Concussion in Sports Traumatology: Future Trends

253

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Contents

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Abstract

Evaluation and management of sports-related concussive injuries has received tremendous attention by the media as well as the medical and scientific community in the past decade. The assessment of sports-related concussions, however, remains challenging for physicians given the highly variable duration of symptoms associated with each individual injury. About 80–90 % of athletes achieve a complete recovery within 1–3 weeks after the initial impact, leaving 10–20 % of athletes remaining symptomatic for months or even longer in some cases. This chapter will review the epidemiology, sideline evaluation, and management of sports-related concussions and discuss recent recommendations for the management of concussions, including the neurocognitive testing, and the subsequent steps recommended for returning an athlete to play.

Introduction

Concussion derives from the Latin word *concutere*: "to shake violently" (Shaw 2002). It is classified as a subset of mild traumatic brain injury (mTBI) and is the most common subtype with approximately four million concussive injuries occurring annually in the United States (Ellemberg et al. 2009). Concussion was historically defined as a head injury that caused a temporary loss of consciousness (LOC) and was

thus commonly viewed as a minor injury without significant or long-term consequence (De Beaumont et al. 2012). This mindset, however, has changed dramatically over the last decade, in part, because of the forced retirement of several high-profile athletes sustaining persistent neurological dysfunction and the improved understanding of concussive injuries, which have led to a paradigm shift in terms of the definition, diagnostic criteria, treatment modalities, and awareness of this injury (De Beaumont et al. 2012). These changes are of particular importance when evaluating athletes on the field and determining whether or not an athlete has sustained a concussion and subsequent return-to-play status. In fact, 90 % of sports-related concussions occur without the dramatic on-field nature of LOC, which makes them increasingly difficult to detect and therefore underdiagnosed or misdiagnosed. According to the definition proposed by the 4th International Consensus Conference on Concussion, concussion is (a) a complex pathophysiologic process, induced by traumatic forces leading to temporary disruption of the brain function without structural abnormality of the brain; (b) reveals no abnormal structural neuroimaging findings (i.e., magnetic resonance imaging, computed tomography scanning); and (c) results in a constellation of physical, cognitive, emotional, and/or sleep-related symptoms and may or may not involve a LOC with the initial insult (McCrory et al. 2013).

Epidemiology

According to the Centers for Disease Control (CDC), as many as four million sports-related concussions are estimated to occur annually in the United States (Colvin et al. 2009). Between 1997 and 2007, the number of emergency department visits for 8- to 13-year-old children affected by concussion has doubled, and in the 14- to 19-year-old age group, they have increased by more than 200 % (McCrea et al. 2013). However, the actual number of sports-related concussion is likely much higher, as many concussions go undiagnosed because athletes often fail to report concussive symptoms or are not accurately diagnosed as having concussive symptoms at the time of injury (Marar et al. 2012). In fact, McCrea et al. reported that almost two-thirds of high school soccer players failed to report having a concussion because they were not aware that they needed medical treatment for their symptoms (McCrea et al. 2013).

Previous investigation has shown that the rates of concussion are higher in competition than in practice. Further, concussions occur in all sports but are higher for certain high-risk contact and collision sports such as ice hockey, soccer, and lacrosse; however, American football accounts for the highest proportion of sports-related concussion, comprising almost 50 % of observed concussions (Guerriero et al. 2012). Fortunately, between 80 % and 90 % of athletes achieve a complete recovery within 1–3 weeks after concussion. Approximately 10–20 % of athletes remain symptomatic beyond this initial window of recovery, with prolonged post-concussive symptoms or other functional impairments (Collins et al. 2006). With regard to neurocognitive symptoms, high-school athletes have been found, as a group, to take twice as long (10–14 days) to recover from a concussion when compared to collegiate athletes (3–7 days) (Covassin et al. 2012). In addition to age, differences in recovery after concussion with respect to gender have been examined. Several studies have reported that female athletes demonstrated significantly poorer visual memory performance, slower reaction times, and had a higher incidence of post-concussive symptoms when compared with male athletes (Colvin et al. 2009; Covassin et al. 2012).

Sideline Evaluation and Management

The sideline evaluation of concussion remains a challenge for sports medicine physicians. Moreover, diagnostic criteria for concussion on the sideline remain controversial. Exclusion of more significant brain injury and avoidance of "second impact syndrome" are of paramount importance (Guskiewicz and Broglio 2011). Initial assessment requires not only a thorough knowledge of

the signs and symptoms of acute concussion but a distinct knowledge of each athlete and their disposition and personality, since athletes often attempt to conceal their symptoms because they are eager to return to play. Furthermore, a careful assessment with early diagnosis and treatment can alter outcomes and recovery time when treating sports-related concussions. Missed or delayed diagnosis and treatment of concussion can be associated with prolonged symptoms and recovery and can evolve into other serious conditions.

