

Current concepts in concussion diagnosis and management in sports: A clinical review

The definition, diagnosis, and management of concussion have all been revised in recent years—here is an update.

ABSTRACT: Concussion is a potentially serious injury for athletes. Recent statistics suggest that approximately 300 000 sports-related traumatic brain injuries occur annually in the United States. Soccer, rugby, football, and ice hockey are all considered high-risk team sports for concussion. Hockey-related concussions are of particular concern in Canada, where over 500 000 players compete annually in ice hockey. An understanding of current concepts in concussion diagnosis and management as well as a background on scientific concepts relating to concussion can help general practitioners. GPs can also benefit from knowing about the latest recommendation from two recent international conferences on concussion in sport, which have produced new guidelines at variance with previously accepted protocols.

The word “concussion” derives from the Latin *concussus*, which means to shake violently. Concussion was initially felt to involve only transient disturbance of brain function without gross structural change. It is now recognized that some concussions do involve structural damage with loss of neurons. Sports concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.¹ A high incidence of concussion in contact sports is well documented in the literature.¹⁻⁵

There are several common features of a concussive head injury:

- Concussion may be caused either by a direct blow to the head, face, or neck, or by a blow elsewhere on the body that transmits an “impulsive” force to the head.
- Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.
- Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.
- Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cog-

nitive symptoms typically follows a sequential course.

- Concussion is typically associated with grossly normal structural neuroimaging studies.⁶

Recently, the premature retirement of some professional ice hockey players because of concussion-related symptoms has increased awareness of concussion in Canada, but questions remain about whether there is adequate understanding of appropriate concussion management.⁷ Wennberg recently reported that the National Hockey League (NHL) concussion rate in the

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past 5 years was 3 times that reported in the previous decade.⁸ It may be assumed erroneously that this represents the effect of bigger, faster players colliding with one another, but in fact the primary reason for the higher rate is improved recognition and injury reporting.

In 2001 the first International Conference on Concussion in Sport was held in Vienna and a summary and agreement statement was published in the *British Journal of Sports Medicine*,⁶ the *Clinical Journal of Sports Medicine*, and *The Physician and Sportsmedicine*. The aim of the symposium was to gather world concussion experts to provide recommendations for improvement of health and safety of athletes who suffer concussion. Three Canadians were included in the expert group: Dr Willem Meuwisse, Dr Karen Johnston, and Dr Mark Aubry. The entire group has been referred to as the Concussion in Sport Group (CISG). Guidelines were established for "return to sport," with the understanding that further changes could be made to this protocol with new information obtained through present and future research. A second international conference on concussion in sport was held in Prague in the fall of 2004, where revisions and further recommendations were made.⁹

One of the key points from the discussions at these conferences was the need to individualize return-to-play decisions rather than relying on arbitrary grading scale algorithms that are not based on science. Also, determining the severity of concussion is only possible in retrospect, when all symptoms have cleared and cognitive function has returned to normal.

Traditionally, loss of consciousness was thought to be the primary measure of concussion severity, but recent studies have cast doubt on this. Studies have associated loss of con-

sciousness with specific early deficits but not necessarily with overall severity.¹⁰ Because many concussion scales rely on loss of consciousness as a grading component, this may lead to mismanagement. More recent evidence suggests that posttraumatic amnesia might be a more important measure of injury severity.^{11,12}

Incidence

Recent statistics estimate that approximately 300 000 sports-related traumatic brain injuries occur annually in the United States.¹³ Concussion as an injury group in the US increased 269% in ice hockey from 1990 to 1999 according to a National Electronic Injury Surveillance System (NEISS) report.¹⁴ This report raises concerns regarding the risk of traumatic brain injuries in soccer, football, and ice hockey, especially since the NEISS collects data on only those injuries that are seen and treated in participating hospital emergency departments across the US. Many other brain injuries may have gone unreported if the athlete was not seen at an emergency department.

In the 1990s, concussive injury in a number of high-profile professional athletes resulted in the implementation of baseline neuropsychological testing by the National Football League (NFL). Similar injuries in hockey led the NHL to make the same requirement.

