dinged&quot; or &quot;dazed&quot;</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Confusion</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Feeling like &quot;in a fog&quot;</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Fatigue or low energy</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>More emotional than usual</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

(follow up symptoms only)

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadness</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Nervous or Anxious</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

**What should I do?**

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

**Signs to watch for:**
Problems could arise over the first 24-48 hours. You should not be left alone and must go to a hospital at once if you:
- Have a headache that gets worse
- Are very drowsy or can't be awakened (woken up)
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused; are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on your feet; have slurred speech

Remember, it is better to be safe. Consult your doctor after a suspected concussion.

**What can I expect?**
Concussion typically results in the rapid onset of short-lived impairment that resolves spontaneously over time. You can expect that you will be told to rest until you are fully recovered (that means resting your body and your mind). Then, your doctor will likely advise that you go through a gradual increase in exercise over several days (or longer) before returning to sport.
Sport Concussion Assessment Tool (SCAT)

The SCAT Card
(Sport Concussion Assessment Tool)

Medical Evaluation

Name: __________________________ Date: __________________________

Sport/Team: __________________________ Mouth guard? Y N

1) SIGNS
Was there loss of consciousness or unresponsiveness? Y N
Was there seizure or convulsive activity? Y N
Was there a balance problem / unsteadiness? Y N

2) MEMORY
Modified Maddocks questions (check correct)

At what venue are we? __: Which half is it? __: Who scored last? __

What team did we play last? __: Did we win last game? __

3) SYMPTOM SCORE
Total number of positive symptoms (from reverse side of the card) = _______

4) COGNITIVE ASSESSMENT

5 word recall

Immediate Delayed
(Examples) (after concentration tasks)

Word 1 ________ cat ________
Word 2 ________ pen ________
Word 3 ________ shoe ________
Word 4 ________ book ________
Word 5 ________ car ________

Months in reverse order:
Jun-May-Apr-Mar-Feb-Jan-Dec-Nov-Oct-Sep-Aug-Jul (circle correct) or

Digits backwards (check correct)

5-2-8 ________ 3-9-1 ________
6-2-9-4 ________ 4-3-7-1 ________
8-3-2-7-9 ________ 1-4-9-3-6 ________
7-3-9-1-4-2 ________ 5-1-8-4-6-8 ________

Ask delayed 5-word recall now

5) NEUROLOGIC SCREENING

Pass Fail

Speech ________ ________
Eye Motion and Pupils ________ ________
Pronator Drift ________ ________
Gait Assessment ________ ________

Any neurologic screening abnormality necessitates formal neurologic or hospital assessment

6) RETURN TO PLAY
Athletes should not be returned to play the same day of injury.
When returning athletes to play, they should follow a stepwise symptom-limited program with all stages of progression. For example:
1. rest until asymptomatic (physical and mental rest)
2. light aerobic exercise (e.g. stationary cycle)
3. sport-specific exercise
4. non-contact training drills (start light resistance training)
5. full contact training after medical clearance
6. return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur.
Resistance training should only be added in the later stages.
Medical clearance should be given before return to play.

Instructions:
This side of the card is for the use of medical doctors, physiotherapists or athletic therapists. In order to maximize the information gathered from the card, it is strongly suggested that all athletes participating in contact sports complete a baseline evaluation prior to the beginning of their competitive season. This card is a suggested guide only for sports concussion and is not meant to assess severe forms of brain injury. Please give a COPY of this card to the athlete for their information and to guide follow-up assessment.

Signs:
Assess for each of these items and circle Y (yes) or N (no).

Memory: If needed, questions can be modified to make them specific to the sport (e.g. "pencil versus "ball")

Cognitive Assessment:
Select any 5 words (an example is given). Avoid choosing related words such as "dark" and "moon" which can be recalled by means of word association. Read each word at a rate of one word per second. The athlete should not be informed of the delayed testing of memory (to be done after the reverse months and/or digits). Choose a different set of words each time you perform a follow-up exam with the same candidate.