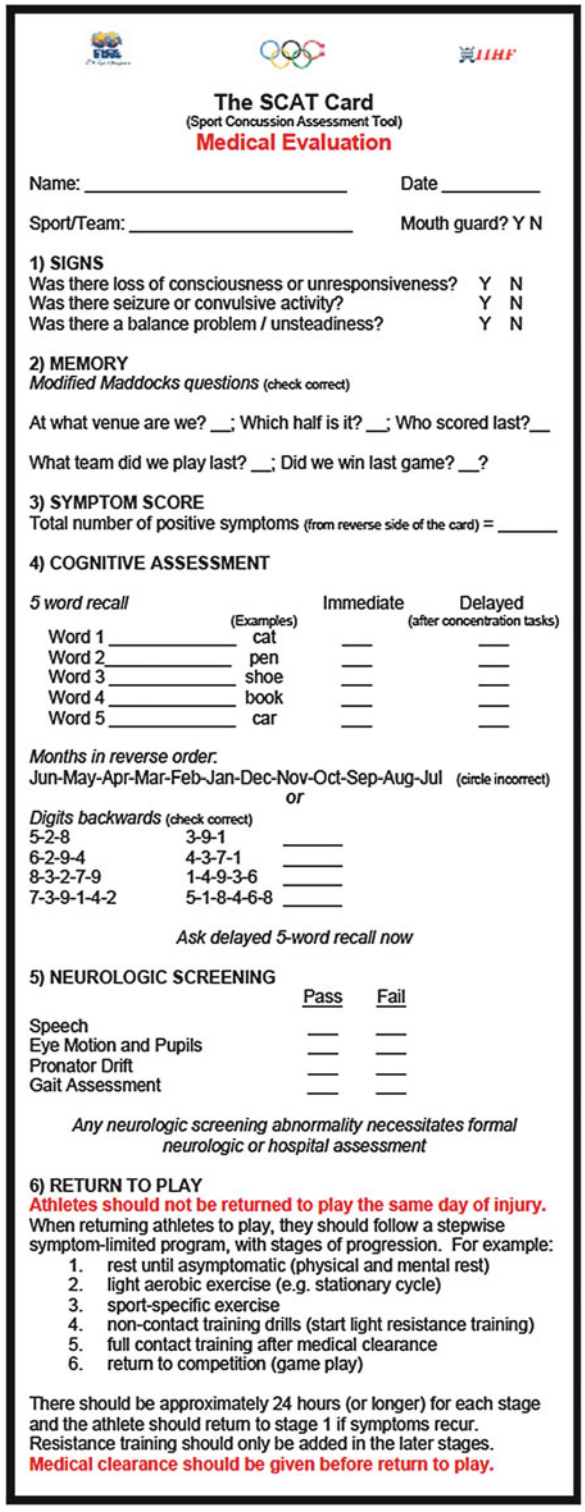
Ideally, and referring to prevention is better than cure, athletes, coaches, and medical personnel should be educated about concussion and must read and sign a statement confirming that they understand the signs and symptoms of a concussion, as well as understand their responsibility to report a suspected concussion to the medical staff (Guskiewicz and Broglio 2011). As mentioned previously, symptom recognition remains the key element of concussion assessment; however, the most dramatic signs and symptoms of concussion, such as LOC, seizures, aphasia, and amnesia, occur rarely, which increases the difficulty of early diagnosis of sports-related concussion (Guerriero et al. 2012).

Athletes suspected of undergoing a concussive injury should be removed from play and carefully evaluated on the sideline or removed from the game setting and evaluated in a quiet environment (Putukian et al. 2013). A commonly used sideline test for quick and reliable concussion examination is the Standardized Concussion Assessment Tool (SCAT) (Fig. 1). At the scholastic level, any athlete demonstrating symptoms of concussion (i.e., LOC, dizziness, fogginess, aphasia, ataxia, nausea, vomiting, headache, or visual disturbances) should be removed for the duration of the contest. Evaluation should then occur in the office setting within 2–3 days of the event to evaluate progression or changes in symptoms.