A recent systematic review by Koh and colleagues¹⁵ provides useful data on concussion incidence in all sports and shows ice hockey to have the highest incidence of concussion among team sports. Rugby is shown to have the second highest incidence of concussion among team sports, followed by football and soccer. Looking at individual sports, it is no surprise to see boxing with the highest incidence of concussion, followed by taekwon do.

Female athletes are not immune to concussions, with higher incidences being reported in more elite players. Schick and Meeuwisse studied injury rates and profiles in female hockey players and found that the rate of concussion was higher than previously reported and also that it was the most frequent cause of time loss from play.¹⁶ Female lacrosse and soccer players are also at a high risk of suffering concussion.¹⁷ With increasing numbers of females participating in rugby, it is anticipated that concussion will be an important injury in this sport also.

Pathophysiology

Discovering the exact pathophysiological changes in concussion by experimental means is inherently difficult. A variety of animal models have been used to study concussion, but all of these models can be criticized to one degree or another.¹⁸ The use of anesthetized animals makes it difficult to identify acute clinical effects and additionally it is impossible to evaluate cognitive symptoms such as posttraumatic amnesia in these models. Animals with small brains can also tolerate much higher acceleration or deceleration forces than humans can. Most animal models use loss of consciousness as the primary evidence of presence of concussion, but the majority of sports concussions do not exhibit this sign.¹⁹

Giza and Hovda have outlined a cascade of metabolic, ionic, and neurochemical changes immediately after experimental brain injury.²⁰ Excitatory amino acids may be released during brain injury that precipitate receptor-mediated neuroexcitation leading to influx of sodium and calcium ions.²¹ Other researchers have shown an apparent mismatch between hyperglycolysis and decreased cerebral blood flow.²² The complexity of the various neurometabolic and histological changes in the concussed brain

Table 1. Typical symptoms and signs of concussion.

Symptoms	Signs
<ul style="list-style-type: none"> • Headache • Dizziness • Feeling dazed, stunned • Sensitivity to light • Tiredness • Irritability • Seeing stars • Double vision • Sleepiness • Nausea 	<ul style="list-style-type: none"> • Poor balance or coordination • Slow or slurred speech • Poor concentration • Vacant stare • Confusion, disorientation • Amnesia • Loss of consciousness • Unusual emotions • Personality change • Inappropriate behavior

remains incompletely understood at present.

Increased interest in the pathophysiology of concussion has raised questions regarding the risk of multiple concussions in the developing child or adolescent, including the risk of permanent learning deficits.²³ In Canada most elite ice hockey players begin body checking at age 11, and some players are permitted to begin checking at age 9. Body checking accounts for up to 86% of injuries among players age 9 to 15.²⁴ Each year, 10% to 12% of hockey players age 9 to 17 who are injured report a brain injury, most of which are concussions.^{25,26}

In the past, conventional wisdom held that the younger brain was more resilient to injury. Research in young rats suggested that low rates of injury occurred with moderate percussion injury.²⁷ However, evidence now suggests that there are specific developmental periods when the immature brain may be more vulnerable to injury.

More research about the long-term sequelae of concussion in sports is required, particularly with high numbers of children and teenagers involved in contact sport. At the Prague conference, the concept of “cognitive rest” was introduced with reference to the

child’s need to limit exertion in activities of daily living and scholastic endeavors while still symptomatic.⁹

Evaluation of the concussed athlete

Sideline evaluation is an essential step in determining the immediate management of the athlete who may be concussed. Typical symptoms and signs to be monitored are shown in **Table 1**.

If any one of the symptoms or signs listed is present, a traumatic brain injury should be suspected and appropriate management instituted. A key point of education for athletes, parents, and ancillary personnel is that a player does not need to have lost consciousness to suffer a concussion.

