

Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008



EDITOR'S CHOICE

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This paper is a revision and update of the recommendations developed following the 1st (Vienna) and 2nd (Prague) International Symposia on Concussion in Sport.^{1,2} The Zurich Consensus statement is designed to build on the principles outlined in the original Vienna and Prague documents and to develop further conceptual understanding of this problem using a formal consensus-based approach. A detailed description of the consensus process is outlined at the end of this document. This document is developed for use by physicians, therapists, certified athletic trainers, health professionals, coaches and other people involved in the care of injured athletes, whether at the recreational, elite or professional level. While agreement exists pertaining to principal messages conveyed within this document, the authors acknowledge that the science of concussion is evolving and therefore management and return to play decisions remain in the realm of clinical judgement on an individualised basis. Readers are encouraged to copy and distribute freely the Zurich Consensus document and/or the Sports Concussion Assessment Tool (SCAT2) card and neither is subject to any copyright restric-

tion. The authors request, however that the document and/or the SCAT2 card be distributed in their full and complete format.

The following focus questions formed the foundation for the Zurich concussion consensus statement:

Acute simple concussion

- ▶ Which symptom scale and which sideline assessment tool is best for diagnosis and/or follow up?
- ▶ How extensive should the cognitive assessment be in elite athletes?
- ▶ How extensive should clinical and neuropsychological (NP) testing be at non-elite level?
- ▶ Who should do/interpret the cognitive assessment?
- ▶ Is there a gender difference in concussion incidence and outcomes?

Return to play (RTP) issues

- ▶ Is provocative exercise testing useful in guiding RTP?
- ▶ What is the best RTP strategy for elite athletes?
- ▶ What is the best RTP strategy for non-elite athletes?
- ▶ Is protective equipment (eg, mouthguards and helmets) useful in reducing concussion incidence and/or severity?

Complex concussion and long-term issues

- ▶ Is the simple versus complex classification a valid and useful differentiation?
- ▶ Are there specific patient populations at risk of long-term problems?
- ▶ Is there a role for additional tests (eg, structural and/or functional MRI, balance testing, biomarkers)?

- ▶ Should athletes with persistent symptoms be screened for depression/anxiety?

Paediatric concussion

- ▶ Which symptoms scale is appropriate for this age group?
- ▶ Which tests are useful and how often should baseline testing be performed in this age group?
- ▶ What is the most appropriate RTP guideline for elite and non-elite child and adolescent athletes?

Future directions

- ▶ What is the best method of knowledge transfer and education?
- ▶ Is there evidence that new and novel injury prevention strategies work (eg, changes to rules of the game, fair play strategies, etc)?

The Zurich document additionally examines the management issues raised in the previous Prague and Vienna documents and applies the consensus questions to these areas.

SPECIFIC RESEARCH QUESTIONS AND CONSENSUS DISCUSSION

1. Concussion

1.1 Definition of concussion

A panel discussion regarding the definition of concussion and its separation from mild traumatic brain injury (mTBI) was held. Although there was acknowledgement that the terms refer to different injury constructs and should not be used interchangeably, it was not felt that the panel would define mTBI for the purpose of this document. There was unanimous agreement, however, that concussion is defined as follows:

Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilised in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" 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 neuropathological changes but the acute clinical symptoms largely reflect a functional

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disturbance rather than a structural injury.

4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course; however it is important to note that in a small percentage of cases however, post-concussive symptoms may be prolonged.

5. No abnormality on standard structural neuroimaging studies is seen in concussion.

1.2 Classification of concussion

There was unanimous agreement to abandon the simple versus complex terminology that had been proposed in the Prague agreement statement as the panel felt that the terminology itself did not fully describe the entities. The panel however unanimously retained the concept that the majority (80–90%) of concussions resolve in a short (7–10 day) period, although the recovery time frame may be longer in children and adolescents.²

2. Concussion evaluation

2.1 Symptoms and signs of acute concussion

The panel agreed that the diagnosis of acute concussion usually involves the assessment of a range of domains including clinical symptoms, physical signs, behaviour, balance, sleep and cognition. Furthermore, a detailed concussion history is an important part of the evaluation both in the injured athlete and when conducting a pre-participation examination. The detailed clinical assessment of concussion is outlined in the SCAT2 form (see p 85).

The suspected diagnosis of concussion can include one or more of the following clinical domains:

- Symptoms—somatic (eg, headache), cognitive (eg, feeling like in a fog) and/or emotional symptoms (eg, lability).
- Physical signs (eg, loss of consciousness, amnesia).
- Behavioural changes (eg, irritability).
- Cognitive impairment (eg, slowed reaction times).
- Sleep disturbance (eg, drowsiness).

If any one or more of these components is present, a concussion should be suspected and the appropriate management strategy instituted.

2.2 On-field or sideline evaluation of acute concussion

When a player shows *any* features of a concussion:

- The player should be medically evaluated onsite using standard emergency management principles and particular attention should be given to excluding a cervical spine injury.
- The appropriate disposition of the player must be determined by the treating healthcare provider in a timely manner. If no healthcare provider is available, the player should be safely removed from practice or play and urgent referral to a physician arranged.
- Once the first aid issues are addressed, then an assessment of the concussive injury should be made using the SCAT2 or other similar tool.
- The player should not be left alone following the injury and serial monitoring for deterioration is essential over the initial few hours following injury.
- A player with diagnosed concussion should not be allowed to return to play on the day of injury. Occasionally in adult athletes, there may be return to play on the same day as the injury. See Section 4.2.

It was unanimously agreed that sufficient time for assessment and adequate facilities should be provided for the appropriate medical assessment both on and off the field for all injured athletes. In some sports this may require rule change to allow an off-field medical assessment to occur without affecting the flow of the game or unduly penalising the injured player's team.

Sideline evaluation of cognitive function is an essential component in the assessment of this injury. Brief neuropsychological test batteries that assess attention and memory function have been shown to be practical and effective. Such tests include the Maddocks questions^{3,4} and the Standardized Assessment of Concussion (SAC).^{5–7} It is worth noting that standard orientation questions (eg, time, place, person) have been shown to be unreliable in the sporting situation when compared with memory assessment.^{4,8} It is recognised, however, that abbreviated testing paradigms are designed for rapid concussion screening on the sidelines and are not meant to replace comprehensive neuropsychological testing which is sensitive to detect subtle deficits that may exist beyond the acute episode; nor should they be used as a stand-alone tool for the ongoing management of sports concussions.

It should also be recognised that the appearance of symptoms might be

delayed several hours following a concussive episode.

2.3 Evaluation in emergency room or office by medical personnel

An athlete with concussion may be evaluated in the emergency room or doctor's office as a point of first contact following injury or may have been referred from another care provider. In addition to the points outlined above, the key features of this exam should encompass:

- A medical assessment including a comprehensive history, and detailed neurological examination including a thorough assessment of mental status, cognitive functioning and gait and balance.
- A determination of the clinical status of the patient including whether there has been improvement or deterioration since the time of injury. This may involve seeking additional information from parents, coaches, teammates and eyewitnesses to the injury.
- A determination of the need for emergent neuroimaging in order to exclude a more severe brain injury involving a structural abnormality

In large part, these points above are included in the SCAT2 assessment, which forms part of the Zurich consensus statement.

