Australian Government
Australian Sports Commission

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Australian Institute of Sport and Australian Medical Association Concussion in Sport Position Statement

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"if in doubt, sit them out"

Concussion Position Statement

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1. EXECUTIVE SUMMARY

There has been growing concern in Australia and internationally about the incidence of sport-related concussion and potential health ramifications for athletes. Concussion affects athletes at all levels of sport from the part-time recreational athlete to the full-time professional. If managed appropriately most symptoms and signs of concussion resolve spontaneously, however complications can occur including prolonged duration of symptoms and increased susceptibility to further injury. There is also growing concern about potential long-term consequences of multiple concussions. The Australian Institute of Sport (AIS) is Australia's peak high-performance sport agency. The Australian Medical Association (AMA) is the peak membership organisation representing the registered medical practitioners (doctors) and medical students of Australia. Both AIS and AMA have clear and unequivocal focus on ensuring the safety and welfare of Australians participating in sport.

Over recent years there has been elevated public awareness of sport-related concussion and increased focus on the importance of diagnosing and managing the condition promptly, safely and appropriately. There has also been concern over the possible long-term consequences of recurrent concussion.

Sport administrators, medical practitioners, coaches, parents and athletes are seeking information regarding the timely recognition and appropriate management of sport-related concussion. There is need for clear, unequivocal and reliable information to be readily accessible to all members of the community.

Funded by the Australian Government, this AIS/AMA Position Statement on Concussion in Sport brings together the most contemporary evidence-based information and presents it in a format that is appropriate for all stakeholders. The AIS and AMA seek to ensure that all members of the public have rapid access to information to increase their understanding of sport-related concussion and to assist in the delivery of best practice medical care.

This Position Statement is intended to ensure that participant safety and welfare is paramount when dealing with concussion in sport.

2. AIS-AMA POSITION STATEMENT ON CONCUSSION IN SPORT

Introduction

Sport-related concussion is a growing health concern in Australia. It affects athletes at all levels of sport from the part-time recreational athlete to the full-time professional. Concerns about the incidence, and possible health ramifications for athletes, have led to an increased focus on the importance of diagnosing and managing the condition safely and appropriately[3-6]. Parents, coaches, athletes, medical practitioners and others involved in sport are seeking information regarding the best management of sport-related concussion. Participant safety and welfare is paramount when dealing with all concussion incidents.

The Australian Institute of Sport (AIS) is Australia's peak high-performance sport agency. The Australian Medical Association (AMA) is the peak membership organisation representing the registered medical practitioners (doctors) and medical students of Australia. Both AIS and AMA have clear and unequivocal focus on ensuring the safety and welfare of Australians participating in sport.

Funded by the Australian Government, this position statement aims to:

- provide improved safety and health outcomes for all people who suffer concussive injuries while participating in sport
- assist all sporting organisations and clubs to align their policy and procedures to the most up-to-date evidence
- protect the integrity of sport through the consistent application of best practice protocols and guidelines
- provide a platform to support the development of national policy for the management of concussion in Australia.

What is concussion?

Concussion is a type of brain injury, induced by a force to the head or anywhere on the body, which transmits an impulsive force to the head. It commonly causes short-lived neurological impairment and the symptoms may evolve over the hours or days following the injury. The symptoms should resolve without medical intervention. Rest, followed by gradual return to activity, is the main treatment[2]. Evidence from animal and functional imaging studies points toward a series of interrelated biochemical and physiological changes that impair neuronal function[7-15].

Recognising concussion

Recognising concussion can be difficult. The symptoms and signs are variable, non-specific and may be subtle. Onlookers should suspect concussion when an injury results in a knock to the head or body that transmits a force to the head. A hard knock is not required, concussion can occur from relatively minor knocks.

