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Management of Cerebral Concussion in Sports: The Athletic Trainer's Perspective

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Objective: To present a new approach in the evaluation and management of concussion from the athletic trainer's perspective.

Background: The evaluation and management of concussion continues to be a controversial topic among sports medicine professionals. Inconsistent management, lack of objective data, and confusion concerning assessment techniques may lead to inappropriate decisions regarding when to return an athlete to competition after concussion. In this article, we provide recommendations and considerations for the certified athletic trainer in the management of concussion. We also present a quantifiable assessment technique that provides more information on which return-to-play decisions can be made; this technique can be used during the initial sideline examination as well as during subsequent follow-up examinations.

Recommendations: Certified athletic trainers and team physicians should consistently use appropriate grading scales. Assessment of concussion should include a symptom checklist, the Balance Error Scoring System, and the Standardized Assessment of Concussion, and the results should be compared with the athlete's normal baseline scores. Follow-up neuropsychological and postural stability testing is recommended. Return-to-play decisions should be based on the grade of concussion, scores on objective tests, and presence of concussive symptoms during exertional activities.

Key Words: mild head injury, neuropsychological testing, postural stability testing, grading scales

The evaluation and management of concussions continues to be a controversial topic among certified athletic trainers (ATCs) and other sports medicine professionals. Choices about assessment protocol and return-to-play decisions have been based on poorly validated guidelines and clinical judgment. With an incidence of 300 000 sport-related concussions per year[1] and the potential for catastrophic outcomes,[2] better guidelines for managing cerebral concussion in sport are needed.

The complexity of this topic may stem from a lack of agreement in the sports medicine community concerning the definition of, and the critical symptoms relating to, a cerebral concussion. The 1966 Committee on Head Injury Nomenclature[3] defined a cerebral concussion as a clinical syndrome characterized by ''immediate and transient impairment of neural functions, such as an alteration of consciousness, disturbance of vision and equilibrium due to brain stem involvement.'' It is important to note that an athlete sustaining a cerebral concussion does not have to lose consciousness. In fact, loss of consciousness (LOC) is reported in only 8.9% of those sustaining a concussion.[4] Because more than 90% of concussions do not result in LOC, many of these injuries go unreported or are not reported until the end of the practice or competition.[5] For this reason, it is important for the ATC and team physician to be aware of other signs and symptoms associated with concussion. These symptoms may include but are not limited to headache, confusion, tinnitus, dizziness, balance disturbance, blurred vision, nausea, and posttraumatic amnesia.[4,6]

The difficulty in using the current grading scales for evaluating concussion is that most are based on loss of consciousness and the presence of posttraumatic amnesia, which occur very infrequently, while essentially ignoring multiple symptoms that present in a variable pattern within this group of athletes. The result is that ATCs and physicians have difficulty distinguishing among the various degrees of concussion. The confusion and frustration with the current scales have resulted in many sports medicine professionals not using the grading scales for evaluation purposes. In a recent study, up to 63% of ATCs reported not using any scale for evaluating concussion.[7] The ramifications of not using a grading scale are compounded by the lack of a biological marker for making return-to-play decisions. Instead, decisions to return an athlete to competition are based largely on the initial evaluation and subsequent follow-up evaluations.

Our main purpose is to present the perspective of 3 ATCs on a more comprehensive approach for evaluating and managing concussion. In describing this new approach to managing concussion, we present a model for making return-to-play decisions that are not based solely on a guideline but rather on the athlete's symptoms and performance on objective tests such as the Balance Error Scoring System (BESS) and the Standardized Assessment of Concussion (SAC). This model is much like the functional performance model of injury management that ATCs are accustomed to using with musculoskeletal injuries.

A SYSTEMATIC APPROACH

A systematic approach to management of concussion requires that all sports medicine personnel involved in treating

athletes must be familiar with instruments, procedures, and recommendations for evaluation, follow-up care, and return-to-play decisions. Physicians are present at a relatively small percentage of practices and contests. Thus, the initial evaluation and management often is completed by an ATC. Physicians and ATCs should agree on definitions, procedures, and referral guidelines. Clear communication among sports medicine personnel is necessary to provide consistent and proper care to the athlete.