Ask the athlete to recite the months of the year in reverse order, starting with a random month. Do not start with December or January. Circle any months not recited in the correct sequence.

For digits backwards, if correct, go to the next string length. If incorrect, read trial 2. Stop after incorrect on both trials.

Neuromuscular Screening:
Trained medical personnel must administer this examination. These individuals might include medical doctors, physiotherapists or athletic therapists.

Speech should be assessed for fluency and lack of slurring. Eye movement should reveal no diplopia in any of the four planes of movement (vertical, horizontal and both diagonal planes). The pronator drift is performed by asking the patient to hold both arms in front of them, palms up, with eyes closed. A positive test is pronating the forearm, dropping the arm, or drift away from midline. For gait assessment, ask the patient to walk away from you, turn and walk back.

Return to Play:
A structured, graded exertion protocol should be developed, individualized on the basis of sport, age and the concussion history of the athlete. Exercise or training should be commenced only after the athlete is clearly asymptomatic with physical and cognitive rest. Final decision for clearance to return to competition should ideally be made by a medical doctor.

For more information see the "Summary and Agreement Statement of the Second International Symposium on Concussion in Sport" in the April 2005 Clinical Journal of Sport Medicine (vol 15), British Journal of Sports Medicine (vol 39), Neurosurgery (vol 59) and the Physician and Sportsmedicine (vol 33). ©2005 Concussion in Sport Group
symptoms typically follows a sequential course." Fifth, "concussion is typically associated with grossly normal structural neuroimaging studies." All five of these conclusions are supported by current evidence.

No single concussion grading scale was endorsed by the conference—perhaps in part because experts who had produced grading scales of their own were at the writing table. In place of a single grading scale and in the absence of any scientifically validated return-to-play guidelines, the participants recommended the use of a clinical construct based on an assessment of recovery from injury and graded return to play. This construct includes the sideline evaluation of signs and symptoms of concussion as well as repeated assessments until all postconcussion symptoms resolve. It was recommended that a scale of postconcussion symptoms be used for both the initial sideline assessment and subsequent assessments. (See Appendices 2 and 3 for examples of a symptom checklist and a postconcussion symptom scale, respectively.) The conference participants concluded that sideline evaluation, including neurological assessment and mental status testing, is an essential component in evaluating sports-related concussion. I believe that these recommendations are sound and are not controversial.

Another consensus of this group was that "neuropsychological testing is one of the cornerstones of concussion evaluation and contributes significantly to both understanding of the injury and management of the individual." It was suggested that the computer-based programs Immediate Postconcussion Assessment and Cognitive Testing (ImPACT), CogSport, Automated Neuropsychological Assessment Metrics (ANAM), Sports Medicine Battery, and HeadMinder may have advantages over paper-and-pencil neuropsychological tests such as the McGill Abbreviated Concussion Evaluation (ACE) and the Standardized Assessment of Concussion (SAC). This is the first time that neuropsychological testing has been so strongly advocated in a concussion-in-sport consensus statement.

A new initiative that emerged from this group was the recommendation that return to play after concussion should follow a stepwise process. In this protocol, the injured athlete initially follows a regimen of complete rest until he or she is asymptomatic without activity. This initial stage is followed by one in which the athlete engages in light aerobic exercise, such as walking or stationary cycling. Having successfully completed that second stage, the athlete moves on to sport-specific training (for example, skating drills in hockey or running in soccer). The athlete then progresses from that third stage to a fourth one involving noncontact training drills, then to a fifth one in which full-contact training drills are allowed before receiving medical clearance to return to game play. It was recommended that this stepwise progression be followed and that the athlete proceed to the next level if asymptomatic at the current level. If any symptoms occur after ascending to a given level, the athlete should drop back down to the level at which he or she had been asymptomatic.

Although I believe that this is a prudent protocol for cases in which athletes have been away from play for weeks or a month or more after a concussion, I do not think that this protocol is necessary for athletes who are allowed to return to play within a week.

