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REVIEW

Concussion in sport: what is known and what is new?

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The aim of this article was to summarise the latest definition of concussion, signs of concussion, as well as important facts on recovery and graduated return to play, for different age groups. New technologies available to the sports physician are listed.

Keywords: concussion, diagnosis, return to play, signs

Introduction

An integrated definition of mild traumatic brain injury (TBI) or concussion that fully characterises the disease has proven to be as elusive as the criteria for recovery from it. The Congress of Neurological Surgeons first proposed a definition for concussion that highlighted common symptoms, such as problems with balance, vision and altered mental state. Physiological symptoms such as headaches and nausea were excluded, which attracted considerable criticism from physicians and researchers for the next 30 years.[1]

In 1993, the American College of Rehabilitative Medicine included objective criteria for the first time, such as loss of consciousness and amnesia, and made use of the Glasgow Coma Scale for the definition of mild TBI.[2] However, the importance of loss of consciousness declined after the Centers for Disease Control and Prevention (CDC) suggested that mild TBI might not necessarily include loss of consciousness.[3]

Because of the influence of the Concussion in Sport Group (CISG), the basic definition of mild TBI remained the same until 2001. In 2002, the pioneering CISG consensus definition on sport concussion was published and has been referred to ever since.[4] After the 2nd International Conference on Concussion in Sport, the CISG revised the 2002 definition and added that post-concussive symptoms may be persistent, in some cases. During this period, the Sport Concussion Assessment Tool (SCAT)[5] was also developed. In 2007, the CDC suggested a comprehensive mild TBI definition that would inform clinicians and medical staff of the individualised nature of the injury.[6]

The most recent definitions on what concussion is, and how to manage it, originate from the consensus statements that followed the 2008 and 2012 Zurich concussion in sport consensus meetings. World experts in concussion meet every four years to review existing evidence on concussion in sport.

Concussion is now defined[7] as follows:

- Concussion is a brain injury, caused by either direct or indirect forces to the head, typically resulting in the rapid onset of short-lived impairment of brain function.
- Loss of consciousness occurs in less than 15% of concussion cases, and while it is a feature of concussion, loss of consciousness is not a requirement for diagnosis.
- Concussion results in disturbance of the brain function, e.g. memory disturbance and balance problems, rather than damage to structures, such as blood vessels, brain tissue or the skull.
- Typically, standard neuroimaging, such as magnetic resonance imaging (MRI) or a computed tomography (CT) scan, presents as normal.

The managing bodies of different sporting codes, such as the International Rugby Board (IRB), support and include the Zurich 2012 Concussion Consensus conference principles in their guidelines to medical practitioners and approved health care professionals.[8] The aim is to promote effective management of sports concussion to ensure the short and long term health of athletes.

Diagnosis: signs and symptoms

Concussion is known to be one of the most complex injuries in sports medicine to diagnose, assess and manage. Patricios and Makdissi[9] summarised the main recurrent principles learned from the concussion consensus documents as follows:

- The clinical presentation and assessment of concussions is multifaceted.
- Signs and symptoms evolve and resolve over varying periods, making serial and repeated assessments essential.
- Certain cohorts, most notably children and athletes with modifying characteristics, require a more conservative approach.
- No player suspected of suffering from concussion should return to play on the same day that it occurred.
- The decision to return to play is a clinical one, best made by medical doctors who are familiar with the consensus protocol.

The Zurich 2012 Concussion Consensus Group developed the Pocket Concussion Recognition Tool™ for clinicians, and supports the "Recognise and remove" and "If in doubt, sit them out" messages. The signs and symptoms of concussion are listed in Table 1. It is also known that concussion symptoms can present at any time, but typically become evident in the first 24–48 hours following a head injury.[8]

An athlete who presents with any of the above signs should be removed according to emergency management procedures, and followed-up with a medical assessment. Emergency healthcare professionals with suitable spinal care training must remove athletes with suspected cervical spine injuries. The IRB adopted the "as soon as possible" assessment procedure owing to the fact that there was uncertainty with

regard to the timing of the side line assessment. The reason is that a sooner, rather than later, test result is more sensitive, even though player fatigue may influence the results. This is in line with the IRB's "safety first" approach.[8]

Diagnosis: the gold standard

Clinical diagnosis by a doctor is the gold standard (Zurich 2012) and should be supported by three assessments; a standardised checklist of symptoms, a cognitive assessment and a balance evaluation.