A systematic evaluation begins with baseline testing in the preparticipation physical examination. The baseline scores provide an individualized ''normal'' to be used for comparison should the athlete sustain a concussion. Obtaining baseline scores on a series of cognitive and postural stability tests is paramount, considering that, unlike orthopaedic injuries, there is no contralateral limb to use for comparison. Baseline scores are obtained for the BESS and the SAC, both of which can easily be readministered on the sideline or in the locker room after injury. A brief battery of neuropsychological tests and a more sophisticated balance test performed on a computerized forceplate can also be administered if these resources are available.[8,9]

Baseline testing should be conducted with the cooperation of the team physician and coaching staff. The neuropsychological and balance testing can be administered as part of the preparticipation physical examination or during the summer sessions if the athletes are available.

Table 1. Postconcussion Symptom Scale (0–6)*

Symptom	Preseason Baseline	Time of Injury	2 to 3 Hours Postinjury
Headache			
Nausea			
Vomiting			
Dizziness			
Poor balance			
Sensitivity to noise			
Ringing in ears			
Sensitivity to light			
Blurred vision			
Poor concentration			
Memory problems			
Trouble sleeping			
Drowsiness			
Fatigue			
Sadness/depression			
Irritability			
Neck pain			
Total score			

*0 = none, 6 = severe.

Recognition and Evaluation

Acute injury assessment begins with the observation and recognition that a concussion may have occurred. Loss of consciousness, although relatively infrequent, is the first consideration in concussion management. When the athlete sustains a concussion that results in LOC, a primary survey must be performed to determine if the airway or circulation has been compromised, causing a critical situation. Unconscious athletes must be treated as if they have also sustained a cervical spine injury. These athletes must be placed on a spine board and transported to the hospital for further evaluation. The athlete with an altered state of consciousness who is unable to communicate with the ATC regarding his or her symptoms should also be placed on a spine board and sent for evaluation of possible intracranial pathology.

Certified athletic trainers are most often presented with an athlete who has sustained a concussion but has not been rendered unconscious. Athletes commonly believe that having ''their bell rung'' is a natural part of the game and do not report receiving a concussion. Unlike ankle or knee injuries that result in obvious impairment, those athletes sustaining concussions are not always distinguishable.

Once the ATC has recognized a concussion and performed a primary survey to rule out life-threatening injuries, a thorough history must be obtained regarding any LOC, confusion, or amnesia. Because ATCs observe the occurrence of a concussion from the sideline, it is sometimes necessary to obtain information about the athlete from those who were on the field. This can include asking officials or teammates for information. Testing for amnesia and orientation is best done by asking questions of recent memory and not items such as name, date of birth, or specific date.[10] Most often, testing occurs on the sideline and should be performed at the end of the bench area, away from teammates and other distractions. Occasionally, it is necessary to perform the tests in the athletic training room or locker room because of the distraction from fans, teammates, or other sideline personnel. Test results are not environmentally sensitive, which allows for sideline scores to be compared with baseline test scores administered in other laboratory or classroom settings.[11]

Postconcussive Symptoms

Testing continues with the presentation of a postconcussion symptom scale (Table 1), which, in addition to being administered at preseason baseline, time of injury, and 2 to 3 hours postinjury, should also be administered daily until the athlete is asymptomatic. The athlete is asked to rate the severity of each concussive symptom on the list from 0 (none) to 6 (severe). This allows the clinician a more objective measure of symptom severity, and changes in symptoms can be quantified for better comparison. It is recommended that the athlete remain out of competition until symptom scores return to 0 or to baseline scores.