3. Concussion investigations

A range of additional investigations may be utilised to assist in the diagnosis and/or exclusion of injury. These include the following.

3.1 Neuroimaging

It was recognised by the panellists that conventional structural neuroimaging is normal in concussive injury. Given that caveat, the following suggestions are made: brain CT (or where available, MR brain scan) contributes little to concussion evaluation but should be employed whenever suspicion of an intracerebral structural lesion exists. Examples of such situations may include prolonged disturbance of conscious state, focal neurological deficit or worsening symptoms.

Newer structural MRI modalities including gradient echo, perfusion and diffusion imaging have greater sensitivity for structural abnormalities. However, the lack of published studies as well as absent pre-injury neuroimaging data limits the usefulness of this approach in clinical management at the present time. In

addition, the predictive value of various MR abnormalities that may be incidentally discovered is not established at the present time.

Other imaging modalities such as functional MRI (fMRI) show activation patterns that correlate with symptom severity and recovery in concussion.^{9–13} While not part of routine assessment at the present time, they nevertheless provide additional insight to pathophysiological mechanisms. Alternative imaging technologies (eg, positron emission tomography, diffusion tensor imaging, magnetic resonance spectroscopy, functional connectivity), while demonstrating some compelling findings, are still at early stages of development and cannot be recommended other than in a research setting.

3.2 Objective balance assessment

Published studies, using both sophisticated force plate technology and less sophisticated clinical balance tests (eg, balance error scoring system (BESS)), have identified postural stability deficits lasting approximately 72 hours following sport-related concussion. It appears that postural stability testing provides a useful tool for objectively assessing the motor domain of neurological functioning, and should be considered a reliable and valid addition to the assessment of athletes suffering from concussion, particularly where symptoms or signs indicate a balance component.^{14–20}

3.3 Neuropsychological assessment

The application of neuropsychological (NP) testing in concussion has been shown to be of clinical value and continues to contribute significant information in concussion evaluation.^{21–26} Although in most cases cognitive recovery largely overlaps with the time course of symptom recovery, it has been demonstrated that cognitive recovery may occasionally precede or more commonly follow clinical symptom resolution, suggesting that the assessment of cognitive function should be an important component in any return to play protocol.^{27–28} It must be emphasised however, that NP assessment should not be the sole basis of management decisions; rather it should be seen as an aid to the clinical decision-making process in conjunction with a range of clinical domains and investigational results.

Neuropsychologists are in the best position to interpret NP tests by virtue of their background and training.

However, there may be situations where neuropsychologists are not available and other medical professionals may perform or interpret NP screening tests. The ultimate return to play decision should remain a medical one in which a multidisciplinary approach, when possible, has been taken. In the absence of NP and other (eg, formal balance assessment) testing, a more conservative return to play approach may be appropriate.

In the majority of cases, NP testing will be used to assist return to play decisions and will not be done until patient is symptom free.^{29–30} There may be situations (eg, child and adolescent athletes) where testing may be performed early while the patient is still symptomatic to assist in determining management. This will normally be best determined in consultation with a trained neuropsychologist.^{31–32}

3.4 Genetic testing

The significance of apolipoprotein (Apo) E4, ApoE promoter gene, tau polymerase and other genetic markers in the management of sports concussion risk or injury outcome is unclear at this time.^{33–34} Evidence from human and animal studies in more severe traumatic brain injury shows induction of a variety of genetic and cytokine factors, such as: insulin-like growth factor-1 (IGF-1), IGF binding protein-2, fibroblast growth factor, Cu–Zn superoxide dismutase, superoxide dismutase-1 (SOD-1), nerve growth factor, glial fibrillary acidic protein (GFAP) and S-100. Whether such factors are affected in sporting concussion is not known at this stage.^{35–42}

3.5 Experimental concussion assessment modalities

Different electrophysiological recording techniques (eg, evoked response potential (ERP), cortical magnetic stimulation and electroencephalography) have demonstrated reproducible abnormalities in the post-concussive state; however not all studies reliably differentiated concussed athletes from controls.^{43–49} The clinical significance of these changes remains to be established.

In addition, biochemical serum and cerebral spinal fluid markers of brain injury (including S-100, neuron specific enolase (NSE), myelin basic protein (MBP), GFAP, tau, etc) have been proposed as means by which cellular damage may be detected if present.^{50–56} There is currently insufficient evidence however, to justify the routine use of these biomarkers clinically.

4. Concussion management

The cornerstone of concussion management is physical and cognitive rest until symptoms resolve and then a graded programme of exertion prior to medical clearance and return to play. The recovery and outcome of this injury may be modified by a number of factors that may require more sophisticated management strategies. These are outlined in the section on modifiers below.

As described above, the majority of injuries will recover spontaneously over several days. In these situations, it is expected that an athlete will proceed progressively through a stepwise return to play strategy.⁵⁷ During this period of recovery while symptomatic, following an injury, it is important to emphasise to the athlete that physical *and* cognitive rest is required. Activities that require concentration and attention (eg, scholastic work, videogames, text messaging, etc) may exacerbate symptoms and possibly delay recovery. In such cases, apart from limiting relevant physical and cognitive activities (and other risk-taking opportunities for re-injury) while symptomatic, no further intervention is required during the period of recovery and the athlete typically resumes sport without further problem.

4.1 Graduated return to play protocol

Return to play protocol following a concussion follows a stepwise process as outlined in table 1.

With this stepwise progression, the athlete should continue to proceed to the next level if asymptomatic at the current level. Generally each step should take 24 hours so that an athlete would take approximately one week to proceed through the full rehabilitation protocol once they are asymptomatic at rest and with provocative exercise. If any post-concussion symptoms occur while in the stepwise programme, the patient should drop back to the previous asymptomatic level and try to progress again after a further 24-hour period of rest has passed.

4.2 Same day RTP

With adult athletes, in some settings, where there are team physicians experienced in concussion management and sufficient resources (eg, access to neuropsychologists, consultants, neuroimaging, etc) as well as access to immediate (ie, sideline) neurocognitive assessment, return to play management may be more rapid. The RTP strategy must still follow the same basic management principles,

Table 1 Graduated return to play protocol

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective of each stage
1. No activity	Complete physical and cognitive rest	Recovery
2. Light aerobic exercise	Walking, swimming or stationary cycling keeping intensity <70% maximum predicted heart rate No resistance training	Increase heart rate
3. Sport-specific exercise	Skating drills in ice hockey, running drills in soccer. No head impact activities	Add movement
4. Non-contact training drills	Progression to more complex training drills, eg passing drills in football and ice hockey May start progressive resistance training)	Exercise, coordination, and cognitive load
5. Full contact practice	Following medical clearance participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6. Return to play	Normal game play	

namely full clinical and cognitive recovery before consideration of return to play. This approach is supported by published guidelines, such as the American Academy of Neurology, US Team Physician Consensus Statement, and US National Athletic Trainers Association Position Statement.⁵⁸⁻⁶⁰ This issue was extensively discussed by the consensus panellists and it was acknowledged that there is evidence that some professional American football players are able to RTP more quickly, with even same day RTP supported by National Football League studies without a risk of recurrence or sequelae.⁶¹ There are data however, demonstrating that at the collegiate and high school level, athletes allowed to RTP on the same day may demonstrate NP deficits post-injury that may not be evident on the sidelines and are more likely to have delayed onset of symptoms.⁶²⁻⁶⁸ It should be emphasised however, that the young (<18) elite athlete should be treated more conservatively even though the resources may be the same as for an older professional athlete (see Section 6.1).