There may be obvious signs of concussion such as loss of consciousness, brief convulsions or difficulty balancing or walking. However, the signs of concussion can be more subtle. The Sport Concussion Assessment Tool (SCAT 3) identifies 22 possible symptoms[1,16,18]:

- headache
- 'don't feel right'
- 'pressure in the head'
- difficulty concentrating
- neck pain
- difficulty remembering
- nausea or vomiting
- fatigue or low energy
- dizziness
- confusion
- blurred vision
- drowsiness
- balance problems
- trouble falling asleep
- sensitivity to light
- more emotional
- sensitivity to noise
- irritability
- feeling slowed down
- sadness
- feeling like 'in a fog'
- nervous or anxious

Recognising concussion is critical to correct management and prevention of further injury. The Pocket Concussion Recognition Tool, developed by the Concussion in Sport Group to help those without medical training detect concussion, includes a list of these symptoms[1].

When an athlete is suspected of having a concussion, first-aid principles still apply, and a systematic approach to assessment of airway, breathing, circulation, disability and exposure applies in all situations. Cervical spine injuries should be suspected if there is any loss of consciousness, neck pain or a mechanism that could lead to spinal injury. Manual inline stabilisation should be undertaken and a hard collar applied until a cervical spine injury can be ruled out.

A medical doctor should review any athlete with suspected concussion. In a situation where there is no access to a medical practitioner, the athlete must not be returned to sport on the same day. If there is any doubt about whether an athlete is concussed that athlete should not be allowed to return to sport that day. An athlete with suspected concussion should be reassessed to look for developing symptoms and cleared by a medical practitioner before returning to sport. Due to the evolving nature of concussion, any athlete cleared to return to sport after being assessed for suspected concussion should be monitored closely during the game/competition for developing symptoms or signs.

Sometimes there will be clear signs that an athlete has sustained a concussion. Medical practitioners covering sporting events should immediately remove an athlete with any of the following clinical features:

- loss of consciousness
- no protective action in fall to ground directly observed or on video
- impact seizure or tonic posturing
- confusion, disorientation
- memory impairment[18]
- balance disturbance (e.g. ataxia)
- athlete reports significant, new or progressive concussion symptoms
- dazed, blank/vacant stare or not their normal selves
- behaviour change atypical of the athlete.

Athletes displaying these signs should be treated as concussed and not be returned to sport.

Some features suggest more serious injury and athletes displaying any of these signs should be immediately referred to the nearest emergency department:

- neck pain
- increasing confusion or irritability
- repeated vomiting
- seizure or convulsion
- weakness or tingling/burning in the arms or legs
- deteriorating conscious state
- severe or increasing headache
- unusual behavioural change
- double vision.

Medical assessment of concussion

The diagnosis of concussion should be made by a medical practitioner after a clinical history and examination that includes a range of domains including mechanism of injury, symptoms and signs, cognitive functioning and neurological assessment including balance testing[16,18]. The SCAT 3 is the internationally recommended concussion assessment tool and covers the above mentioned domains[1]. This should not be used in isolation but as part of the overall clinical assessment. Computerised neurocognitive testing can be undertaken as part of the assessment but again, should not be used in isolation. Baseline neurocognitive testing can be useful in the pre-season period for comparison with post-injury scores. Many programs however have reference ranges that can be applied in the absence of a baseline test.

There are currently no serum biomarkers that assist in the diagnosis of concussion. Blood tests are not indicated for uncomplicated concussion. Medical imaging is not indicated in the diagnosis or management of uncomplicated concussion. Medical imaging may be indicated however where there is suspicion of more serious head or brain injury[1].

Where resources allow, sporting organisations should optimise the use of modern technology such as pitch-side instant video replay, to enhance the ability to detect and manage concussion.

Modifying factors

While the medical practitioner assessing the athlete with suspected concussion should make optimal use of available assessment tools, clinical judgement remains a cornerstone of concussion diagnosis and management. Concussion modifiers are factors that may impact upon the clinician's management of the concussed athlete[1]. Such modifiers can be associated with a more protracted recovery time[28,29,30,32]. Concussion modifiers include the following:

- a high number of concussive symptoms
- high severity of concussive symptoms
- prolonged loss of consciousness (greater than one minute)
- post-concussive seizure
- previous history of concussion
- age of the athlete
- history of depression, anxiety, migraine, learning disability, ADHD or sleep disturbance
- use of medications, especially psychoactive or anticoagulant medication.