Cranial Nerve Testing

After reviewing the athlete's symptoms, assess the function of the cranial nerves. The cranial nerves can be tested quickly: sense of smell (I), eye tracking and pupil reactivity (III, IV, V), facial expressions (VII), biting down (V), swallowing (X), protrusion of the tongue (XII), and shoulder shrugs (XI).[12] Alterations of the cranial nerve responses may indicate a more severe head injury and the need for immediate referral of the athlete to a physician or transferal to the hospital.

Balance Error Scoring System

Once cranial nerve function is determined to be intact, the ATC should test equilibrium and balance on the BESS.[9] The BESS is a quantifiable version of a modified Romberg test for balance, consisting of 3 tests lasting 20 seconds each, performed on firm and foam surfaces. The athlete first stands with the feet narrowly together, the hands on the iliac crests, and

Table 2. Balance Error Scoring System (BESS)

Scorecard (No. of errors)	Firm Surface	Foam Surface
Double-leg stance		
Single-leg stance		
Tandem stance		
Total errors		
Total score		

the eyes closed. The athlete holds this stance for 20 seconds while the ATC records the number of balance errors. A balance error is operationally defined as opening the eyes, hands coming off the hips, taking a step, moving the hips into 30° or more abduction, lifting the forefoot or heel, or remaining out of testing position for more than 5 seconds. The test is repeated with a single-leg stance using the nondominant foot and again using a heel-toe stance with the nondominant foot in the rear. All 3 tests are performed on a firm surface (grass, turf, court) and again on a piece of medium-density foam. A piece of foam can easily be carried in a travel trunk or equipment bag for road games. The number of errors on each of the 6 tests are added for a total BESS score (Table 2).

Standardized Assessment of Concussion

Neuropsychological testing and testing of mental status are performed using the SAC. The SAC measures the immediate neurocognitive effects of concussion and is designed to assess orientation, immediate memory, concentration, and delayed memory.[13] Deficits in these cognitive functions are often associated with athletes sustaining a concussion.[14] Administration of the SAC takes 5 minutes; orientation, immediate memory, neurologic function, concentration, delayed recall, and symptoms during exertional testing are assessed.[13]

The scores obtained from these tests should be compared with the athlete's baseline scores obtained in the preseason screening process or physical examination. If a physician is present, the ATC should provide the physician with the scores and refer the athlete to the physician for definitive evaluation and classification of the severity of the concussion.

A classification guide that includes concentration, coordination, and cranial nerve assessment (3 Cs), along with the traditional landmarks of consciousness and amnesia, can be very useful to the ATC and team physician (Table 3). By using the BESS to identify problems with coordination and the SAC to detect impaired concentration, the ATC and team physician may have a more objective means of assessing an athlete's concussion.

MANAGEMENT

Once the athlete has been properly evaluated, the ATC and physician must decide on the best course of management for the athlete. This decision is based not only on the evaluation but also on any previous history of concussion and the potential for further injury. If the athlete was rendered unconscious for 1 minute or longer and continues to have disturbed sensorium, he or she should be transported to the hospital for further neurologic testing and imaging. The use of neuroimaging (magnetic resonance imaging and computerized tomography scanning) to assist in the evaluation and management of concussion has been debated. Magnetic resonance imaging has been reported effective in demonstrating contusions and larger cranial lesions, but often these neuroimaging devices are not sensitive enough to detect axonal damage resulting from a concussive blow.[15]

The goals in managing an athlete with a concussion should be to prevent a catastrophic outcome and to return the athlete to competition in a manner that minimizes both the time away from competition and, more importantly, the possibility of second-impact syndrome or more severe head injury. Obviously, this is a delicate balance and not an easy goal to achieve. The more objective information obtained during the decision process, the more comfortable the decision being rendered as to an athlete's ability to safely return to play.