4.3 Psychological management and mental health issues

In addition, psychological approaches may have potential application in this injury, particularly with the modifiers listed below.⁶⁹⁻⁷⁰ Caregivers are also encouraged to evaluate the concussed athlete for affective symptoms such as depression, as these symptoms may be common in concussed athletes.⁵⁷

4.4 The role of pharmacological therapy

Pharmacological therapy in sports concussion may be applied in two distinct situations. The first of these situations is the management of specific prolonged symptoms (eg, sleep disturbance, anxiety, etc). The second situation is where drug

therapy is used to modify the underlying pathophysiology of the condition with the aim of shortening the duration of the concussion symptoms.⁷¹ In broad terms, this approach to management should only be considered by clinicians experienced in concussion management.

An important consideration in RTP is that concussed athletes should not only be symptom-free but also should not be taking any pharmacological agents/medications that may mask or modify the symptoms of concussion. Where antidepressant therapy may be commenced during the management of a concussion, the decision to return to play while still on such medication must be considered carefully by the treating clinician.

4.5 The role of pre-participation concussion evaluation

Recognising the importance of a concussion history, and appreciating the fact that many athletes will not recognise all the concussions they may have suffered in the past, a detailed concussion history is of value.⁷²⁻⁷⁵ Such a history may pre-identify athletes that fit into a high risk category and provides an opportunity for the healthcare provider to educate the athlete in regard to the significance of concussive injury. A structured concussion history should include specific questions as to previous symptoms of a concussion; not just the perceived number of past concussions. It is also worth noting that dependence on the recall of concussive injuries by teammates or coaches has been shown to be unreliable.⁷² The clinical history should also include information about all previous head, face or cervical spine injuries as these may also have clinical relevance. It is worth emphasising that in the setting of maxillofacial and cervical spine injuries, coexistent concussive injuries may be missed unless specifically assessed. Questions pertaining to disproportionate impact versus

symptom severity matching may alert the clinician to a progressively increasing vulnerability to injury. As part of the clinical history it is advised that details regarding protective equipment employed at time of injury be sought, for both recent and remote injuries. A comprehensive pre-participation concussion evaluation allows for modification and optimisation of protective behaviour and an opportunity for education.

5. Modifying factors in concussion management

The consensus panel agreed that a range of 'modifying' factors may influence the investigation and management of concussion and in some cases, may predict the potential for prolonged or persistent symptoms. These modifiers would also be important to consider in a detailed concussion history and are outlined in Table 2.

In this setting, there may be additional management considerations beyond simple RTP advice. There may be a more important role for additional investigations, including formal NP testing, balance assessment and neuroimaging. It is envisioned that athletes with such modifying features would be managed in a multidisciplinary manner coordinated by a physician with specific expertise in the management of concussive injury.

The role of female gender as a possible modifier in the management of concussion was discussed at length by the panel. There was not unanimous agreement that the current published research evidence is conclusive that this should be included as a modifying factor, although it was accepted that gender may be a risk factor for injury and/or influence injury severity.⁷⁶⁻⁷⁸

5.1 The significance of loss of consciousness (LOC)

In the overall management of moderate to severe traumatic brain injury, duration of LOC is an acknowledged predictor of outcome.⁷⁹ While published findings in concussion describe LOC associated with specific early cognitive deficits it has not been noted as a measure of injury severity.⁸⁰⁻⁸¹ Consensus discussion determined that prolonged (>1 minute duration) LOC would be considered as a factor that may modify management.

5.2 The significance of amnesia and other symptoms

There is renewed interest in the role of post-traumatic amnesia and its role as a

Table 2 Concussion modifiers

Factors	Modifier
Symptoms	Number Duration (>10 days) Severity
Signs	Prolonged loss of consciousness (>1 min), amnesia
Sequelae	Concussive convulsions
Temporal	Frequency—repeated concussions over time Timing—injuries close together in time “Recency”—recent concussion or traumatic brain injury
Threshold	Repeated concussions occurring with progressively less impact force or slower recovery after each successive concussion
Age	Child and adolescent (<18 years old)
Co- and pre-morbidities	Migraine, depression or other mental health disorders, attention deficit hyperactivity disorder, learning disabilities, sleep disorders
Medication	Psychoactive drugs, anticoagulants
Behaviour	Dangerous style of play
Sport	High risk activity, contact and collision sport, high sporting level

surrogate measure of injury severity.^{67 82 83} Published evidence suggests that the nature, burden and duration of the clinical post-concussive symptoms may be more important than the presence or duration of amnesia alone.^{80 84 85} Further it must be noted that retrograde amnesia varies with the time of measurement post-injury and hence is poorly reflective of injury severity.^{86 87}

5.3 Motor and convulsive phenomena

A variety of immediate motor phenomena (eg, tonic posturing) or convulsive movements may accompany a concussion. Although dramatic, these clinical features are generally benign and require no specific management beyond the standard treatment of the underlying concussive injury.^{88 89}

5.4 Depression

Mental health issues (such as depression) have been reported as a long-term consequence of traumatic brain injury, including sports related concussion. Neuroimaging studies using fMRI suggest that a depressed mood following concussion may reflect an underlying pathophysiological abnormality consistent with a limbic-frontal model of depression.^{52 90–100}

6. Special populations

6.1 The child and adolescent athlete

There was unanimous agreement by the panel that the evaluation and management recommendations contained herein could be applied to children and adolescents down to the age of 10 years. Below that age children report different concussion symptoms from adults and would require age appropriate symptom checklists as a component of assessment. An additional consideration in assessing the

child or adolescent athlete with a concussion is that in the clinical evaluation by the healthcare professional there may be the need to include both patient and parent input as well as teacher and school input when appropriate.^{101–107}

The decision to use NP testing is broadly the same as the adult assessment paradigm. However, timing of testing may differ in order to assist planning in school and home management (and may be performed while the patient is still symptomatic). If cognitive testing is performed, it must be developmentally sensitive until the late teen years due to the ongoing cognitive maturation that occurs during this period which, in turn, makes the utility of comparison to either the person's own baseline performance or to population norms limited.²⁰ In this age group it is more important to consider the use of trained neuropsychologists to interpret assessment data, particularly in children with learning disorders and/or attention deficit hyperactivity disorder (ADHD) who may need more sophisticated assessment strategies.^{31 32 101}

The panel strongly endorsed the view that children should not be returned to practice or play until clinically completely symptom-free, which may require a longer time frame than for adults. In addition, the concept of “cognitive rest” was highlighted with special reference to a child's need to limit exertion with activities of daily living and to limit scholastic and other cognitive stressors (eg, text messaging, videogames, etc) while symptomatic. School attendance and activities may also need to be modified to avoid provocation of symptoms.