A detailed history will be needed after the sideline evaluation is complete. As well as asking questions about the current injury, it is extremely important to make pointed inquiries about previous injuries, including those that may have been suffered in the off-season or in another activity. Many athletes will not recognize all the previous concussions they have suffered. Most serious athletes in contact sports will have suffered at least one concussion but may be unaware of this. A study of Canadian Football League players in the 1997 season

revealed that 44.8% suffered probable concussions, yet only 18.8% of these concussed players recognized that they had suffered a concussion.²⁸ Kaut and colleagues recently reported on the high frequency of college athletes reporting concussions (approximately 20%) coupled with a large proportion who continue to play with symptoms.²⁹ It is therefore very important to question athletes about the previous *symptoms* of a concussion rather than just asking for their perceived number of past concussions. It has been suspected that athletes who have suffered one concussion are at increased risk of a second and subsequent such injury, although some question this concept. However, a recent large prospective cohort study by Zemper suggested that the risk of sustaining a cerebral concussion is nearly 6 times greater for individuals with a history of concussion than for individuals with no such history.³⁰

Additional questions on the relationship between impact force and symptom severity may reveal a progressive, increased vulnerability to injury (i.e., more pronounced or prolonged symptoms from smaller hits with subsequent injuries). This disturbing trend has been noted by clinicians who deal with elite hockey players (oral communication with Dr Karen Johnston, 2001).

Conventional structural neuroimaging by CT or MRI should be used whenever suspicion of a structural lesion exists, even though the results are usually normal in concussive injury. Neuroimaging is also required when there is prolonged disturbance of a conscious state, focal neurological deficit, seizure activity, or persistent clinical or cognitive symptoms.

Neuropsychological testing

Several neuropsychological test bat-

teries are available, including the Maddocks Questions¹⁹ and the Standardized Assessment of Concussion (SAC).³¹ Another protocol developed at McGill by Johnston and colleagues has been compared with the NHL standard test battery.³² The 2004 Prague conference led to the development of the Sports Concussion Assessment Tool (SCAT), based on many other forms and cards. This can be used for patient education as well as for assessment purposes and is available free of charge at the ThinkFirst web site (www.thinkfirst.ca/documents/SCAT-v13-2.pdf).

Previously, more detailed baseline and follow-up neuropsychological testing was expensive and restricted to those groups associated with qualified neuropsychologists. New computer programs now permit the large-scale testing of sports teams and rapid access to repeat testing after suspected concussions. Players can also undergo follow-up testing when they are symptom-free to compare their test results with their baseline results and to determine if there are any reasons to suspect residual cognitive deficits. A neuropsychologist should be consulted regarding difficult management issues.

Classification of concussions

At least 25 scales for grading concussions exist.³⁰ The final statements from the Vienna and Prague conferences on concussion in sport recommend abandoning any management approach that relies on grading scales^{6,9} because many of the scales are based on consensus and clinical opinion rather than on scientific data. For instance, in one study of 21 professional rugby league athletes, concussion severity as defined by several scales was not clearly related to the presence or duration of impairment as indicated by neuropsychological test performance.³³ Thus, current return-to-

Table 2. Simple versus complex concussion.

<p>Simple concussion</p> <ul style="list-style-type: none"> • All symptoms and signs resolve by 10 days and do not recur during rehabilitation—that is, while patient is being monitored at each step of the return-to-play protocol (Table 3) 	<p>Complex concussion</p> <ul style="list-style-type: none"> • Preceded by prolonged loss of consciousness (more than 1 minute) • Symptoms and signs persist beyond 10 days or recur during rehabilitation—that is, while patient is being monitored at each step of the return-to-play protocol (Table 3) • Prolonged cognitive impairment
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play programs rely more on symptoms than grading.

The grading scales may still be of value for research purposes and for determining the athlete’s safety after sustaining multiple concussions, but at present their clinical usefulness is open to question. The Concussion in Sport Group stated in Vienna that while they recognized the strengths of several existing concussion scales, no single scale could be endorsed.