The ATC is an invaluable member of the health care team, particularly when an athlete suffers a concussion. The ATC often has daily interaction and the opportunity to establish a trusting relationship with the athletes. This trust is a vital part of the management process. Athletes who do not report injuries or who underreport symptoms may be placing themselves at risk for a catastrophic outcome. Athletes may be more com-

Table 3. University of North Carolina Classification of Cerebral Concussion

Grade	Level of Consciousness	Cranial Nerves, Cognition,* and Coordination (3 Cs)	Headache
0 (mild)	No LOC†	Mild confusion but asymptomatic in 10 minutes; passes functional tests without recurrence of signs and symptoms	Possibly develops later
1 (mild)	No LOC	At least 1 of the following is present: 1. Abnormal cranial nerve function lasting <1 hour 2. Abnormal cognition lasting <1 hour 3. Abnormal coordination lasting < 3 days	Probable; lasts from 10 minutes to as long as 2 days
2 (moderate)	Brief LOC from 10 seconds to 1 minute or altered consciousness lasting <2 minutes	At least 1 of the following is present: 1. Abnormal cranial nerve function lasting >1 hour 2. Abnormal cognition lasting >1 hour 3. Abnormal coordination lasting longer than 3 days	Probable; lasts 24 hours to 4 days
3 (severe)	LOC >1 minute or altered consciousness lasting >2 minutes	2 of 3 Cs are abnormal for more than 24 hours	Likely; lasts longer than 4 days

*Cognition includes orientation, memory, concentration, and attention.
†LOC indicates loss of consciousness.

fortable reporting symptoms to an ATC, whom they see on a daily basis, rather than to a physician they do not see regularly. The ATC may also be better able to identify subtle signs that an athlete is suffering from a concussion by knowing the athlete's usual behavior and demeanor. It is paramount for the ATC to educate the athlete about the signs and symptoms of concussion and the dangers of second-impact syndrome, which can result from not reporting concussion symptoms to the ATC.

Return-to-Play Decisions

Like grading scales, a number of guidelines have been proposed for returning an athlete to competition after sustaining a concussion.[2,16–18] These guidelines are very conservative and are based less on scientific data and more on clinical experiences and educated estimates of time needed for the complications of concussion to resolve. Evidence suggests that athletes are frequently being returned to competition on a more aggressive timetable than the guidelines recommend.[4] A great deal of variation exists among the guidelines, but the consensus is that return to competition should not occur until the athlete is asymptomatic, both at rest and during exertion. The guidelines in Table 4 are based not only on severity of concussion but also on recent research addressing the sequelae of concussion (K. M. Guskiewicz, PhD, ATC, unpublished data, 2000).[19] It is important to remember that these are just guidelines for returning an athlete to competition. Each case should be reviewed on an individual basis to determine whether the individual is able to return safely to sport. Several factors should be considered when making this decision. The first is the athlete's prior concussion history. An athlete with a previous concussion during the season is at 3 to 4 times greater risk for suffering a second concussion.[4,20] The risk of concussion increases further after each subsequent concussion. Another factor to consider is the sport the athlete is playing. An athlete participating in a noncontact, low-risk sport will most likely be returned to competition sooner than an athlete returning to a high-risk, collision sport, such as football or wrestling. Early assessment and daily follow-up examinations allow the ATC and team physician to determine when the athlete is asymptomatic based on comparisons with baseline neuropsychological and postural stability tests. More importantly, they also allow clinicians to observe an athlete whose status is deteriorating due to possible intracranial pathology. These athletes must be identified and treated emergently.

