Concussion Assessment and Management

Tamerah Hunt, PhD\textsuperscript{a,}* \text{and Chad Asplund, MD\textsuperscript{b}}

**KEYWORDS**

- Concussion
- Head injury
- Athletic training
- Assessment
- Management

Sport-related concussion is a common injury in athletes. However, it is frequently underreported, which makes the diagnosis a challenge. The management of sport-related concussions has changed significantly over the last several years. The previously used grading systems and return-to-play guidelines have been abandoned in favor of more individualized assessment and management. A multidisciplinary approach, including neuropsychological testing, is being used more frequently to assist in management. After recovery, it is recommended that athletes’ return-to-play progress is in a gradual, stepwise fashion while being monitored by a health care provider.

Concussions have reached near-epidemic proportions in contact sports at professional and amateur levels; there are an estimated 1.6 to 3.8 million sport-related concussions occurring in the United States annually.\textsuperscript{1} The effects of a concussion can have severe negative effects on athletes’ scholastic abilities and can sometimes end a career.

Proper assessment and management of a sport-related concussion is crucial, as repeat concussions can result in decreased neurocognitive functioning, increased symptomatology, and at times, catastrophic outcomes. Recently, there has been an abundance of research in an effort to better define, diagnose, manage, and treat concussion. 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. The purpose of this article is to discuss the current evidence available to assist practitioners in the diagnosis and management of concussion to ensure safe participation for all athletes.

**DEFINITION**

Sports-related concussion appears to result in transient symptoms with short duration. There are no universal agreements on the definition of concussion. The most

\textsuperscript{a} School of Allied Medical Professions, The Ohio State University, 2050 Kenny Road Suite 3100, Columbus, OH 43221, USA

\textsuperscript{b} Department of Family Medicine, Division of Sports Medicine, The Ohio State University, 2050 Kenny Road, Suite 3100, Columbus, OH 43221, USA

* Corresponding author.

\textit{E-mail address:} tamerah.hunt@osumc.edu (T. Hunt).


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commonly accepted and cited definition is based on functional status and the nature of medical signs and symptoms present at the time of injury.

Concussion has been defined as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.”\textsuperscript{2,3} This consensus from the First and Third International Conference for Concussion suggested five conditions for concussion:

1. Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive or rotational 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 neuropathologic changes, but the acute clinical symptoms rarely 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.

This accepted definition has changed the evaluation techniques and management of sports-related concussion for many medical professionals.

COMMONLY USED EVALUATION TOOLS

Recently, several agencies have produced position and consensus statements suggesting a multifaceted approach to assessment and management of concussion.\textsuperscript{4–6} The multifaceted approach captures the variability of deficits following injury. The recent addition of neuropsychological and balance assessment to the concussion assessment battery provides the clinician with additional information specific to areas commonly associated with concussion. The concussion assessment battery begins with physical evaluation and may contain imaging, self-reported symptoms, and sideline assessments; neuropsychological and postural testing provides the most comprehensive test battery for individualized concussion assessment.

**Physical Evaluation**

Physical evaluation typically occurs on the sideline or within the first few minutes of injury. When surveyed, more than 85% of physicians used the clinical examination as the primary assessment tool for concussion. Although physical examination is typically the first line of assessment, it is often combined with additional concussion assessment tools.\textsuperscript{7} The physical evaluation typically includes a complete history and an evaluation of nervous, motor, and sensory systems following injury.

A complete history provides information regarding the likelihood of previous concussion, symptoms occurring not related to current concussive injury, or post-concussive symptoms. Nervous evaluation typically consists of cranial nerve assessment with special emphasis on pupillary reflex. Motor system evaluation includes myotome strength testing for tone and ability with special emphasis on the cervical region and areas distal to the injury. Sensory assessment involves evaluation of dull and sharp sensation, bilateral sensation, and dermatome testing.
**Imaging**

The hallmark of sports-related concussion presents with functional deficits rather than structural deficits. There is good evidence that imaging techniques such as X-ray, MRI, and CT would be unable to detect concussion unless there were gross structural changes in the brain. CT and traditional MRI, therefore, may not be as useful as initially thought. Newer technologies may offer different techniques to evaluate brain function using imaging.