Another observation to emerge from the Vienna conference was that because the brain is not an organ that can be conditioned to withstand concussive injury, there are relatively few means by which such injury can be minimized in sports. Thus, perhaps the most important ways to reduce or prevent concussions are rule changes and rule enforcement. The authors acknowledged that the science of studying concussion is at an early stage and that, as a result, decisions regarding concussion management and return to play lie largely in the realm of clinical judgment and must be made on an individual basis.

The group concluded that whenever a player shows any symptoms or signs of concussion, he or she should not be allowed to return to play in the current game or practice, should not be left alone, should undergo regular monitoring for deterioration of condition, should undergo medical evaluation after the injury, and that return to play should follow a medically supervised, stepwise process. It was emphasized that the player should never return to play while symptomatic and that the adage "when in doubt, sit them out" should be followed. I believe these conclusions are sound, especially with regard to return-to-play issues.

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

In my opinion, this position statement, which was published in 2004 in the Journal of Athletic Training, is the most comprehensive document published to date on sports-related concussion. The writing team was chaired by Kevin Guskiewicz, Chair of the Department of Sport and Exercise Science at the University of North Carolina, and included seven other recognized experts in the field of concussion. The writing process took more than a year and resulted in a document that comprises 36 specific recommendations and contains sections on defining and recognizing concussion; evaluating and making return-to-play decisions; and assessment tools, including instruments for postconcussion symptom assessment, cognitive screening, postural stability assessment, and neuropsychological testing (with subsections devoted to computerized neuropsychological tests and neuropsychological testing methods). It also contains sections on when to refer an athlete to a physician after a concussion and when to disqualify an athlete, as well as sections on special considerations for the young athlete, home care, and equipment issues.

As a reference source on the entire subject of sport concussion as well as for its comprehensive bibliography source on sport concussion, I strongly endorse this document.

Summary and Agreement Statement of the 2nd International Conference on Concussion in Sport, Prague 2004

The same organizational bodies that convened the First International Conference on Concussion in Sport in Vienna in 2001, namely the International Ice Hockey Federation, FIFA, and the IOC, convened a second conference on concussion in sport in Prague in November 2004. At the conclusion of the Prague conference, a small writing group composed of the same individuals who were involved with the Vienna document of 2001 was given the task of drafting a document describing the agreement positions reached by those in attendance at the meeting on
Concussion consensus statements

a variety of topics related to sport concussion. These topics included epidemiology, basic and clinical science, injury grading systems, cognitive assessment, new research methods, protective equipment, management, prevention, and long-term outcomes. Like the first document, this second document was published concurrently in the British Journal of Sports Medicine, the Clinical Journal of Sport Medicine, and Physician and Sports Medicine.5

This second international conference on concussion in sport was considerably more widely attended than the first and had a much greater representation from new groups, such as trauma surgeons and sports psychologists. The summary and agreement statement included a new pocket-sized, sideline-assessment summary card for use by clinicians. No significant breakthroughs in scientifically validated information on concussion had occurred between the two conferences; therefore, the second document might best be viewed as a modest updating of the first. One of the most meritorious recommendations from that statement was the one that concussion severity should only be determined after the following criteria have been met: 1) all signs and symptoms of concussion have cleared; 2) the results of neurological examination have returned to normal; and 3) the results of any neuropsychological tests or other cognitive function tests that might have been performed have returned to baseline or above.

Noting that brief loss of consciousness does not necessarily correlate with concussion severity; despite its association with early neuropsychological deficits, the participants recommended that loss of consciousness not be relied on as a measure of concussion severity. Another recommendation was that pediatric cases could be managed using guidelines similar to those used in caring for adult patients.

The authors also elaborated on the concept of “cognitive risks.” They suggested that scholastic activities and activities of daily living be modified while an athlete is still symptomatic following a concussion, because vigorous pursuits might intensify or prolong postconcussion symptoms.