Managing concussion

Head-injury advice should be given to all athletes with concussion, and to their carers. Any athlete with suspected or confirmed concussion should remain in the company of a responsible adult and not be allowed to drive. They should be advised to avoid alcohol and check medications with their doctor. Specifically, they should avoid aspirin, anti-inflammatories, sleeping tablets and sedating pain medications.

Once the diagnosis of concussion has been made immediate management is physical and cognitive rest[19,20]. This may include time off school or work and rest from all cognitive activity. The majority of concussive symptoms should resolve in 7-10 days. After a minimum of 24 hours without any symptoms, the patient can commence a return to cognitive and physical activity[1,21]. The activity phase should proceed as outlined below with a minimum of 24 hours spent at each level. The activity should only be upgraded if there has been no recurrence of symptoms during that time. If there is a recurrence of symptoms, there should be a 'step down' to the previous level for at least 24 hours (after symptoms have resolved)[1]. The steps in the activity phase are:

- begin with light aerobic activity
- basic sport-specific drills which are non-contact and with no head impact
- more complex sport-specific drills without contact. May add resistance training.
- full contact practice following medical review
- normal competitive sporting activity.

Sporting organisations need to continually review their policies for best practice concussion diagnosis and management. High-risk sports such as professional collision sports need to ensure that medical personnel are appropriately trained in the detection and management of concussion. The potential benefits of rule changes such as introduction of independent concussion doctors require careful consideration against possible unintended negative consequences. Those who know the athlete may be best equipped to detect some of the subtle signs of concussion. Removing the team doctor entirely from the assessment and decision-making could conceivably compromise the ability to detect subtle concussions. A compromise could be a model that allows team doctors to assess concussions, with independent doctors to oversee the process and sign off on any athletes being returned to the field.

See diagram 1 on page 8.

Children and adolescents

Children and adolescents aged 18 and under may be more susceptible to concussion and take longer to recover, requiring a more conservative approach to concussion[22-25,31]. Return to learn should take priority over return to sport. School programs may need to be modified to include more regular breaks, rests and increased time to complete tasks. The symptom-free rest period should be extended in this group. The graduated return to sport protocol should be extended such that the child does not return to contact training, sport or play less than 14 days from the resolution of all symptoms.

See diagram 2 on page 9.

Long-term consequences

There is concern about potential long-term consequences of concussion[33,34]. There is currently no reliable evidence clearly linking sport-related concussion with chronic traumatic encephalopathy (CTE)[17,35-38]. The evidence purporting to show a link between sport-related concussion and CTE consists of case reports, case series and retrospective analyses. Due to the nature of the studies, and the reliance on retired athletes volunteering for an autopsy diagnosis, there is significant selection bias in many of the reported cases. The studies to date have not adequately controlled for the potential contribution of confounding variables such as alcohol abuse, drug abuse, genetic predisposition and psychiatric illness[17,39,40].

Given that concussion is very common and the number of cases of CTE reported is extremely small, the link between sport-related concussion and CTE remains tenuous. The potential link between concussion and CTE is of concern however and there is need for well-designed prospective epidemiological studies, which take into account the potential confounding variables.

Education

A number of studies have demonstrated that general knowledge about concussion is inadequate. Education programmes must target the various groups involved in sport-related concussion in order to effectively improve awareness and understanding in the community. Athletes themselves need to have a good

understanding of concussion in order to appreciate the importance of reporting symptoms and complying with rest and return to sport advice. Parents and coaches must also be able to recognise the symptoms and signs of concussion in order to detect concussions at the community sport level where there is no medical supervision present [41-47]. Sporting and medical organisations continue to develop specific recommendations around concussion in order to educate their own participants[46, 48, 49].

Concussion research priorities

There is a clear need for well-designed prospective research to inform the diagnosis and management of concussion. Areas that require priority in terms of resource allocation include the biological processes underlying concussion, the impact of concussion on long-term health, the role of concussion in special groups such as children and the effectiveness or otherwise of concussion education programs. There also needs to be ongoing research to constantly update and improve clinical tools used in the diagnosis and management of concussion.