Functional MRI (fMRI) provides information regarding neural function during task performance using a noninvasive technique. Other techniques include magnetic source imaging (MSI), which uses MRI to obtain anatomic information while investigating the electrophysiology data from magnetoencephalography. MSI offers tracking of real-time brain activity, without distorting, by conduction through the brain, skull, and scalp.

The metabolic changes post concussion suggests the use of positron emission tomography (PET) and single-photon emission CT (SPECT), which evaluates metabolism of the specified region and blood flow (respectively) associated with activation of that region. These measures attempt to quantify correlations between metabolic flow and injury severity, post-concussion symptoms, and recovery.

As technology continues to improve, understanding the effects and consequences of concussion should also improve. Newer techniques are currently only available to researchers because of cost, availability, and accessibility. Use of X-ray, MRI, and CT scan may be helpful in identifying life-threatening injuries and should be used as a precaution when fMRI, MSI, PET, and SPECT scans are not available. If imaging is not possible, continual monitoring of symptoms and patients’ condition can provide useful information post concussion.

**Self-Report Symptoms**

Interactions between medical professionals and athletes are commonly completed by athlete self-report of symptoms. Several self-report symptom scales and checklists exist to quantify symptom severity and duration. Common scales are the Post Concussion Symptom Scale, the Graded Symptom Checklist, and the Head Injury Scale. When surveyed, 85% of certified athletic trainers used symptom checklists as part of concussion assessment battery.

Several symptoms have been linked to the occurrence of concussion. These symptoms can be divided into somatic, cognitive, and sensory domains. These include somatic symptoms such as headache, nausea, and vomiting; cognitive symptoms to include memory loss and slowed thinking; and sensory symptoms such as fatigue, drowsiness, and difficulty sleeping. Concussed athletes exhibit an increase in symptoms reported acutely, but follow a nonlinear recovery. Baseline assessment is valuable in symptom assessment as several investigators found that athletes self-report the presence of symptoms during baseline testing. Although attention must be paid to concussion-related symptoms that naturally occur, such as headache, the intensity and frequency of these symptoms will increase following concussion. Reliable self-reports are dependent upon the interaction between athlete and medical professional and the desire for the athlete to return to participation. Clinicians should take caution when relying solely on athletes’ self report alone, the use of a multifaceted approach is still highly recommended.

**Sideline Assessments**

Acutely, a concussed individual may display transient changes in cognition, postural ability, and symptom reports. The ability to obtain a measure of these deficits
immediately following injury provides invaluable information for the occurrence and management of concussion. The most commonly used sideline assessment is the Standardized Assessment of Concussion (SAC), and more recently, the Sport Concussion Assessment Tool (SCAT).

The SAC is a neurocognitive examination that was specifically intended for the assessment of athletes who have concussions on the sideline of play. The test components include orientation, memory, concentration, and delayed recall. Athletes who had concussion scored significantly different than athletes who did not, with scores 48 hours post-injury returning to baseline values for the injured group. A decline in SAC score at the time of injury is 95% sensitive and 76% specific in accurately classifying injured and uninjured subjects. Reliability analysis demonstrated that test-retest reliability of 0.53.

The SCAT was developed as a part of the Summary and Agreement Statement of the Second International Symposium on Concussion. The SCAT is a compilation of tools commonly used by sports medicine professionals. It includes a concussion symptom checklist, concentration and memory tasks, and neurologic screening; however, reliability and validity evidence is unavailable at this time.

Neuropsychological Tests

Recently, neuropsychological tests have gained favor in the profession of athletic training as tools for assessing cognitive function before and following concussion. Neuropsychological testing is used to provide a sensitive index of higher brain functioning by measuring functions such as memory, attention, executive function, and speed and flexibility of cognitive processing. These functions have been determined to become sensitive during impairments associated with concussion.