Table 4. University of North Carolina Return-to-Play Guidelines After Concussion

Grade	Suggested Action
0	Remove the athlete from contest. Examine immediately for abnormal cranial nerve function, cognition, or coordination or other postconcussive symptoms at rest and with exertion. May return to contest if examination is normal and asymptomatic for 20 minutes. If any symptoms develop within 20 minutes, return that day is not permitted.
1	If athlete is removed from contest after developing symptoms, daily follow-up evaluations are necessary. May begin restricted participation when asymptomatic at rest and after exertional tests for 2 days. Unrestricted participation allowed if asymptomatic for 1 additional day and neuropsychological and balance testing normal.
2	Remove the athlete from contest and prohibit return that day. Examine immediately and at 5-minute intervals for evolving intracranial pathology. Reexamine daily. May return to restricted participation when athletic trainer and physician are assured the athlete has been asymptomatic at rest and with exertional testing for 4 days. Unrestricted participation if asymptomatic for an additional 2 days and performing restricted activities normally and comfortably.
3	Treat the athlete on field or court as if cervical spine injury has occurred. Immediate examination and reevaluation at 5-minute intervals for signs of intracranial pathology. Reexamine daily. Return is based on resolution of symptoms: 1. If symptoms totally resolve within first week, return to restricted participation when the athlete has been asymptomatic at rest and with exertion for 10 days. If asymptomatic for an additional 3 days of restricted activity, the athlete may return to full participation. 2. If symptoms do not resolve within the first week, the athlete may return to restricted participation when asymptomatic at rest and with exertion for 17 days. Return to unrestricted participation if asymptomatic an additional 3 days.

Note: If the athlete suffers a second concussion within 3 months of the first concussion, the athlete must be removed for twice the maximum time for the respective grade of concussion.

Establishing Protocol

The establishment of a specific protocol in managing concussion is necessary to maintain the consistency of care and ensures that proper procedures are followed when making decisions about returning athletes to competition. The protocol should cover procedures for the most mild injuries, in which the athlete is permitted to return to the game, to the most severe injuries, involving the presence of a variety of symptoms for days or weeks.

An athlete sustaining a grade 0 concussion who has successfully passed all tests on the sideline or in the locker room and has been asymptomatic for at least 15 minutes should perform exertional testing, such as sprints and push-ups, as well as sport-specific functional tests. Recurrent symptoms preclude the athlete from returning to participation. Postconcussive symptoms may manifest during these procedures due to increased intracranial pressure, indicating unresolved pathology. Athletes whose symptoms linger or return during testing should be removed from competition and reevaluated. Athletes sustaining concussions graded 1 through 3 need to undergo further, more sensitive testing at regulated intervals.

Neuropsychological and Postural Stability Testing

A more comprehensive neuropsychological test battery and more sophisticated postural stability testing can be performed in the clinic or athletic training room on subsequent postinjury days. The Neurocom Smart Balance Master System (Neurocom International, Inc, Clackamas, OR) has been used to quantify balance deficits and sensory organization problems resulting from concussion. Recovery curves have also been established that allow the clinician to determine if improved scores occur from learning or from an alleviation of concussive symptoms. Clinicians in settings without sophisticated forceplate systems should perform postural stability testing using the BESS as previously described. Researchers have de-

Table 5. Neuropsychological Test Battery

Neuropsychological Test	Function(s) Assessed
Stroop Color World Part 3	Mental flexibility and attention
Hopkins Verbal Learning	Verbal memory
Symbol Digit Modalities	Visual scanning and attention
Trail-Making B	Visual scanning, mental flexibility, and attention
Control Oral Word Association	Verbal fluency
Wechsler Digit Span Forward and Backward	Attention span

scribed a strong correlation between the BESS and more expensive platform balance systems.[21]

A suggested battery of neuropsychological tests (Table 5) should be given 24 hours after injury and again on the initial postinjury days until the athlete has returned to baseline on all tests. Along with the neuropsychological tests, the concussion symptom checklist should be administered to track changes in symptoms.