Key Points for coaches, parents and athletes

- Concussion is a type of brain injury that occurs from a knock to head or body.
- Recognising concussion is critical to correctly managing and preventing further injury.
- The Pocket Concussion Recognition Tool is recommended to help recognise the signs and symptoms of concussion. This can be freely downloaded at bjsm.bmj.com/content/47/5/267.full.pdf
- First-aid principles apply in the management of the athlete with suspected concussion. This includes observing first-aid principles for protection of the cervical spine.
- Any athlete suspected of having concussion should be removed from sport and not allowed to return to sport that day. This athlete should be reviewed by a medical doctor.
- Features that suggest more serious injury and should prompt immediate emergency department referral include neck pain, increased confusion or irritability, repeated vomiting, seizure, weakness or tingling/burning in the arms or legs, reduced level of consciousness, severe or increasing headache, or unusual behaviour.
- When assessing a patient with suspected concussion, a medical doctor will ask about details of the event as well as past medical history and then assess the patient including asking about symptoms, signs, testing memory function and concentration, balance and neurologic function.
- There is no single test that can determine whether someone has sustained a concussion, your doctor may not order blood tests or medical imaging unless they wish to exclude other more serious injuries.
- Once a diagnosis of concussion has been confirmed the main treatment for concussion is rest. When symptoms have resolved for a minimum of 24 hours (longer for children) gradual return to sport can usually begin.
- The activity phase should proceed as outlined below with a minimum of 24 hours spent at each level. The activity should only be upgraded if there has been no recurrence of symptoms during that time. If this occurs there should be a 'step down' to the previous level for at least 24 hours (after symptoms have resolved):
  - begin with light aerobic activity
  - basic sport-specific drills which are non-contact and with no head impact
  - more complex sport-specific drills without contact, may add resistance training
  - full contact practice following medical review
  - normal competitive sporting activity.
- Children and adolescents take longer to recover from concussion. They should have a longer rest period (48 hours) and recommended minimum of 14 days from when symptoms cease before returning to full contact sport (after medical clearance).
- The long-term consequences of concussion and especially multiple concussions are not yet clearly understood.
- **If in doubt, sit them out.**

See diagrams 3 and 4 for non-medical assessment of concussion (on and off field) on pages 10-11.

Key Points for medical practitioners

- Concussion can be very difficult to detect. The symptoms and signs can be varied, non-specific and subtle.
- Athletes with suspected concussion should be removed from sport and assessed by a medical doctor.
- When assessing acute concussions, a standard primary survey and cervical spine precautions should be used.
- The diagnosis of concussion should be based on a clinical history and examination that includes a range of domains including mechanism of injury, symptoms and signs, cognitive functioning, neurology including balance assessment.
- The SCAT 3 is the internationally recommended concussion assessment tool and covers the abovementioned domains. It can be freely downloaded at bjsm.bmj.com/content/47/5/259.full.pdf. This should not be used in isolation but as part of the overall clinical assessment.
- Computerised neurocognitive testing can be undertaken as part of the assessment but should not be used in isolation.
- Children and adolescents may be more susceptible to concussion and take longer to recover. A more conservative approach should be taken with those aged 18 years or younger and the symptom-free rest period should be extended in this group. The graduated return to sport protocol should be extended such that the child does not return to contact training, sport or play in less than 14 days.
- Blood tests are not indicated for uncomplicated concussion. Medical imaging is not indicated unless there is suspicion of more serious head or brain injury.
- Standard head-injury advice should be given to all athletes suffering concussion and to their carer.
- Once the diagnosis of concussion has been made, immediate management is physical and cognitive rest. This includes time off school or work and rest from all cognitive activity. The majority of concussive symptoms should resolve in 7-10 days. After a minimum of 24 hours without any symptoms the patient can commence a return to cognitive and physical activity.
- Some sports have their own guidelines or recommendations around the management of concussion in sport which should also be considered.
- **If in doubt, sit them out.**

There is currently no strong evidence clearly linking sport-related concussion with chronic traumatic encephalopathy (CTE). The evidence purporting to show a link between sport-related concussion and CTE consists of case reports, case series and retrospective analyses. Due to the nature of the condition and the reliance on retired athletes nominating to posthumously undergo autopsy as part of this research there is significant bias in the samples examined and confounding factors such as alcohol abuse, drug abuse, genetic predisposition and psychiatric illness have not been controlled for adequately. Further well designed prospective studies are needed to better understand the possible relationship.