Commonly used pencil and paper tests include Trail Making Test, Digit Symbol Substitution Test, Controlled Oral Word Association Test, Hopkins Verbal Learning Test, and the Stroop Word Color Test. Several computerized neuropsychological platforms have recently been developed and include the Automated Neuropsychological Assessment Metrics, Cogsport, Headminder, and Immediate Post-Assessment of Concussion Test. These platforms boost higher sensitivity and more accurate measures of reaction time. Further, the computerized battery can be administered in small groups with no loss of reliability.

A significant amount of evidence supports the use of neuropsychological testing following concussion. The evidence suggests that recovery patterns for collegiate and professional athletes following concussion lasts from hours up to 7 days. Following a concussive injury, individuals typically display transient deficits in cognitive functioning that can often be detected through neuropsychological assessment.

Although these tests are considered to be the gold standard in concussion assessment, they have never been validated for use with concussed athletes. Further, there has been no consensus among researchers as to which neuropsychological tests within the battery are the most sensitive in detecting change following concussion.

Posturography

Following concussive injuries, athletes may have difficulty integrating information from the three components of the balance mechanism. Although the somatosensory aspect appears to remain normal, integration between the visual and vestibular components does not function properly.
The two most commonly used postural assessments are the Neurocom Sensory Organization Test and the Balance Error Scoring System (BESS). The Sensory Organization Test (SOT) within the Neurocom Smart Balance Master uses a force plate that has the ability to measure angles and forces being generated at the ankle, knee, and hip. The test systematically alters visual and somatosensory referencing in an attempt to individually evaluate the three components of the balance mechanism (visual, vestibular, and somatosensory). The SOT is the gold standard for postural stability in concussion; however, the SOT is not portable and is very expensive.

The BESS was developed as an objective assessment tool to be used by clinicians with minimal cost and training for the evaluation of postural stability following concussion. Athletes who have a concussion have shown deficits in postural stability using the SOT and BESS for up to 5 days postinjury in a collegiate population with recovery to pre-injury values usually occurring within 4 to 7 days. Postural assessment within a concussion battery has been evidenced as postural deficits following injury were present after symptoms resolution and cognitive deficits dissipated.19,28

Concussion assessment tools are recommended in combination to obtain the most complete information regarding deficits post-concussion. Broglio and colleagues29 found that neuropsychological testing in combination with self-reported symptoms produces a sensitivity of 89% to 96% following concussion. As the deficits following concussion carry the same variability as the individuals who have concussions, a multifaceted approach provides information regarding as many deficit areas as possible. Obtaining the most information possible will enable clinicians to offer quality care and management while providing good, reliable, and safe return-to-participation decisions.

TREATMENT OPTIONS

When faced with a sports-related concussion, the provider may ask, “What treatments are available?” There are no specific medical therapies for concussion. Most patients improve with education, cognitive rest, and time for the brain to recover.

Pharmacologic treatment in sports concussion may be applied in two distinct situations: (1) management of specific symptoms (ie, sleep disturbance, anxiety) and (2) to modify the underlying pathophysiology of the condition with the aim of shortening the duration of the concussion symptomatology. Pharmacologic therapies should only be used by those providers with training and experience in managing concussion.3 Although there are no specific treatments, the following therapies have been studied and the evidence is presented.

Educational Interventions

To date, the strongest evidence is in support of the effectiveness of early patient-education initiatives.30 There is good evidence to endorse the notion that supportive patient-centered interaction and the provision of symptom-related education by practitioners is effective in assisting individuals to recover from concussion symptoms. Studies show that most patients respond best to appropriate information and reassurance.31,32

Neurocognitive Rehabilitation

Neurocognitive rehabilitation, which mainly focuses on treating specific individualized cognitive deficits, is one of the most widely used treatments for severe brain injury.33
but there is no conclusive evidence supporting improved outcome in mild traumatic brain injury or concussion. Studies, however, have demonstrated improvement in neuropsychological testing following neurocognitive rehabilitation, but there is some debate over whether this was because of a practice effect, which may have artificially raised scores.\textsuperscript{34}

**Pharmacologic Interventions**

Pharmacologic treatment in sports concussion may be considered in the management of specific symptoms or in an attempt to modify the underlying pathophysiology of the condition with the aim of shortening the duration of the concussion symptomatology.\textsuperscript{35} The most common symptom for which treatment is indicated is the post-concussion headache.\textsuperscript{36} However, the results of studies of the efficacy of pharmacologic therapy have not been promising.