The Sport Concussion Assessment Tool 3 (SCAT 3)[8] introduced after the Zurich 2012 Concussion Consensus Conference compares all of these against a baseline value for each of these 3 supporting assessments. Baseline testing refers to completion by athletes of the symptom checklist, a cognitive assessment and a balance test at the start of the season. A variation in one or more of these assessments, when compared to baseline values, is seen to be indicative of concussion. Reference range baseline data may be used if the athlete did not complete the baseline testing. If there are no available baseline data, the results listed in Table 2 strongly favour a concussion diagnosis.

Table 1: Concussion signs and symptoms for clinicians

Visible clues of potential concussion: what you see

Any one or more of the following visual clues can indicate possible concussion:

- A dazed, blank or vacant look
- Lying motionless on the ground or taking longer than normal to get up
- Being unsteady on the feet, having balance problems or falling over, and incoordination
- Loss of consciousness or responsiveness
- Being confused about, or unaware of, what sport is being played or the event
- Grabbing or clutching the head
- Having convulsions
- Being more emotional or irritable than usual.

Symptoms of potential concussion: what you are told

The presence of any one or more of the following signs and symptoms may suggest concussion:

- Headaches
- Dizziness
- Mental clouding, confusion, or feeling slowed down
- Visual problems
- Nausea or vomiting
- Fatigue
- Drowsiness, the perception of being "in a fog", or having difficulty concentrating
- "Pressure in the head"
- Sensitivity to light or noise.

Questions to ask

Failure to answer any of these questions correctly may suggest concussion:

- "What venue are we at today?"
- "Which half is it now?"
- "Who scored last in this game?"
- "What team did you play last week?" or "What game did you play last week?"
- "Did your team win the last game?"

The use of SCAT 3 is recommended for players aged 13 years and older. A SCAT 3 for children is available from the IRB website for players younger than 13 years of age.[8]

Recovery and graduated return to play: important facts[9]

Usually, spontaneous recovery from an uncomplicated concussion in adults takes between 7–10 days, and slightly longer for children and adolescents.

Associated dangers with premature return to play include:

- A second concussion due to increased risk.
- An increased risk of other injuries because of poor decision-making or reduced reaction time associated with a concussion.
- Reduced performance.
- Serious injury or death due to an unidentified structural brain injury.
- The potential increased risk of developing long-term neurological deterioration.

A summary of the age-dependent minimum rest periods of graduated stages of return to play is provided in Table 3.

Overall, the IRB recommends that graduated return to play should only commence if the player has completed the minimum rest period for his or her age, and is symptom-free and not taking medication that might modify the symptoms of concussion.

New technologies

The fact that symptom-resolution criteria are often used to determine readiness to return to play may increase the chances of re-injury. This is because cognitive symptom measures are largely influenced by compensatory mechanisms.[12] Recurrent head injuries are connected with motor cortex dysfunction, early dementia and plaque build-up in the brain, also called chronic traumatic encephalopathy. Thus, the swift identification of concussion and appropriate athlete management with objective return-to-play criteria is essential for the long term-health and career of the athlete.

Today, new available technologies aid the sports physician in these tasks. By using a combination of objective multimodal methods, the clinician should be capable of managing the patient better than previously possible. A few of these relevant methods are summarised in Table 4.