See diagrams 5 and 6 for medical assessment of concussion (on and off field) on pages 12-13.

Diagram 1: Return to Sport Protocol for adults over 18 years of age

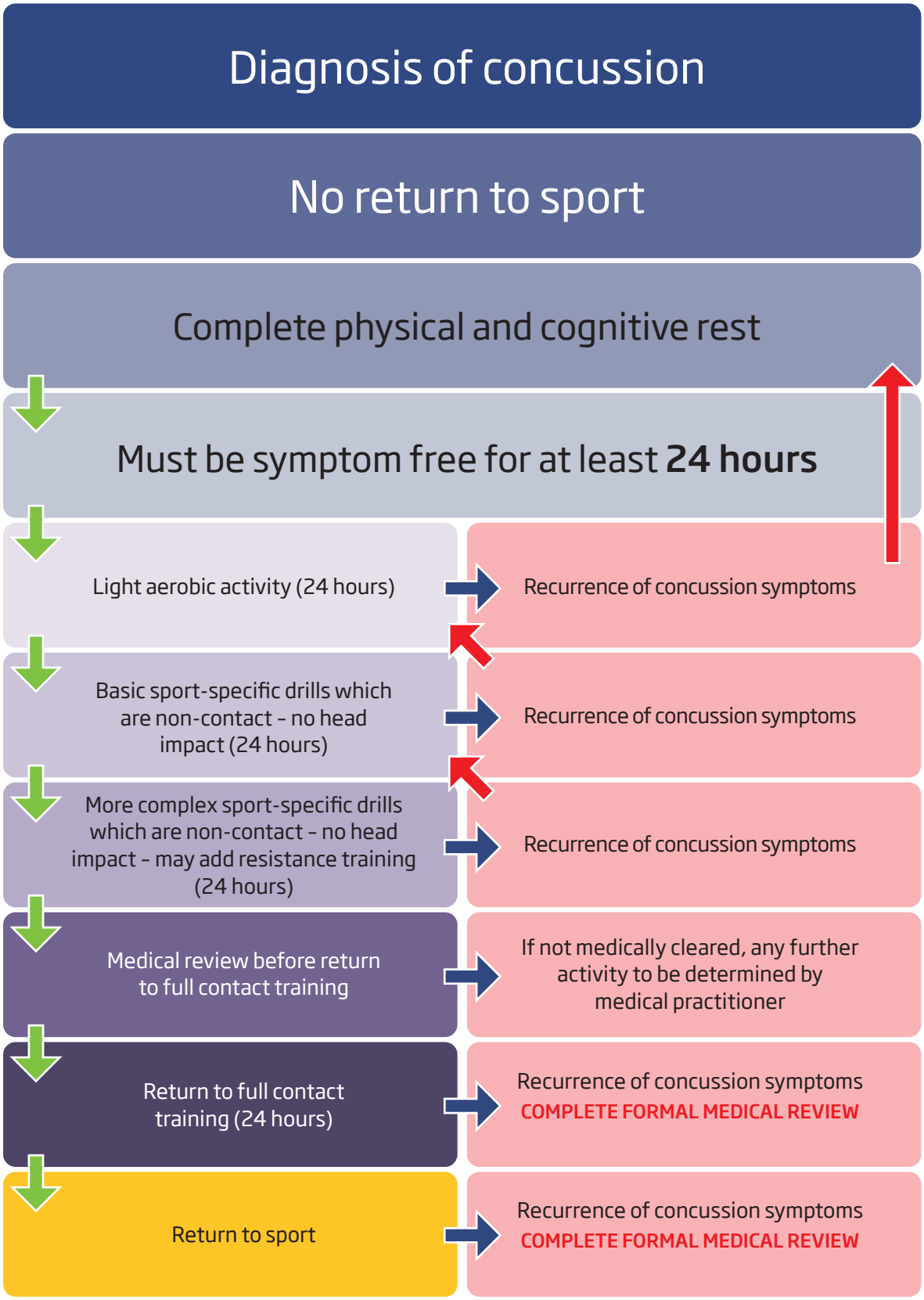