There are many pharmacologic management options that have been proposed for all grades of brain injury, but in many cases, the evidence is based upon studies of severe brain injury and the results may not be directly applicable to concussion. Also, a recent systematic review of pharmacologic interventions after minor traumatic brain injury failed to produce solid evidence that any specific drug treatment is effective for one or more symptoms of mild traumatic brain injury.\textsuperscript{34}

**Amitriptyline**

The evidence is conflicting regarding the effectiveness of amitriptyline as a treatment for persistent post concussion headache. A case series found that amitriptyline may be effective in doses from 75 to 225 mg/d,\textsuperscript{37} whereas a more rigorous clinical trial found no benefit for amitriptyline.\textsuperscript{38}

**Corticosteroids**

Corticosteroids have been used in the past, presumably based on their ability to stabilize membranes and reduce inflammation. However, a systematic review of randomized controlled trials of corticosteroids in acute traumatic brain injury shows that there remains considerable uncertainty over their effects. Neither moderate benefits nor moderate harmful effects can be excluded.\textsuperscript{39}

**Free Radical Scavengers and Antioxidants**

Antioxidant therapies provide numerous beneficial and protective effects following injury in animal models involving physical, cognitive, and affective issues. To date, no human trial performed so far has successfully demonstrated efficacy.\textsuperscript{40} Also, there is some concern raised by the large epidemiologic studies of antioxidant use for cardiovascular disease where antioxidant therapy was associated with an increase in cancer incidence.

**Non-steroidal Antiinflammatory Drugs**

Toxic breakdown products of arachidonic acid metabolism have been hypothesized to exacerbate central nervous system injury. Studies of cyclooxygenase inhibitors (eg, ibuprofen) and mixed cyclooxygenase-lipoxygenase inhibitors have shown some therapeutic benefit in animal models of spinal cord injury, but no specific trials of this therapy have been performed with mild traumatic brain injury.\textsuperscript{41}
Calcium Channel Antagonists

The entry of calcium through voltage-dependent channels may contribute to secondary brain injury. Despite the intuitive logic of treatment with calcium channel antagonists, several randomized trials of various agents have failed to demonstrate protective benefits.\textsuperscript{42,43}

Nicotinamide

Nicotinamide (Vitamin B3) is a potent neuroprotectant following brain injury in animals.\textsuperscript{44} Administration of Vitamin B3 following head injury has also been shown to improve functional recovery in injured rats.\textsuperscript{45} Although early administration of Vitamin B3 is promising, it is unclear if this will translate to humans following concussion.

Hyperbaric Oxygen Therapy

The delivery of high concentrations of oxygen under pressure has been proposed as a means of enhancing cerebral oxygenation, and hence, injury recovery post-concussion. Possible mechanisms of action include cerebral vasoconstriction, improvement in glucose metabolism, and reduction of cerebral edema. However, hyperbaric oxygen may also have a potentially harmful effect by increasing oxygen supply for free radical reactions. In severe brain injuries, randomized trials have demonstrated an improved mortality rate with hyperbaric therapy; however, there was no improvement in functional outcome at 12 months.\textsuperscript{46}

RETURN-TO-PLAY CRITERIA FOLLOWING A CONCUSSION

Each concussion is as individual as the athletes that sustain them, and moreover, every return-to-play criteria varies from institution to institution. The variation typically depends on the training of the medical staff, the tools available to the medical staff, and the relationship that members of the medical staff have with their athletes, coaches, and administration.

A sound plan between all members of the medical team should be agreed upon before any competitive season. The team physician should drive the protocol through a collaborative decision-making process with everyone (athletic trainers, physical therapists, and other allied medical professionals) involved. The team physician should lead this team of professionals by providing information and concurring with the plan of action to ensure continuity of management following a concussive injury.