The use of MRI, CT scanning, positron emission tomography and functional MRI are costly and time-consuming alternatives which are not available to many athletes. Also, it has only recently become known that, contrary to popular belief, concussions do not show up on most MRI examinations or CT scans. On the other hand, the Head Impact Telemetry System shows great potential for the identification of concussion risk and the cumulative effects of subconcussive hits. The effectiveness of some of the other new techniques, such as the quantification of heart rate variability as a non-invasive predictive measure of recovery in head injury,[13]

Table 2: Concussion signs without baseline data[8,10,11]

Symptom checklist, or	One or more symptoms declared from the symptom list which are not usually experienced by the player following a rugby match or training
Balance evaluation, or	*Tandem test:* 3 or more errors *Single-leg stance test:* 4 or more errors
The Standardised Assessment of Concussion (SAC) includes measures of orientation, immediate memory, concentration and delayed recall	*Total SAC score:* 24 or below *Concentration score (reciting digits backwards):* 2 or below *Delayed recall:* 3 or less words

Table 3: Age and graduated return to play[8]

Players aged 15 years and younger	The IRB recommends a minimum symptom-free rest period of two weeks, followed by a graduated return to play. Each stage lasts 48 hours. The earliest return to play should be on the twenty-third day post-injury.
Players aged 16–18 years of age	It is recommended that players aged 16–18 years have a minimum symptom-free rest period of one week, followed by graduated return to play. Each stage should last 24 hours, and the earliest return to play should take place on the twelfth day post-injury.
Adults aged 19 years and older	Adults aged 19 years old and older must have a minimum symptom-free rest period of 24 hours, followed by graduated return to play. Each stage must last 24 hours. The earliest return to play should take place on the sixth day post-injury.

IRB: International Rugby Board

Table 4: New multimodal methods that can be used to manage the patient

Heart rate variability: This is the non-invasive quantification of cardiac control via the sympathetic and parasympathetic branches of the autonomic nervous system.	Blake et al established that there was evidence of increased heart rate and decreased heart rate variability in concussion during low-intensity, steady-state exercise up to 10 days after a concussion incident.[13]
HITS	This has a high predictive value in detecting athletes who display high concussion risk and of quantifying the impact of subconcussive hits.[14]
ImPACT	This is a computer-based neuropsychological test that quantifies attention, working memory, processing speed, response variability and nonverbal problem solving.[15]
An MRI and CT are structural imaging tools used to identify intracranial haemorrhage, contusion, mass effect, herniation, fractures, and other intracranial lesions. The MRI offers superior sensitivity to that of the CT.	Conventional MRI and CT images often appear to be normal in concussed patients.[16]
PET is an imaging tool that uses radio-labelled metabolic analogues.	PET is an objective biomarker that correlates with the neuropsychological symptoms of mild TBI. However, this method is invasive and time consuming, and should be compared with CT and MRI.[17]
Functional MRI indirectly measures local neuronal haemodynamic changes in the brain.	Functional brain activation changes were measured directly after concussion, and also after several months, in a study by Maruta, Lee, Jacobs and Ghajar.[18]
Biomarkers, such as serum protein S100B and apolipoprotein E	There is little consensus as to whether or not either of these biomarkers indicate an increased chance of concussion or are capable of predicting long-term outcomes.[19,20]

CT: computed tomography, HITS: Head Impact Telemetry System, ImPACT: The Immediate Post-Concussion Assessment Cognitive Test, MRI: magnetic resonance imaging, PET: positron emission tomography, TBI: traumatic brain injury

has made the use of some of these new concepts very attractive when investigating an athlete who has been diagnosed with concussion.

However, it is important to remember that that owing to the complex nature of this injury, a single test can never sufficiently describe this complex disorder.

Conclusion

Each year, TBIs contribute to a substantial number of deaths and cases of permanent disability. The development of return-to-play protocols in the adult athlete has received considerable attention in the last decade. This has sparked renewed interest in the field, and subsequently, much research has been conducted on the effects of injury to the human brain. These advances in the understanding of the complex physiological processes involved in concussion have made it possible for objective, well structured protocols to be developed and implemented to currently guide doctors and coaches in how to ensure that athletes are fit enough to participate before returning to the field.

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