Diagram 2: Return to Sport Protocol for children under 18 years of age

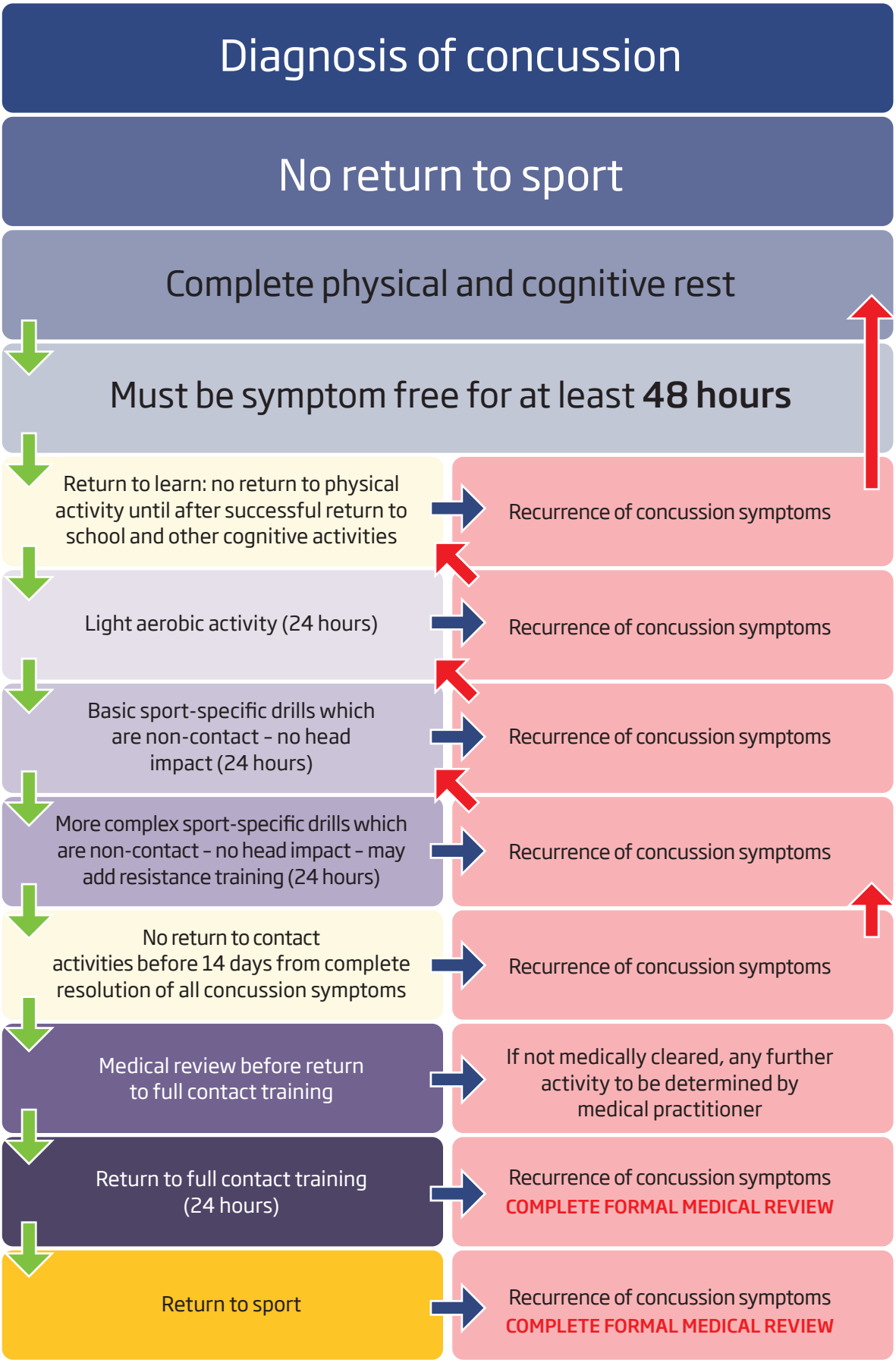


Diagram 3: Non-medical assessment of concussion – on field

(for parents, coaches, teachers, team-mates)