Recent guidelines suggest a multifaceted approach to concussion assessment to capture the variability of deficits following injury. These guidelines are accompanied by the suggestion of baseline testing all athletes before the competitive season to compare pre-morbid function with that of post-injury. Neuropsychological tests for sports-related concussions can be administered before injury. Pretesting provides a baseline to the medical staff who are evaluating athletes post-injury so that subtle changes in cognitive and motor function can be detected. Pretesting would allow for a direct comparison of normal, should athletes become injured. In the event that baseline scores are not available, clinicians should use published norms accounting for any comorbidities that may affect testing, such as learning disabilities, previous history of concussion, medication usage, and mental conditions.

The clinical paradigm for your institution should include some type of cognitive assessment (preferably neuropsychological testing), balance testing, and a self-report
symptom assessment (Fig. 1). All testing should be completed once the athlete is asymptomatic. Testing while the athlete is symptomatic does not provide additional information and typically encourages practice effects. Further, clinical utility of testing while symptomatic is nonsense as return to participation would not be a safe and practical option.

Several return-to-play criteria have been developed. Previously, return-to-play paradigms were based upon anecdotal evidence and symptom resolution. Today, research provides tools that should be used to evaluate athletes’ readiness for return. These guidelines are still based upon symptom resolution; however, additional tools are included in evaluation and return to play to avoid premature return to play and potential secondary injury (Box 1).

Individuals who have a suspected concussion must not be permitted to resume contact or regular activity until they can move with usual dexterity and speed and are perfectly oriented as to the time, place, their own identity, and are able to identify the activities in which they were engaged just before the injury. Each institution can develop their own return-to-play protocols, however the protocol should be a graduated, step-wise protocol with a return to rest upon the presence of symptoms. Further, return-to-play protocols can be extended to fit the severity and duration of initial cognitive symptoms (Box 2).

Fig. 1. The Ohio State University Sports Medical Center clinical paradigm.
During rehabilitation or follow-up, the referring physician should be aware of signs and symptoms of worsening conditions. Further, the physician should caution all of those involved with the rehabilitation process regarding stipulations following a concussive injury. This may include strength and conditioning coaches, academic advisors, and others that have interaction with athletes who have concussions. If athletes report an increase in symptoms, the medical professional should decrease cognitive and physical exertion. Further stipulations include:

- Symptoms increasing with mental and physical exertion
- Mental status changes
- Worsening strength deficits

**FUTURE AREAS OF RESEARCH/INTEREST**

We continually seek the one test that will determine the occurrence of a concussive injury, and how many concussive injuries are too many. These questions haunt the best...
Box 2
The Ohio State University Sports Medical Center’s extended return-to-play exertional protocols

*Extended 5-Day Return to Play*

**Day 1**
- 30 to 40 minutes of nonimpact aerobic activity
- Exercise bike 15 minutes up to heart rate of 120 bpm
- Cool down for 5 minutes
- Increase intensity, maximum heart rate of 145 to 150 bpm, maintain for 15 minutes
- Cool down for 5 minutes
- No additional physical exertion

Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

**Day 2**
- 30 to 40 minutes of nonimpact aerobic activity
- Exercise bike 10 minutes up to heart rate of 120 bpm
- Cool down for 5 minutes
- Increase intensity, maximum heart rate of 145 to 150 bpm, maintain for 25 minutes
- Cool down for 5 minutes
- No additional physical exertion

Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

**Day 3**
- 45 minutes of aerobic activity including jogging, running, sprints, or position-specific athletic drills; no contact
- Cool down for 5 minutes
- After at least 30 minute rest may lift weights for 30 minutes

Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

**Day 4**
- Full participation practice

Immediately discontinue activity if there is any increase in athletes’ symptoms and return to rest without physical activity until symptoms resolve.

**Day 5**
- Full game participation

researchers; however, other questions are revolving and evolving all aspects of concussion assessment and management. These questions resolve around the following:

- The effects of comorbidities in concussion assessment and management
- Predisposing factors associated with incidence of concussion
- Educational interventions and the prevention of secondary injury
Objective testing for the diagnosis of concussion featuring newer technologies  
Rehabilitative techniques and tools that may be used with concussion with the increase of technological improvement

REFERENCES