Perhaps the most contentious recommendation was the suggestion that concussions could be divided into the following two categories. 1) A case of simple concussion was defined as one in which neurological symptoms resolved within 7 to 10 days. 2) A case of complex concussion was defined as one in which symptoms persisted longer than 10 days or the patient lost consciousness for longer than 1 minute, had a convulsive concussion, or had repeated concussions involving diminishing force. The writing group’s decision to use these two categories of concussion was not unanimous, because some members—including me—were certain that they would not refer to a concussion with symptoms lasting 10 days as a simple concussion. The word “simple” may, in fact, not be a good choice for describing any concussion.

Nonetheless, the group members agreed that the number, duration, and severity of total postconcussion symptoms were most important in determining concussion severity and that the combination of symptoms was more important than the single symptom of amnesia.

This document also described the motor phenomena, such as tonic posturing and convulsive movement, seen with convulsive concussion and emphasized that although the presentation is dramatic, the outcome is usually benign and this form of concussion requires no specific treatment beyond the usual concussion management.

Another less-than-unanimous conclusion was that neuropsychological assessment following concussion is definitely of value, but should not be performed until all signs and symptoms have resolved. A unanimous conclusion regarding neuropsychological testing was that it is one piece of the concussion management puzzle but should never be a sole criterion to determine when an athlete should be allowed to return to play.

The statements regarding concussion management and rehabilitation were largely the same as those found in the Vienna document.

Concussion (Mild Traumatic Brain Injury) and the Team Physician: A Consensus Statement

In 2006, the ACSM published a sports-related concussion consensus statement (Concussion [Mild Traumatic Brain Injury] and the Team Physician: A Consensus Statement) in Medicine Science and Sports and Exercise.4 Created as a reference tool for team physicians, this statement represented the collaborative effort of six major professional associations, including the American Academy of Family Physicians, the American Academy of Orthopedic Surgeons, the ACSM, the American Medical Society for Sports Medicine, the American Orthopedic Society for Sports Medicine, and the American Osteopathic Academy for Sports Medicine. The team physician consensus statement was endorsed by a number of additional organizations, including the American Osteopathic Association, the NATA, the North American Spine Society, the National Collegiate Athletic Association, the National Youth Sports Safety Foundation, the American Academy of Podiatric Sports Medicine, and the American Kinesiotherapy Association. The expert writing panel was chaired by Stanley A. Herring. I believe this is an extremely useful document. The major goal of the writing group was to provide an overview of selected medical issues that are of keen importance to team physicians responsible for athletes with concussion. The areas covered include concussion epidemiology, pathophysiology, game-day evaluation and treatment, post–game-day evaluation and treatment, diagnostic imaging, management principles, return-to-play decisions, complications of concussion, and prevention. Each section of the document begins with the panel’s consensus on what is essential and continues with what is desirable for the team physician to know and understand. This is the feature of this document that I personally find most useful. Categorized as essential were methods of recognizing and evaluating athletes with concussion, the necessity for individualized management and treatment of athletes with concussion, the need for return-to-play decisions to be based on clinical judgment, the importance of developing a game-day medical plan specific to concussion injury, and the necessity of documentation. The paucity of well-designed studies of concussion and its natural history was also noted. It was concluded that it would be desirable for the team physician to have the ability to coordinate a systematic approach for the treatment of athletes with concussion, to identify risk factors and implement appropriate treatment, to under-
stand the potential sequelae of concussive injuries, and to understand preventive strategies.