Because of the different physiological response and longer recovery after

concussion and specific risks (eg, diffuse cerebral swelling) related to head impact during childhood and adolescence, a more conservative return to play approach is recommended. It is appropriate to extend the amount of time of asymptomatic rest and/or the length of the graded exertion in children and adolescents. It is not appropriate for a child or adolescent athlete with concussion to RTP on the same day as the injury regardless of the level of athletic performance. Concussion modifiers apply even more to this population than adults and may mandate more cautious RTP advice.

6.2 Elite versus non-elite athletes

The panel unanimously agreed that all athletes regardless of level of participation should be managed using the same treatment and return to play paradigm. A more useful construct was agreed whereby the available resources and expertise in concussion evaluation were of more importance in determining management than a separation between elite and non-elite athlete management. Although formal baseline NP screening may be beyond the resources of many sports or individuals, it is recommended that in all organised high risk sports consideration be given to having this cognitive evaluation regardless of the age or level of performance.

6.3 Chronic traumatic brain injury

Epidemiological studies have suggested an association between repeated sports concussions during a career and late life cognitive impairment. Similarly, case reports have noted anecdotal cases where neuropathological evidence of chronic traumatic encephalopathy was observed in retired football players.^{108–112} Panel discussion was held and no consensus was reached on the significance of such observations at this stage. Clinicians need to be mindful of the potential for long-term problems in the management of all athletes.

7. Injury prevention

7.1 Protective equipment: mouthguards and helmets

There is no good clinical evidence that currently available protective equipment will prevent concussion although mouthguards have a definite role in preventing dental and orofacial injury. Biomechanical studies have shown a reduction in impact forces to the brain with the use of head gear and helmets, but these findings have not been translated to show a reduction

in concussion incidence. For skiing and snowboarding there are a number of studies to suggest that helmets provide protection against head and facial injury and hence should be recommended for participants in alpine sports.^{113–116} In specific sports such as cycling, motor and equestrian sports, protective helmets may prevent other forms of head injury (eg, skull fracture) that are related to falling on hard road surfaces; these may be an important injury prevention issue for those sports.^{116–128}

7.2 Rule change

Consideration of rule changes to reduce the head injury incidence or severity may be appropriate where a clear-cut mechanism is implicated in a particular sport. An example of this is in football (soccer) where research studies demonstrated that upper limb to head contact in heading contests accounted for approximately 50% of concussions.¹²⁹ As noted earlier, rule changes may also be needed in some sports to allow an effective off-field medical assessment to occur without compromising the athlete's welfare, affecting the flow of the game or unduly penalising the player's team. It is important to note that rule enforcement may be a critical aspect of modifying injury risk in these settings; referees play an important role in this regard.

7.3 Risk compensation

An important consideration in the use of protective equipment is the concept of risk compensation.¹³⁰ This is where the use of protective equipment results in behavioural change, such as the adoption of more dangerous playing techniques, which can result in a paradoxical increase in injury rates. This may be a particular concern in child and adolescent athletes where head injury rates are often higher than in adult athletes.^{131–133}

7.4 Aggression versus violence in sport

The competitive/aggressive nature of sport which makes it fun to play and watch should not be discouraged. However, sporting organisations should be encouraged to address violence that may increase concussion risk.^{134 135} Fair play and respect should be supported as key elements of sport.

8. Knowledge transfer

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues and the general public is a mainstay of

progress in this field. Athletes, referees, administrators, parents, coaches and healthcare providers must be educated regarding the detection of concussion, its clinical features, assessment techniques and principles of safe return to play. Methods to improve education, including web-based resources, educational videos and international outreach programmes are important in delivering the message. In addition, concussion working groups plus the support and endorsement of enlightened sport groups, such as Fédération Internationale de Football Association (FIFA), International Olympic Commission (IOC), International Rugby Board (IRB) and International Ice Hockey Federation (IIHF), who initiated this endeavour have enormous value and must be pursued vigorously. Fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly coaches, parents and managers play an important part in ensuring these values are implemented on the field of play.^{57 136–148}

9. Future directions

The consensus panellists recognise that research is needed across a range of areas in order to answer some critical research questions. The key areas for research identified include:

- ▶ Validation of the SCAT2.
- ▶ Gender effects on injury risk, severity and outcome.
- ▶ Paediatric injury and management paradigms.
- ▶ Virtual reality tools in the assessment of injury.
- ▶ Rehabilitation strategies (eg, exercise therapy).
- ▶ Novel imaging modalities and their role in clinical assessment.
- ▶ Concussion surveillance using consistent definitions and outcome measures.
- ▶ Clinical assessment where no baseline assessment has been performed.
- ▶ "Best-practice" neuropsychological testing.
- ▶ Long-term outcomes.
- ▶ On-field injury severity predictors.

10. Medico-legal considerations

This consensus document reflects the current state of knowledge and will need to be modified according to the development of new knowledge. It provides an overview of issues that may be of

importance to healthcare providers involved in the management of sports related concussion. It is not intended as a standard of care, and should not be interpreted as such. This document is only a guide, and is of a general nature, consistent with the reasonable practice of a healthcare professional. Individual treatment will depend on the facts and circumstances specific to each individual case.

It is intended that this document will be formally reviewed and updated prior to 1 December 2012.

11. Statement on background to consensus process

In November 2001, the 1st International Conference on Concussion in Sport was held in Vienna, Austria. This meeting was organised by the IIHF in partnership with FIFA and the Medical Commission of the IOC. As part of the resulting mandate for the future, the need for leadership and future updates was identified. The 2nd International Conference on Concussion in Sport was organised by the same group with the additional involvement of the IRB and was held in Prague, Czech Republic in November 2004. The original aims of the symposia were to provide recommendations for the improvement of safety and health of athletes who suffer concussive injuries in ice hockey, rugby, football (soccer) and other sports. To this end, a range of experts were invited to both meetings to address specific issues of epidemiology, basic and clinical science, injury grading systems, cognitive assessment, new research methods, protective equipment, management, prevention and long-term outcome.^{1 2}

The 3rd International Conference on Concussion in Sport was held in Zurich, Switzerland on 29–30 October 2008 and was designed as a formal consensus meeting following the organisational guidelines set forth by the US National Institutes of Health. (Details of the consensus methodology can be obtained at: <http://consensus.nih.gov/ABOUTCDP.htm>) The basic principles governing the conduct of a consensus development conference are summarised below:

1. A broad based non-government, non-advocacy panel was assembled to give balanced, objective and knowledgeable attention to the topic. Panel members excluded anyone with scientific or commercial conflicts of interest and included researchers in clinical medicine, sports medicine, neuroscience, neuroimaging, athletic training and sports science.