Using the Information

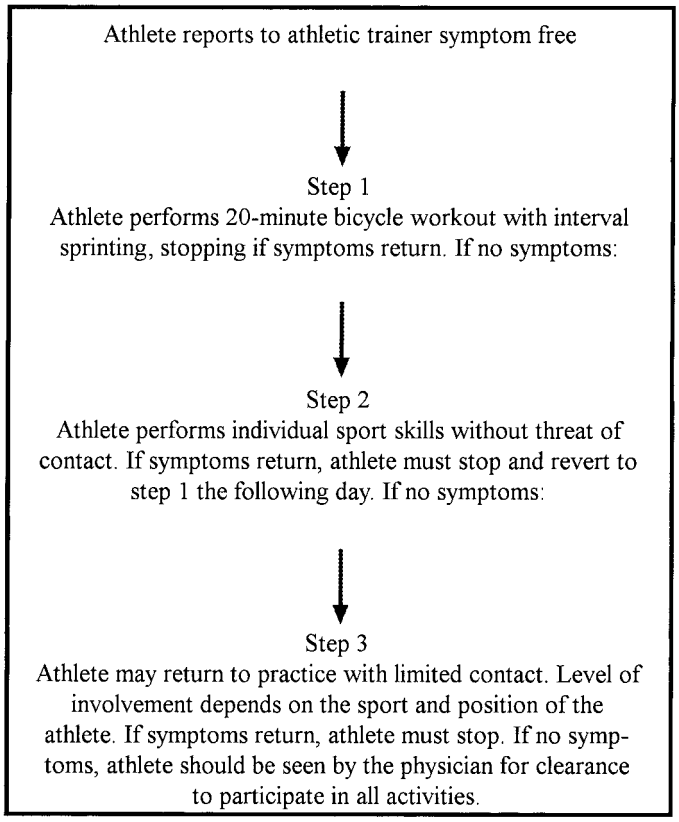
The testing protocol provides the clinician with objective, quantifiable data on the athlete from the establishment of a baseline ''normal'' to time of injury until full recovery. The frequent testing allows the clinician to make daily recommendations concerning recovery rather than holding an athlete out longer than necessary or returning the player to sport before recovery has occurred. Although guidelines are used to assist us with decision making, return-to-play decisions are based on the athlete's symptoms, test scores, and ability to perform exertional activities without an increase in symptoms.

Once an athlete is free of postconcussive symptoms, he or she is not immediately placed back into competition. Rather, the athlete is progressed back into activities with the ATC documenting any change in symptoms (Figure).

Athletes who do not experience recurrent symptoms and have returned to 95% of baseline scores on the cognitive and balance tests are good candidates for return-to-participation clearance by the physician. The methods used for returning the athlete to participation are similar to those employed by ATCs in deciding when to return an athlete after suffering a musculoskeletal injury. A window of protection is followed by successive performance-based criteria that, when achieved, advance the athlete to the next level of participation. A contact athlete may be able to participate in drills and activities wearing a jersey designating ''no contact.'' The athlete can work on skills and timing without the threat of contact and recurrent concussion. It is important that the coaching staff supports and complies with the noncontact activity, understanding that it may allow for a quicker and safer return to play for that athlete.

PREVENTION

Unlike musculoskeletal injuries, few strength and conditioning methods will help prevent further concussions. However, that does not mean no preventive measures can be taken to minimize recurrence of concussions and other head injuries. Again, athletes sustaining a concussion are at a 3-fold increased risk for future concussions, and that risk increases with each successive injury.[4,19]



Returning an athlete to competition after concussion.

In order to prevent recurrence, it is necessary to determine how the concussive incident occurred. Reviewing game or practice films may provide an opportunity to see the mechanism of injury: a direct blow, a blow from hitting the ground, or even a rotational component. More importantly, the film may help reveal poor techniques, such as leading with the head to tackle or block or heading a soccer ball incorrectly. Reviewing the tape with the athlete and the coach may be useful in improving the athlete's technique or changing the coach's teaching methods. Preventing another concussion may be the difference in an athlete's ability to return to participation during the season.

CONCLUSIONS

Recognition and proper assessment of concussion in athletes continues to be a difficult problem in the field of sports medicine. The difficulty stems from the inconsistent use of terms and guidelines available for evaluation. This confusion is made more problematic by a lack of objective information used in the assessment and follow-up care of athletes with concussions.