One of the Prague meeting’s key conclusions was that concussions are best classified as “simple” or “complex”⁹ for concussion management purposes. Simple concussion represents the most common form of injury and may be appropriately managed by primary care physicians. In simple concussion, an athlete suffers an injury that progressively resolves without complication over 7 to 10 days. Apart from encouraging the athlete to rest while symptomatic and to resume sport by a graduated return-to-play protocol, no specific further interventions are needed in these cases, and the athlete typically resumes sport without further problem.

Complex concussion requires the attention of physicians specially trained in the management of these injuries (see **Table 2**). Formal neuropsychological testing may be indicated in cases of complex concussion, and management by sports medicine physicians, sports neurologists, or neuro-

surgeons in a multidisciplinary group may be needed. Often the classification of the concussion can only be made in retrospect since it is not possible to predict with complete certainty whether the concussion will resolve promptly and be classed as “simple,” or the athlete will go on to have prolonged symptoms and the concussion will be classed as “complex.”

Management

Initial management consists of following the basic principles of trauma care. It is always important not to overlook a cervical spine injury. It is also important not to overlook the possibility of coexisting concussion when considering more obvious neck, maxillofacial, or dental injuries.³⁴ And while it is important to identify all past concussions, management decisions should not be based solely on the number of concussions, as was done in the past with the “three strike rule,” which excluded an athlete from play after a third concussion.³⁵

The injured player should be examined by a medical doctor and should not be left alone. Regular monitoring for deterioration is essential over the initial few hours. Further neurological evaluation to look for evidence of potentially catastrophic brain injury is appropriate if the clinical situation dictates this. Most physicians experienced in concussion management do not routinely order neuroimaging un-

Table 3. Return-to-play protocol.**Step 1**

No activity, complete rest

Once patient is asymptomatic, proceed to Step 2 and continue to subsequent steps if patient remains asymptomatic. If symptoms recur, drop back to a step where there are no symptoms, and try to progress again.

Step 2

Light exercise off the game field (stationary biking, walking)

Step 3

Sport-specific activity without body contact (light running, skating)

Step 4

On-field practice without body contact

Step 5

On-field practice with body contact, once cleared by a medical doctor (The time required to progress from noncontact exercise to full contact will vary with the severity of the concussion and the individual.)

Step 6

Return to competition

less features suggesting a more complicated injury are present.

At present, there is no specific treatment for concussion other than rest until the athlete is asymptomatic. Complex concussions may require pharmacological agents in the later stages if sleep or mood disturbances are involved, but these cases are likely best managed by physicians with experience in this area.

Return to play

The fundamental dictum currently is that all concussed athletes must be asymptomatic at rest before returning to any type of training, game play, or physical exertion. Until recently, it was felt safe to allow a player with a so-called grade 1 concussion, where all symptoms clear within 15 minutes, to return to play in the contest. Recent research suggests that this protocol may be too lenient. Thirty-six hours after injury, mildly concussed high school athletes demonstrated a decline in memory and a dramatic increase in

self-reported symptoms compared with baseline performance.³⁶ Returning these athletes to play may be too liberal and needs to be evaluated.

Hockey Canada Guidelines state that any athlete with a suspected concussion must be evaluated by a physician before return to play. These stringent guidelines are supported by practice: the decision usually made by the physician, even with so-called bell-ringers, is that the athlete cease play for a period of time and not return to the current competition. It should be noted that even asymptomatic players may go on to develop concussive symptoms minutes, hours, or possibly days later, and that players, coaches, and trainers should not ignore the possibility of concussive injury just because they do not have ready access to a physician.

Concussion-associated convulsions often raise undue anxiety about the severity of injury or the risk of postinjury epilepsy. Athletes who suffer these episodes can be reassured that

such events are usually benign, are not associated with the long-term risk of epilepsy, do not require specific pharmacotherapy, and that overall management should focus on the correct management of the associated concussive injury.³⁷

Other factors that may influence the return-to-play decision include injury severity, previous history, sport, and speed of resolution of the acute symptoms.^{3,38} The currently established step-wise return-to-play protocol is outlined in **Table 3**. Whenever possible, return to play should be medically supervised or under the direction of an experienced trainer.