2. These experts presented data in a public session, followed by inquiry and discussion. The panel then met in an executive session to prepare the consensus statement.
3. A number of specific questions were prepared and posed in advance to define the scope and guide the direction of the conference. The principle task of the panel was to elucidate responses to these questions. These questions are outlined above.
4. A systematic literature review was prepared and circulated in advance for use by the panel in addressing the conference questions.
5. The consensus statement is intended to serve as the scientific record of the conference.
6. The consensus statement will be widely disseminated to achieve maximum impact on both current healthcare practice and future medical research.

The panel chairperson (WM) did not identify with any advocacy position. The chairperson was responsible for directing the consensus session and guiding the panel's deliberations. Panellists were drawn from clinical practice, academic and research in the field of sports related concussion. They do not represent organisations per se but were selected for their expertise, experience and understanding of this field.

Competing interests: None.

Consensus panellists (listed in alphabetical order):

In addition to the authors above, the consensus panellists were S Broglio, G Davis, R Dick, J Dvorak, R Echemendia, G Gioia, K Guskiewicz, S Herring, G Iverson, J Kelly, J Kissick, M Makdissi, M McCrea, A Pfito, L Purcell, M Putukian. Also invited but not in attendance: R Bahr, L Engebretsen, P Hamlyn, B Jordan, P Schamasch.

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REFERENCES

1. **Aubry M**, Cantu R, Dvorak J, *et al.* Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med* 2002;**36**:6–10.
2. **McCroly P**, Johnston K, Meeuwisse W, *et al.* Summary and agreement statement of the 2nd

- International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med* 2005;**39**:196–204.
3. **Maddocks D**, Dicker G. An objective measure of recovery from concussion in Australian rules footballers. *Sport Health* 1989;**7**(Suppl):6–7.
4. **Maddocks DL**, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med* 1995;**5**:32–5.
5. **McCrea M**. Standardized mental status assessment of sports concussion. *Clin J Sport Med* 2001;**11**:176–81.
6. **McCrea M**, Kelly J, Randolph C, *et al.* Standardised assessment of concussion (SAC): on site mental status evaluation of the athlete. *J Head Trauma Rehab* 1998;**13**:27–36.
7. **McCrea M**, Randolph C, Kelly J. *The Standardized Assessment of Concussion (SAC): manual for administration, scoring and interpretation*, 2nd edn. Waukesha, WI: 2000.
8. **McCrea M**, Kelly JP, Kluge J, *et al.* Standardized assessment of concussion in football players. *Neurology* 1997;**48**:586–8.
9. **Chen J**, Johnston K, Collie A, *et al.* A validation of the Post Concussion Symptom Scale in the assessment of complex concussion using cognitive testing and functional MRI. *J Neurol Neurosurg Psychiatry* 2007;**78**:1231–8.
10. **Chen J**, Johnston K, Frey S, *et al.* Functional abnormalities in symptomatic concussed athletes: an fMRI study. *Neuroimage* 2004;**22**:68–82.
11. **Chen JK**, Johnston KM, Collie A, *et al.* Association between symptom severity, cogspport tests results, and functional MRI activation in symptomatic concussed athletes. *Clin J Sport Med* 2004;**14**:379.
12. **Chen JK**, Johnston KM, Collie A, *et al.* Behavioural and functional imaging outcomes in symptomatic concussed athletes measured with cogspport and functional MRI. *Br J Sports Med* 2004;**38**:659.
13. **Pfito A**, Chen JK, Johnston KM. Contributions of functional magnetic resonance imaging (fMRI) to sport concussion evaluation. *NeuroRehabilitation* 2007;**22**:217–27.
14. **Guskiewicz K**. Postural stability assessment following concussion. *Clin J Sport Med* 2001;**11**:182–90.
15. **Guskiewicz KM**. Assessment of postural stability following sport-related concussion. *Curr Sports Med Rep* 2003;**2**:24–30.
16. **Guskiewicz KM**, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train* 2001;**36**:263–73.
17. **Cavanaugh JT**, Guskiewicz KM, Giuliani C, *et al.* Detecting altered postural control after cerebral concussion in athletes with normal postural stability. *Br J Sports Med* 2005;**39**:805–11.
18. **Cavanaugh JT**, Guskiewicz KM, Giuliani C, *et al.* Recovery of postural control after cerebral concussion: new insights using approximate entropy. *J Athl Train* 2006;**41**:305–13.
19. **Cavanaugh JT**, Guskiewicz KM, Stergiou N. A nonlinear dynamic approach for evaluating postural control: new directions for the management of sport-related cerebral concussion. *Sports Med* 2005;**35**:935–50.
20. **Fox ZG**, Mihalik JP, Blackburn JT, *et al.* Return of postural control to baseline after anaerobic and aerobic exercise protocols. *J Athl Train* 2008;**43**:456–63.
21. **Collie A**, Darby D, Maruff P. Computerised cognitive assessment of athletes with sports related head injury. *Br J Sports Med* 2001;**35**:297–302.
22. **Collie A**, Maruff P. Computerised neuropsychological testing. *Br J Sports Med* 2003;**37**:2–3.
23. **Collie A**, Maruff P, McStephen M, *et al.* Psychometric issues associated with computerised neuropsychological assessment of concussed athletes. *Br J Sports Med* 2003;**37**:556–9.
24. **Collins MW**, Grindel SH, Lovell MR, *et al.* Relationship between concussion and neuropsychological performance in college football players. *JAMA* 1999;**282**:964–70.
25. **Lovell MR**. The relevance of neuropsychologic testing for sports-related head injuries. *Curr Sports Med Rep* 2002;**1**:7–11.
26. **Lovell MR**, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil* 1998;**13**(2):9–26.
27. **Bleiberg J**, Cernich AN, Cameron K, *et al.* Duration of cognitive impairment after sports concussion. *Neurosurgery* 2004;**54**:1073–80.
28. **Bleiberg J**, Warden D. Duration of cognitive impairment after sports concussion. *Neurosurgery* 2005;**56**:E1166.
29. **Broglio SP**, Macciocchi SN, Ferrara MS. Neurocognitive performance of concussed athletes when symptom free. *J Athl Train* 2007;**42**:504–8.
30. **Broglio SP**, Macciocchi SN, Ferrara MS. Sensitivity of the concussion assessment battery. *Neurosurgery* 2007;**60**:1050–8.
31. **Gioia G**, Janusz J, Gilstein K, *et al.* Neuropsychological management of concussion in children and adolescents: effects of age and gender on ImPact (abstract). *Br J Sports Med* 2004;**38**:657.
32. **McCroly P**, Collie A, Anderson V, *et al.* Can we manage sport related concussion in children the same as in adults? *Br J Sports Med* 2004;**38**:516–9.
33. **Kristman VL**, Tator CH, Kreiger N, *et al.* Does the apolipoprotein epsilon 4 allele predispose varsity athletes to concussion? A prospective cohort study. *Clin J Sport Med* 2008;**18**:322–8.
34. **Terrell TR**, Bostick RM, Abramson R, *et al.* APOE, APOE promoter, and tau genotypes and risk for concussion in college athletes. *Clin J Sport Med* 2008;**18**:10–7.
35. **Vagnozzi R**, Tavazzi B, Signoretto S, *et al.* Temporal window of metabolic brain vulnerability to concussions: mitochondrial-related impairment—part I. *Neurosurgery* 2007;**61**:379–89.
36. **Hang CH**, Chen G, Shi JX, *et al.* Cortical expression of nuclear factor kappaB after human brain contusion. *Brain Res* 2006;**1109**:14–21.
37. **Peng RY**, Gao YB, Xiao XY, *et al.* [Study on the expressions of basic fibroblast growth factor and nervous growth factor genes in rat cerebral concussion]. *Zhongguo Wei Zhong Bing Ji Jiu Yi Xue* 2003;**15**:213–6.
38. **Yunoki M**, Kawauchi M, Ukita N, *et al.* Effects of lecitithinized SOD on sequential change in SOD activity after cerebral contusion in rats. *Acta Neurochir Suppl* 1998;**71**:142–5.
39. **Hinkle DA**, Baldwin SA, Scheff SW, *et al.* GFAP and S100beta expression in the cortex and hippocampus in response to mild cortical contusion. *J Neurotrauma* 1997;**14**:729–38.
40. **Holmin S**, Schalling M, Hojeberg B, *et al.* Delayed cytokine expression in rat brain following experimental contusion. *J Neurosurg* 1997;**86**:493–504.
41. **Sandberg Nordqvist AC**, von Holst H, Holmin S, *et al.* Increase of insulin-like growth factor (IGF)-1, IGF binding protein-2 and -4 mRNAs following cerebral contusion. *Brain Res Mol Brain Res* 1996;**38**:285–93.
42. **Fukuhara T**, Nishio S, Ono Y, *et al.* Induction of Cu, Zn-superoxide dismutase after cortical contusion injury during hypothermia. *Brain Res* 1994;**657**:333–6.
43. **Boutin D**, Lassonde M, Robert M, *et al.* Neurophysiological assessment prior to and following sports-related concussion during childhood: a case study. *Neurocase* 2008;**14**:239–48.
44. **De Beaumont L**, Brisson B, Lassonde M, *et al.* Long-term electrophysiological changes in athletes with a history of multiple concussions. *Brain Inj* 2007;**21**:631–44.
45. **De Beaumont L**, Lassonde M, Leclerc S, *et al.* Long-term and cumulative effects of sports concussion on motor cortex inhibition. *Neurosurgery* 2007;**61**:329–37.
46. **Gaetz M**, Weinberg H. Electrophysiological indices of persistent post-concussion symptoms. *Brain Inj* 2000;**14**:815–32.
47. **Gosselin N**, Theriault M, Leclerc S, *et al.* Neurophysiological anomalies in symptomatic and asymptomatic concussed athletes. *Neurosurgery* 2006;**58**:1151–61.