We have presented a systematic approach to evaluating and managing concussions based on objective, quantifiable data. Evaluation guidelines for grading concussions will allow for improved communication among caregivers and more consistency of care. Guidelines for return-to-play decisions after a concussion are based on quantifiable data and a model similar to the protocol for returning athletes to competition after musculoskeletal injury. As with any injury, the goal in managing players with concussions is to decrease the chance of recurrence. This is especially important considering the possibility,

although remote, of a catastrophic outcome from second-impact syndrome after a concussion. We hope that using this new, systematic approach to evaluation and management with objective guidelines will allow athletes to return to play in a safer, more consistent manner after a concussion.

REFERENCES

1. Thurman JD, Branche CM, Sniezek JE. The epidemiology of sports-related traumatic brain injuries in the United States: recent developments. *J Head Trauma Rehabil.* 1998;13:1–8.
2. Cantu RC. Guidelines for return to contact sports after a cerebral concussion. *Physician Sportsmed.* 1986;14(10):75–83.
3. Congress of Neurologic Surgeons. Glossary of head injury including some definitions of injury to the cervical spine. *Clin Neurosurg.* 1966; 14:424–445.
4. Guskiewicz KM, Weaver NL, Padua DA, Garrett WE Jr. Epidemiology of concussion in collegiate and high school football players. *Am J Sports Med.* 2000;28:643–650.
5. Torg J. *Athletic Injuries to the Head, Neck & Face.* St Louis, MO: Mosby-Year Book; 1991.
6. Barth JT, Macciocchi SN, Giordani B, Rimel R, Jane JA, Boll TJ. Neuropsychological sequelae of minor head injury. *Neurosurgery.* 1983;13: 529–533.
7. Ferrara MS, McCrea M, Peterson CL, Guskiewicz KM. A survey of practice patterns in concussion assessment and management. *J Athl Train.* 2001;36:145–149.
8. Guskiewicz KM, Perrin DH, Gansneder BM. Effect of mild head injury on postural stability in athletes. *J Athl Train.* 1996;31:300–306.
9. Guskiewicz KM, Riemann BL, Perrin DH, Nashner LM. Alternative approaches to the assessment of mild head injury in athletes. *Med Sci Sports Exerc.* 1997;29(7 suppl):S213–S221.
10. Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med.* 1995;5:32–35.
11. Onate JA, Guskiewicz KM, Riemann BL, Prentice WE. A comparison of sideline versus clinical cognitive test performance in collegiate athletes. *J Athl Train.* 2000;35:155–160.
12. Arnheim D, Prentice W. *Principles of Athletic Training.* 8th ed. St Louis, MO: McGraw-Hill; 1997.
13. McCrea M, Kelly JP, Randolph C, et al. Standardized assessment of concussion (SAC): on-site mental status evaluation of the athlete. *J Head Trauma Rehabil.* 1998;13:27–35.
14. Capruso D, Levin H. Cognitive impairment following closed head injury. *Neurol Trauma.* 1992;10:879–893.
15. Evans R. The post-concussion syndrome and the sequelae of mild head injury. *Neurol Clin.* 1992;10:815–847.
16. Practice parameter: the management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee. *Neurology.* 1997;48:581–585.
17. Jordan BD. Head injuries in sports. In: Jordan BD, Tsairas P, Warren RF, eds. *Sports Neurology.* Rockville, MD: Aspen Publishers Inc; 1989.
18. Kelly JP, Nichols JS, Filley CM, Lillehei KO, Rubinstein D, Kleinschmidt-DeMasters BK. Concussion in sports: guidelines for the prevention of catastrophic outcome. *JAMA.* 1991;266:2867–2869.
19. Guskiewicz KM, Barth JT. Head injuries. In: Schenk RC, Barnes RP, Behnke RS, eds. *Athletic Training and Sports Medicine.* 3rd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 1999:143–167.
20. Gerberich SG, Priest JD, Boen JR, Straub CP, Maxwell RE. Concussion incidents and severity in secondary school varsity football players. *Am J Public Health.* 1983;73:1370–1375.
21. Riemann BL, Guskiewicz KM. Effects of mild head injury on postural stability as measured through clinical balance testing. *J Athl Train.* 2000; 35:19–25.