In the case of recurrent injury, a more conservative time frame for return to play should be considered. Clearly the athlete must be asymptomatic before beginning the return-to-play protocol. As well, a slower advancement of the steps should be considered by the supervising clinician.

The minimum time allowed for each step in the return-to-play protocol is 1 day, which means that the concussed athlete will not be able to enter competition for approximately 1 week. The cornerstone of concussion management is rest. Once all symptoms and signs resolve, the athlete commences a program of increasing exertion before returning to full competition. It is important to emphasize to the athlete that physical and cognitive rest are required during the period of recovery, especially in the first few days after an injury. Activities that require concentration and attention, such as reading or computer work, may exacerbate symptoms and delay recovery. In symptomatic children, there may be a need to limit not only exertion with activities of daily living, but also television watching, computer game playing, and scholastic activities. This latter recommendation may

require a written note to the child's teacher. Meditation techniques have been used by one of the authors (BH) to accelerate recovery from concussion.

Postconcussion syndrome

Persistent complaints of symptoms such as headache, dizziness, sleep disturbance, poor concentration, and memory problems can occur after a concussion. It has been reported that the risk of this complication is lower in the sporting community than in the general population.³⁹ As a result, other factors such as medicolegal issues and secondary gain have been postulated as confounding factors.⁴⁰ Despite the relative infrequency of symptoms lasting for months, both authors of this paper have seen cases of athletes who are highly motivated to return to play but who cannot do so because of persistent and prolonged symptoms. Often these athletes have a history of multiple concussions.

Prevention and education

The use of appropriate protective helmets is obviously of paramount importance in those sports where head contact is a factor in the mechanism of concussion. In ice hockey, football, and baseball there is published evidence of benefit for protection by headgear. In other sports, however, there is a suspicion that the use of headgear might actually alter playing behavior and increase risk of injury.⁴¹ Mouthguards have long been proposed as a way to assist in the reduction of concussion incidence, but there is no scientific evidence yet to support their widespread use.⁴² Further lack of evidence of benefit came from a study of basketball players that found no reduction in concussion rates through the use of custom-fitted mouthguards.⁴³ The primary value of mouthguards appears to be for dental and oral soft tissue protection.

Rule changes may play a role in protecting athletes from injury. For example, enforcing rules in hockey to

eliminate checking to the head and also banning hard plastic elbow pads might reduce head injuries. Another prevention strategy—conditioning of the neck muscles to decrease head movement—is still largely a theoretical concept.

In addition to prevention strategies, education of players, coaches and trainers, and parents is crucial. These groups must be given tools to understand and recognize concussion and to assist in appropriate management. There is still considerable need for education as shown by a recent study of British Columbia minor hockey players. Williamson and Goodman⁴⁴ showed that there was significant underreporting on concussions in minor hockey. Estimates from official injury reports for male players were between 0.25 and 0.61 concussions per 1000 player game hours (PGH). Concussion estimates from volunteer reports were between 4.44 and 7.94 per 1000 PGH.

Physicians who treat athletes in high-risk groups also need to educate themselves in the current standard of care. Methods to improve education, including web-based resources, educational videos, and programs such as ThinkFirst (www.thinkfirst.ca) should be used to deliver the message to a wide audience.

Summary

- Return-to-play decisions must be individualized, rather than relying on arbitrary grading scale algorithms that are not based on science.
- Loss of consciousness is no longer the key measure of concussion severity—concussion can occur without loss of consciousness.
- Posttraumatic amnesia might be a more important measure of severity.
- Most serious players in contact sports have suffered a concussion, but are unaware of it.

- Ice hockey has the highest incidence of concussion in team sports, followed by rugby, football, and soccer.
- Computer programs now permit large-scale team testing and rapid access to repeat testing after suspected concussions.
- Athletes suffering a confirmed or suspected concussion should not return to the contest, allowing at least 1 day's rest. Even asymptomatic players may go on to develop concussive symptoms minutes, hours, or even days later.
- Symptomatic children may need to limit not only exertion with activities of daily living, but also television, computer use, and school.

Competing interests

None declared.

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