48. **Lavoie ME**, Dupuis F, Johnston KM, *et al*. Visual p300 effects beyond symptoms in concussed college athletes. *J Clin Exp Neuropsychol* 2004;**26**:55–73.
49. **Rousseff RT**, Tzvetanov P, Atanassova PA, *et al*. Correlation between cognitive P300 changes and the grade of closed head injury. *Electroencephalogr Clin Neurophysiol* 2006;**46**:275–7.
50. **Begaz T**, Kyriacou DN, Segal J, *et al*. Serum biochemical markers for post-concussion syndrome in patients with mild traumatic brain injury. *J Neurotrauma* 2006;**23**:1201–10.
51. **de Bousard CN**, Lundin A, Karlstedt D, *et al*. S100 and cognitive impairment after mild traumatic brain injury. *J Rehabil Med* 2005;**37**:53–7.
52. **Lima DP**, Simao Filho C, Abib Sde C, *et al*. Quality of life and neuropsychological changes in mild head trauma. Late analysis and correlation with S100B protein and cranial CT scan performed at hospital admission. *Injury* 2008;**39**:604–11.
53. **Ma M**, Lindsay CJ, Rosenberry CM, *et al*. Serum cleaved tau does not predict postconcussion syndrome after mild traumatic brain injury. *Am J Emerg Med* 2008;**26**:763–8.
54. **Stalnacke BM**, Tegner Y, Sojka P. Playing ice hockey and basketball increases serum levels of S-100B in elite players: a pilot study. *Clin J Sport Med* 2003;**13**:292–302.
55. **Stalnacke BM**, Tegner Y, Sojka P. Playing soccer increases serum concentrations of the biochemical markers of brain damage S-100B and neuron-specific enolase in elite players: a pilot study. *Brain Inj* 2004;**18**:899–909.
56. **Townend W**, Ingebrigtsen T. Head injury outcome prediction: a role for protein S-100B? *Injury* 2006;**37**:1098–108.
57. **Johnston K**, Bloom G, Ramsay J, *et al*. Current concepts in concussion rehabilitation. *Curr Sports Med Rep* 2004;**3**:316–23.
58. **Guskiewicz KM**, Bruce SL, Cantu RC, *et al*. National Athletic Trainers' Association position statement: management of sport-related concussion. *J Athl Train* 2004;**39**:280–97.
59. **Herring S**, Bergfeld J, Boland A, *et al*. Concussion (mild traumatic brain injury) and the team physician: a consensus statement. *Medicine Sci Sports Exerc* 2006;**38**:395–9.
60. **Kelly JP**, Rosenberg JH. The development of guidelines for the management of concussion in sports. *Journal Head Trauma Rehabil* 1998;**13**:53–65.
61. **Pellman EJ**, Viano DC, Casson IR, *et al*. Concussion in professional football: players returning to the same game—part 7. *Neurosurgery* 2005;**56**:79–92.
62. **Guskiewicz KM**, McCrea M, Marshall SW, *et al*. Cumulative effects associated with recurrent concussion in collegiate football players. *JAMA* 2003;**290**:2549–55.
63. **Lovell M**, Collins M, Bradley J. Return to play following sports-related concussion. *Clin Sports Med* 2004;**23**:421–41.
64. **Collins M**, Field M, Lovell M, *et al*. Relationship between postconcussion headache and neuropsychological test performance in high school athletes. *American J Sports Med* 2003;**31**:168–73.
65. **Collins M**, Grindel S, Lovell M, *et al*. Relationship between concussion and neuropsychological performance in college football players. *JAMA* 1999;**282**:964–70.
66. **Collins MW**, Lovell MR, Iverson GL, *et al*. Cumulative effects of concussion in high school athletes. *Neurosurgery* 2002;**51**:1175–81.
67. **McCrea M**, Guskiewicz KM, Marshall SW, *et al*. Acute effects and recovery time following concussion in collegiate football players. *JAMA* 2003;**290**:2556–63.
68. **McCrea M**, Hammeke T, Olsen G, *et al*. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med* 2004;**14**:13–7.
69. **Bloom G**, Horton A, McCrory P, *et al*. Sport psychology and concussion: new impacts to explore. *Br J Sports Med* 2004;**38**:519–21.
70. **Weiss MR**, Gill DL. What goes around comes around: re-emerging themes in sport and exercise psychology. *Res Q Exerc Sport* 2005;**76**(2 Suppl):S71–87.
71. **McCrory P**. Should we treat concussion pharmacologically? The need for evidence based pharmacological treatment for the concussed athlete. *Br J Sports Med* 2002;**36**:3–5.
72. **McCrory P**. Preparticipation assessment for head injury. *Clin J Sport Med* 2004;**14**:139–44.
73. **Johnston KM**, Lassonde M, Ptitio A. A contemporary neurosurgical approach to sport-related head injury: the McGill concussion protocol. *J Am Coll Surg* 2001;**192**:515–24.
74. **Delaney J**, Lacroix V, Leclerc S, *et al*. Concussions during the 1997 Canadian Football League season. *Clin J Sport Med* 2000;**10**:9–14.
75. **Delaney J**, Lacroix V, Leclerc S, *et al*. Concussions among university football and soccer players. *Clin J Sport Med* 2002;**12**:331–8.
76. **Gessel LM**, Fields SK, Collins CL, *et al*. Concussions among United States high school and collegiate athletes. *J Athl Train* 2007;**42**:495–503.
77. **Dvorak J**, Junge A, Fuller C, *et al*. Medical issues in women's football. *Br J Sports Med* 2007;**41**(Suppl 1):i1.
78. **Dvorak J**, McCrory P, Kirkendall DT. Head injuries in the female football player: incidence, mechanisms, risk factors and management. *Br J Sports Med* 2007;**41**(Suppl 1):i44–6.
79. **Jennett B**, Bond M. Assessment of outcome after severe brain damage: a practical scale. *Lancet* 1975;**1**:480–4.
80. **Leninger B**, Gramling S, Farrell A, *et al*. Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *J Neurol Neurosurg Psychiatry* 1990;**53**:293–6.
81. **Lovell M**, Iverson G, Collins M, *et al*. Does loss of consciousness predict neuropsychological decrements after concussion. *Clin J Sport Med* 1999;**9**:193–9.
82. **McCrea M**, Kelly J, Randolph C, *et al*. Immediate neurocognitive effects of concussion. *Neurosurgery* 2002;**50**:1032–42.