Several authors have evaluated the prevalence of on-field symptoms and their association with prolonged recovery or post-concussion syndrome. The most common presenting symptom at the time of injury is headache, which is found in 95 % of athletes with concussions. The least common presenting symptom is LOC, found in 13 % of athletes and not associated with protracted recovery (Lau et al. 2011). A summary of on-field signs and symptoms is provided in Table 1. In terms of symptomatology related to recovery time, Lau et al. determined that dizziness at the time of concussion was associated with a 6.34 increased odds ratio of protracted (greater than 3 weeks) recovery from concussion (Lau et al. 2013). Furthermore, Babcock et al. evaluated the association of symptoms upon presentation to the emergency department with the development of post-concussive syndrome. Headache and adolescent age were most associated with protracted recovery (Babcock et al. 2013). Headache, along with dizziness and fatigue, was also determined to be predictive of post-concussive syndrome in a study by Yang et al. (2009). Retrograde and posttraumatic amnesia were associated with a tenfold and fourfold increase in post-concussive syndrome risk, respectively, in a study by Collins and colleagues. They further echoed the findings that LOC was not associated with poor outcomes, but mental status changes of greater than 5 min were associated with prolonged symptoms (Collins et al. 2003). Chrisman and colleagues determined that patients presenting with greater than four symptoms had twice the risk of persistent symptoms greater than 1 week from the injury. Loss of consciousness was, again, not a significant predictor of prolonged symptoms (Chrisman et al. 2013).

Baseline Testing and Concussion Management

The role of baseline neurocognitive testing has expanded in recent years. The hypothesis is to determine an individual baseline for each athlete in an effort to be able to objectively identify changes in various neurological realms post-injury. Several computer-based management approaches, including ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing), CogState, Headminders, and ANAM (Automated Neurocognitive Assessment Matrices), have been developed and validated to measure concussive injury. The ImPACT neurocognitive battery (ImPACT Applications, Pittsburgh, PA)



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	(Examples)	Immediate	Delayed (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 incorrect)

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 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 more 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. "period" versus "half")

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.

Neurologic 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 motion should reveal no diplopia in any of the 4 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).

Fig. 1 Sport Concussion Assessment Tool (SCAT)

Table 1 Signs and symptoms of sports concussion according to the University of Pittsburgh Medical Center's sideline concussion card

Signs observed by staff members	Symptoms reported by the athlete
Appears to be dazed or stunned	Headache
Is confused about assignment	Nausea
Forgets plays	Balance problems or dizziness
Is unsure of game, score, or opponent	Sensitivity to light or noise
Moves clumsily	Double or fuzzy/blurry vision
Answers questions slowly	Concentration or memory problems
Loses consciousness	Feeling "foggy" or groggy
Shows behavior or personality change	Feeling sluggish or slowed down
Forgets events before play (retrograde)	Change in sleep pattern (appears later)
Forgets events after hit (posttraumatic)	Feeling fatigued

(Schatz et al. 2006) is the basis of the concussion program not only in Pittsburgh but in many high schools, collegiates, and professional settings in the United States and thus will be the one discussed throughout this chapter.

ImPACT examines four composite areas of testing: verbal memory, visual memory, reaction time, and impulse control, and has been validated independently in numerous peer-reviewed publications (Lau et al. 2009; Schatz and Sandel 2012). Reliable change indices along with score stability over time have been demonstrated (Parsons et al. 2009). Collegiate and professional athletes may undergo testing every 2 years with less than a 10 % change in symptom scale scores and a 0–5 % change in composite scores expected. Immature and high-school athletes may need more frequent testing due to the continuing neural development seen in these age groups (Schatz 2010). Baseline testing, while ideal, is not a prerequisite for ImPACT testing because population norms have been developed and validated at different age ranges and are gender specific (Covassin et al. 2006; Echemendia et al. 2012).

Neurocognitive testing demonstrates both high sensitivity and high specificity for detecting concussion. Schatz and colleagues found 82 % sensitivity and 89 % specificity for ImPACT testing leading to correct identification of 85 % of the concussed athletes in this cohort (Schatz et al. 2006). Athletes cannot be relied upon to report symptoms after the event on a regular basis. Van Kampen et al. reported that 64 % of concussed athletes admitted to a significant increase in symptoms at 2 days post-injury compared with baseline. When the same cohort was evaluated with neurocognitive testing, 83 % of athletes demonstrated worse test results, even after consideration of the reliable change index which allows for intertest performance variation (Parsons et al. 2009). This study showed that almost 20 % of athletes did not recognize continued or worsening cognitive deficits based on self-reporting of symptoms without objective testing (Van Kampen et al. 2006). Neurocognitive tests, such as ImPACT, are also designed to detect attempts at intentional poor performance on the baseline test. The test was able to detect 89 % of attempts to "sandbag" the test in a cohort of collegiate athletes instructed through various methods on ways to evade optimal performance (Schatz and Glatts 2013). No current widely used imaging modality (e.g., MRI, CT scan) can be used to reliably diagnose concussion. Research regarding novel techniques such as diffusion tensor imaging and structural tract imaging is ongoing, but further studies must be performed before widespread acceptance is gained.