For a team physician, another extremely useful aspect of this document was that it was broken down in terms of game-day treatment (treatment on the field as well as treatment on the sideline) and post-game-day treatment, in terms of concussion evaluation, management, and return-to-play criteria. It was considered essential that before any athlete be allowed to return to play, he or she should be asymptomatic at rest and exertion and must remain asymptomatic with exertion. Other factors that were considered essential in return-to-play decisions, especially post-game-day decisions, were the severity of the current injury as documented primarily by the number and duration of concussion symptoms; the number, severity, and proximity of previous concussions; whether a severe injury had occurred in response to what appeared to be a minor blow; the age of the athlete (with heightened concern for trauma to the immature brain); the sport involved; and whether the athlete had any learning disabilities. In addition to persistent concussion symptoms, the following were considered contraindications to return to sport: abnormal results on neurological examination, signs or symptoms of concussion that manifest on exertion, and significant abnormalities on cognitive testing or imaging studies. This document encouraged team physicians to coordinate a group of individuals to implement progressive aerobic and resistive exercise challenge tests that the injured athlete would have to pass prior to full return to play and to recognize that challenging cognitive effort may exacerbate symptoms of concussion and retard recovery. Furthermore, it was recommended that the team physician discuss the status of injured athletes with parents, caregivers, teachers, certified athletic trainers, and the coaching staff within disclosure regulations.

Again, I found this to be a very useful document, especially for physicians on the sideline responsible for athletes who may have a cerebral concussion. This statement was similar to the Vienna and Prague documents in that it emphasized that concussion severity should be determined by the duration and number of postconcussion symptoms, not by whether there was brief loss of consciousness or even whether amnesia alone was one of the symptoms. This means that concussive severity should not be determined in most cases on the day of concussion, but rather only after all symptoms have resolved.

International Conference on Concussion in Sport, St. Moritz 2006

The final document to be briefly mentioned in this paper will be based on a conference that was held this past spring in St. Moritz, Switzerland. Because it is currently being written, the comments included here must be limited.

The document will focus at least in part on three areas in which there is some concern regarding the Prague statement. The first involves neuropsychological testing and its use, including the question of when it should be used in the management and assessment of concussion. The second involves the concept of simple versus complex concussion; and the third involves the question of whether the same concussion protocols should be followed in the management of cases involving young athletes as are followed in cases involving adult athletes. Although many other areas will be covered in the forthcoming document, these are three in which there may be significant variance from what was stated in the Prague document.

Conclusions

This subject is perhaps best summarized by the final comment in the 2004 Prague summary, which states, "This protocol represents a work in progress, and, as with all other recommendations or proposals, it must be updated as new information is added to the current state of the literature and understanding of this injury."

Appendix I

Summary and Agreement Statement of the First International Conference on Concussion in Sport, Vienna 2001 and Summary and Agreement Statement of the 2nd International Conference on Concussion in Sport, Prague 2004

Writing group members:

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

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Concussion consensus statements

Concussion (Mild Traumatic Brain Injury) and the Team Physician: A Consensus Statement

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Appendix 2
Postconcussion signs/symptoms checklist
(symptoms at time of concussion)

bell rung __________
depression __________
dinged __________
dizziness __________
drowsiness __________
excessive sleep __________
fatigue __________
feel “in a fog” __________
feel “slowed down” __________
headache __________
irritability __________
loss of consciousness __________
memory problems __________
nausea __________
nervousness __________
numbness/tingling __________
poor Balance __________
poor Concentration __________
pulling in the ears __________
padness __________
sensitivity to Light __________
sensitivity to Noise __________
trouble Falling Asleep __________
vacant stare/glassy eyed __________
vomiting __________

Appendix 3
Cantu Evidence-Based Grading System for Concussion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td>1 (mild)</td>
<td>No LOC*, PTA&lt; 30 min, PCSS &lt; 24 h</td>
<td></td>
</tr>
<tr>
<td>2 (moderate)</td>
<td>LOC &lt; 1 min or PTA ≥ 30 min &lt; 24 h or PCSS ≥ 24 h &lt; 7 d</td>
<td></td>
</tr>
<tr>
<td>3 (severe)</td>
<td>LOC ≥ 1 min or PTA ≥ 24 h or PCSS ≥ 7 d</td>
<td></td>
</tr>
</tbody>
</table>

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


References

2. Cantu RC: Concussion severity should not be determined until all post concussion symptoms have abated. Lancet Neurology 3:437–438, 2004

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