83. **Cantu RC**. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *J Athl Train* 2001;**36**:244–8.
84. **Lovell MR**, Collins MW, Iverson GL, *et al*. Recovery from mild concussion in high school athletes. *J Neurosurg* 2003;**98**:296–301.
85. **McCrory PR**, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med* 2000;**10**:235–8.
86. **Yarnell P**, Lynch S. The 'ding': amnesic state in football trauma. *Neurology* 1973;**23**:196–7.
87. **Yarnell PR**, Lynch S. Retrograde memory immediately after concussion. *Lancet* 1970;**1**:863–4.
88. **McCrory PR**, Berkovic SF. Video analysis of acute motor and convulsive manifestations in sport-related concussion. *Neurology* 2000;**54**:1488–91.
89. **McCrory PR**, Bladin PF, Berkovic SF. Retrospective study of concussive convulsions in elite Australian rules and rugby league footballers: phenomenology, aetiology, and outcome. *BMJ* 1997;**314**:171–4.
90. **Fleminger S**. Long-term psychiatric disorders after traumatic brain injury. *Eur J Anaesthesiol Suppl* 2008;**42**:123–30.
91. **Chen JK**, Johnston KM, Petrides M, *et al*. Neural substrates of symptoms of depression following concussion in male athletes with persisting postconcussion symptoms. *Arch Gen Psychiatry* 2008;**65**:81–9.
92. **Bryant RA**. Disentangling mild traumatic brain injury and stress reactions. *N Engl J Med* 2008;**358**:525–7.
93. **Vanderploeg RD**, Curtiss G, Luis CA, *et al*. Long-term morbidities following self-reported mild traumatic brain injury. *J Clin Exp Neuropsychol* 2007;**29**:585–98.
94. **Guskiewicz KM**, Marshall SW, Bailes J, *et al*. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc* 2007;**39**:903–9.
95. **Kashluba S**, Casey JE, Paniak C. Evaluating the utility of ICD-10 diagnostic criteria for postconcussion syndrome following mild traumatic brain injury. *J Int Neuropsychol Soc* 2006;**12**:111–8.
96. **Iverson GL**. Misdiagnosis of the persistent postconcussion syndrome in patients with depression. *Arch Clin Neuropsychol* 2006;**21**:303–10.
97. **Chamelian L**, Feinstein A. The effect of major depression on subjective and objective cognitive deficits in mild to moderate traumatic brain injury. *J Neuropsychiatry Clin Neurosci* 2006;**18**:33–8.
98. **Mooney G**, Speed J, Sheppard S. Factors related to recovery after mild traumatic brain injury. *Brain Inj* 2005;**19**:975–87.
99. **Broshnek DK**, Freeman JR. Psychiatric and neuropsychological issues in sport medicine. *Clin Sports Med* 2005;**24**:663–79.
100. **Pellman EJ**. Background on the National Football League's research on concussion in professional football. *Neurosurgery* 2003;**53**:797–8.
101. **Purcell L**, Carson J. Sport-related concussion in pediatric athletes. *Clin Pediatr (Phila)* 2008;**47**:106–13.
102. **Lee LK**. Controversies in the sequelae of pediatric mild traumatic brain injury. *Pediatr Emerg Care* 2007;**23**:580–3.
103. **Schnadower D**, Vazquez H, Lee J, *et al*. Controversies in the evaluation and management of minor blunt head trauma in children. *Current Opin Pediatr* 2007;**19**:258–64.
104. **Wozniak JR**, Krach L, Ward E, *et al*. Neurocognitive and neuroimaging correlates of pediatric traumatic brain injury: a diffusion tensor imaging (DTI) study. *Arch Clin Neuropsychol* 2007;**22**:555–68.
105. **Hayden MG**, Jandial R, Duenas HA, *et al*. Pediatric concussions in sports: a simple and rapid assessment tool for concussive injury in children and adults. *Childs Nerv Syst* 2007;**23**:431–5.
106. **Lee MA**. Adolescent concussions—management recommendations: a practical approach. *Conn Med* 2006;**70**:377–80.
107. **Kirkwood MW**, Yeates KO, Wilson PE. Pediatric sport-related concussion: a review of the clinical management of an oft-neglected population. *Pediatrics* 2006;**117**:1359–71.
108. **Guskiewicz KM**, Marshall SW, Bailes J, *et al*. Association between recurrent concussion and late-life cognitive impairment in retired professional football players. *Neurosurgery* 2005;**57**:719–26.
109. **Nandoe RD**, Scheltens P, Eikelenboom P. Head trauma and Alzheimer's disease. *J Alzheimers Dis* 2002;**4**:303–8.
110. **Stern MB**. Head trauma as a risk factor for Parkinson's disease. *Mov Disord* 1991;**6**:95–7.
111. **Omali BI**, DeKosky ST, Hamilton RL, *et al*. Chronic traumatic encephalopathy in a national football league player: part II. *Neurosurgery* 2006;**59**:1086–93.
112. **Omali BI**, DeKosky ST, Minster RL, *et al*. Chronic traumatic encephalopathy in a National Football League player. *Neurosurgery* 2005;**57**:128–34.
113. **Hagel BE**, Pless IB, Goulet C, *et al*. Effectiveness of helmets in skiers and snowboarders: case-control and case crossover study. *BMJ* 2005;**330**:281.
114. **McCrory P**. The role of helmets in skiing and snowboarding. *Br J Sports Med* 2002;**36**:314.
115. **Mueller BA**, Cummings P, Rivara FP, *et al*. Injuries of the head, face, and neck in relation to ski helmet use. *Epidemiology* 2008;**19**:270–6.
116. **Sulheim S**, Holme I, Ekeland A, *et al*. Helmet use and risk of head injuries in alpine skiers and snowboarders. *JAMA* 2006;**295**:919–24.
117. **Delaney JS**, Al-Kashmiri A, Drummond R, *et al*. The effect of protective headgear on head injuries and concussions in adolescent football (soccer) players. *Br J Sports Med* 2008;**42**:110–5.
118. **Viano DC**, Pellman EJ, Withnall C, *et al*. Concussion in professional football: performance of newer helmets in reconstructed game impacts—part 13. *Neurosurgery* 2006;**59**:591–606.
119. **Finch C**, Braham R, McIntosh A, *et al*. Should football players wear custom fitted mouthguards?