Acute management of concussion within the first few days consists of educating the athlete on the benefits of physical and cognitive rest, as this appears to provide the best chance of avoiding post-concussive syndrome and a prolonged recovery. The importance of having a regimented schedule, particularly with regard to sleep, diet, hydration, exercise, and reducing stress should be emphasized. Specifically, an individual should aim to have a routine sleep schedule and avoid napping during the day so as not to dysregulate the night's sleep schedule. Research has shown that high-school and collegiate athletes who were prescribed 1 week of cognitive and physical rest

consisting of time away from school, no reading or visual stimulation (e.g., television and computers), and no physical activity showed significant improvements in all four areas of ImPACT testing independent of time since the concussive event or other treatment regimens previously undertaken (Moser et al. 2012). However, in many cases, a complete removal from school is not necessary and athletes are encouraged to attend on a tolerate basis with academic accommodations tailored to address their specific needs. For individuals with a history of anxiety, complete removal from school may want to be avoided in order to prevent exacerbation of symptoms secondary to increased stress over their absence. Additionally, some form of light exercise, such as walking, is often recommended initially in order to provide some light exposure to complex environments. Completely removing oneself from all provocative environments will likely only make the transition and exposure back later more difficult. Also, for individuals with a migraine presentation, light exercise may actually help prevent headaches. In most cases, reduction of visual strain is often emphasized, particularly for those with any observed ocular dysfunction. Ultimately, acute management of concussion should emphasize the importance of having a routine schedule, and consideration of the specific areas of impairment should directly inform recommendations.

Although 80 % of athletes recover within the first 3 weeks after concussion injury, the remaining one in five athletes are left with persistent symptoms on a longer term basis and need to be treated. A multidisciplinary approach has been employed with success. Components of this process include a graduated return to academics and athletics, dependent upon the patient's symptoms. Treatment modalities employed include vestibular therapy, oculomotor therapy, and medication management. Several classes of medications can be used in select circumstances, including antidepressants, anxiolytics, stimulants, and dopaminergic agonists. While these medications are currently utilized in an "off-label" manner, studies documenting their efficacy are forthcoming.

Return-to-Play Decisions

Although greater than 80 % of athletes may be expected to return to play within 3 weeks of the initial injury, early diagnosis and treatment are still important in this decision process (Collins et al. 2006). Certain patient groups, such as adolescents and patients with multiple prior concussions, may be expected to take longer on average to return to a symptom-free state (McCrory et al. 2013). A graded return to play is an important therapeutic tool in the management of acute concussion. The patient should undergo a period of therapeutic rest followed by increasing exposure. If the athlete remains asymptomatic upon return to light exertion, then increased activity may be employed. When the athlete remains asymptomatic at rest, asymptomatic with physical exertion, and neurocognitive data are within normal limits, then he or she is cleared to return to play. Neurocognitive testing should be employed during the return-to-play process, preferably with a baseline, to evaluate complete resolution of symptoms and evidence of absence of recidivism. McClincy et al. have reported that deficits have been identified in high-school and collegiate athletes for at least 14 days after the initial injury, generally after athletes report symptom resolution (McClincy et al. 2006). Furthermore, recovery times were unrelated to concussion severity.

Resolution of symptoms and complete recovery prior to return to play is of vital importance to avoid second-impact syndrome (Schatz and Sandel 2012). This is related to an extremely rare cascade of events in which the athlete experiences a catastrophic brain injury following a seemingly mild concussion. It is defined by rapid and profound brain swelling in the absence of a space-occupying lesion or hematoma (Wetjen et al. 2010). The prevalence and incidence of this condition are currently unknown, but when it occurs, morbidity is 100 % and mortality is reported to occur in up to 50 % of cases. The pathophysiologic process is believed to be

related to dysregulation of the arterial tree subsequent to brain trauma and a stress-induced catecholamine surge, which compounds these effects leading to considerable brain swelling and edema.

Conclusion

The incidence of concussion in athletes participating in contact and collision sports has been increasing recently due to advances in recognition and diagnostic ability. Treatment modalities of acute concussion are rapidly evolving, and the use of neurocognitive testing has revolutionized our ability to evaluate, diagnose, treat, and monitor recovery in the concussed athlete. As further studies are performed, the goal of acute management is to decrease the incidence of post-concussion syndrome and the need for prolonged vestibular and oculomotor therapies, in addition to prescription medications. The role of helmets and mouth-guards are still hotly debated with well-designed studies showing both utility and lack of efficacy of preventive modalities. As our understanding of the pathophysiology of concussion continues to advance, treatment and preventive strategies should follow.

Cross-References

▶ Head Injuries in Sports

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