- Results from a group randomised controlled trial. *Inj Prev* 2005;**11**:242–6.
120. **McIntosh A**, McCrory P. The dynamics of concussive head impacts in rugby and Australian rules football. *Med Sci Sports Exerc* 2000;**32**:1980–5.
 121. **McIntosh A**, McCrory P. Impact energy attenuation performance of football headgear. *Br J Sports Med* 2000;**34**:337–42.
 122. **McIntosh A**, McCrory P. Effectiveness of headgear in a pilot study of under 15 rugby union football. *Br J Sports Med* 2001;**35**:167–70.
 123. **McIntosh A**, McCrory P, Finch C, *et al*. *Rugby headgear study report*. School of Safety Science, The University of New South Wales Sydney, Australia, May 2005.
 124. **Finch C**, Newstead S, Cameron M, *et al*. *Head injury reductions in Victoria two years after the introduction of mandatory bicycle helmet use*. Report no. 51. Melbourne: Monash University Accident Research Centre, 1993.
 125. **Curnow WJ**. Bicycle helmets and public health in Australia. *Health Promot J Austr* 2008;**19**:10–5.
 126. **Hewson PJ**. Cycle helmets and road casualties in the UK. *Traffic Inj Prev* 2005;**6**:127–34.
 127. **Davidson JA**. Epidemiology and outcome of bicycle injuries presenting to an emergency department in the United Kingdom. *Eur J Emerg Med* 2005;**12**:24–9.
 128. **Hansen KS**, Engesaeter LB, Viste A. Protective effect of different types of bicycle helmets. *Traffic Inj Prev* 2003;**4**:285–90.
 129. **Andersen T**, Arnason A, Engebretsen L, *et al*. Mechanism of head injuries in elite football. *Br J Sports Med* 2004;**38**:690–6.
 130. **Hagel B**, Meewisse W. Editorial: Risk compensation: a “side effect” of sport injury prevention? *Clin J Sport Med* 2004;**14**:193–6.
 131. **Finch C**, McIntosh AS, McCrory P, *et al*. A pilot study of the attitudes of Australian Rules footballers towards protective headgear. *J Sci Med Sport* 2003;**6**:505–11.
 132. **Finch CF**, McIntosh AS, McCrory P. What do under 15 year old schoolboy rugby union players think about protective headgear? *Br J Sports Med* 2001;**35**:89–94.
 133. **Finch CF**, McIntosh AS, McCrory P, *et al*. A pilot study of the attitudes of Australian Rules footballers towards protective headgear. *J Sci Med Sport* 2003;**6**:505–11.
 134. **Reece RM**, Sege R. Childhood head injuries: accidental or inflicted? *Arch Pediatr Adolesc Med* 2000;**154**:11–5.
 135. **Shaw NH**. Bodychecking in hockey. *CMAJ* 2004;**170**:15–8.
 136. **Denke NJ**. Brain injury in sports. *J Emerg Nurs* 2008;**34**:363–4.
 137. **Gianotti S**, Hume PA. Concussion sideline management intervention for rugby union leads to reduced concussion claims. *NeuroRehabilitation* 2007;**22**:181–9.
 138. **Guilmette TJ**, Malia LA, McQuiggan MD. Concussion understanding and management among New England high school football coaches. *Brain Inj* 2007;**21**:1039–47.
 139. **Hootman JM**, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train* 2007;**42**:311–9.
 140. **Valovich McLeod TC**, Schwartz C, Bay RC. Sport-related concussion misunderstandings among youth coaches. *Clin J Sport Med* 2007;**17**:140–2.
 141. **Sye G**, Sullivan SJ, McCrory P. High school rugby players’ understanding of concussion and return to play guidelines. *Br J Sports Med* 2006;**40**:1003–6.
 142. **Theye F**, Mueller KA. “Heads up”: concussions in high school sports. *Clin Med Res* 2004;**2**:165–71.
 143. **Kashluba S**, Paniak C, Blake T, *et al*. A longitudinal, controlled study of patient complaints following treated mild traumatic brain injury. *Arch Clin Neuropsychol* 2004;**19**:805–16.
 144. **Gabbe B**, Finch CF, Wajswelner H, *et al*. Does community-level Australian football support injury prevention research? *J Sci Med Sport* 2003;**6**:231–6.
 145. **Kaut KP**, DePompei R, Kerr J, *et al*. Reports of head injury and symptom knowledge among college athletes: implications for assessment and educational intervention. *Clin J Sport Med* 2003;**13**:213–21.
 146. **Davidhizar R**, Cramer C. “The best thing about the hospitalization was that the nurses kept me well informed”. Issues and strategies of client education. *Accid Emerg Nurs* 2002;**10**:149–54.
 147. **McCrory P**. What advice should we give to athletes postconcussion? *Br J Sports Med* 2002;**36**:316–8.
 148. **Bazarian JJ**, Veenema T, Brayer AF, *et al*. Knowledge of concussion guidelines among practitioners caring for children. *Clin Pediatr (Phila)* 2001;**40**:207–12.

APPENDIX 1

Sport Concussion Assessment Tool (SCAT2) form: a clinical tool used by practitioners managing athletes with concussion.

APPENDIX 2

Pocket SCAT2: a pocket card designed for lay practitioners to suspect the diagnosis of a concussion.