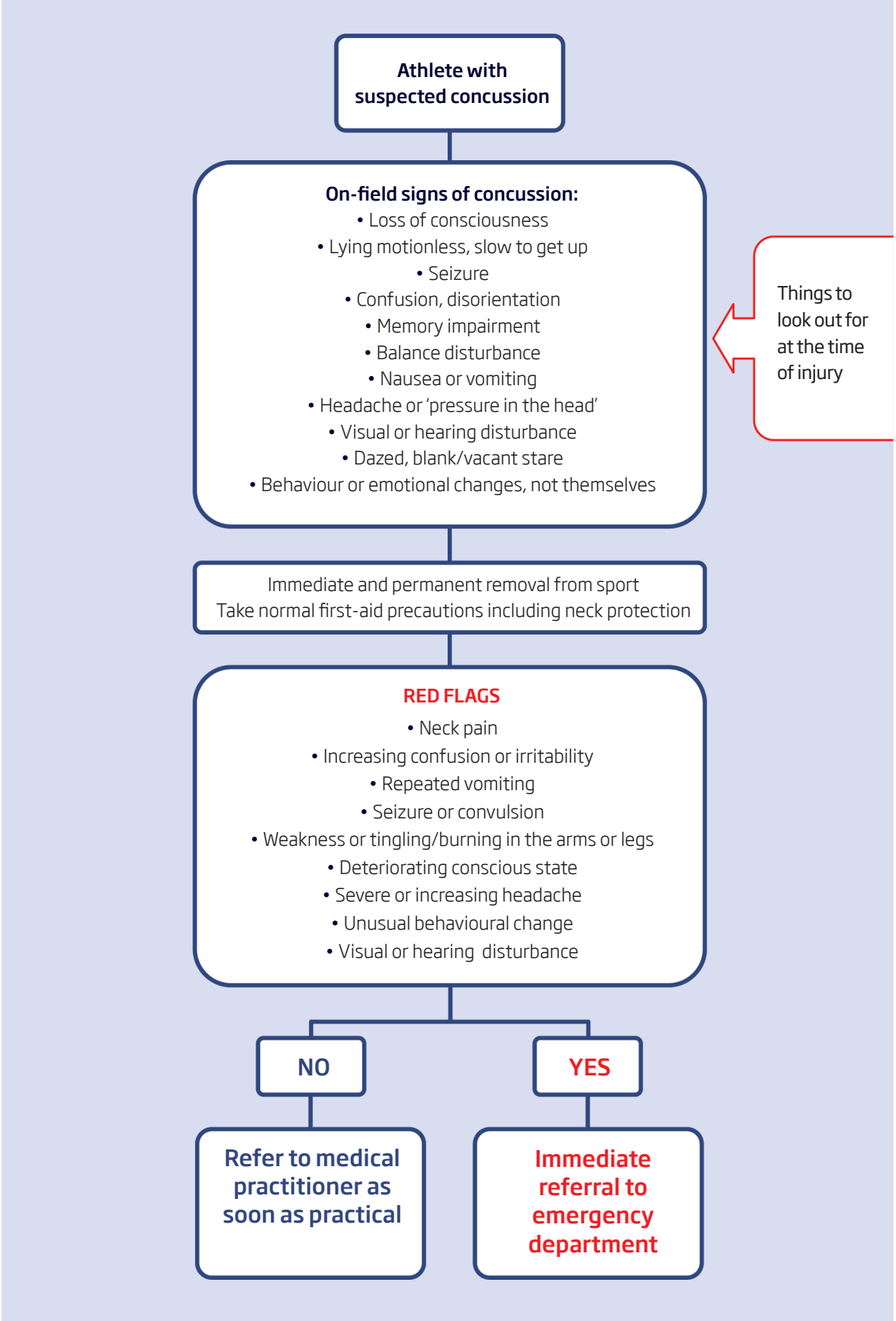


Diagram 4: Non-medical assessment of concussion – off field

(for parents, coaches, teachers, team-mates)

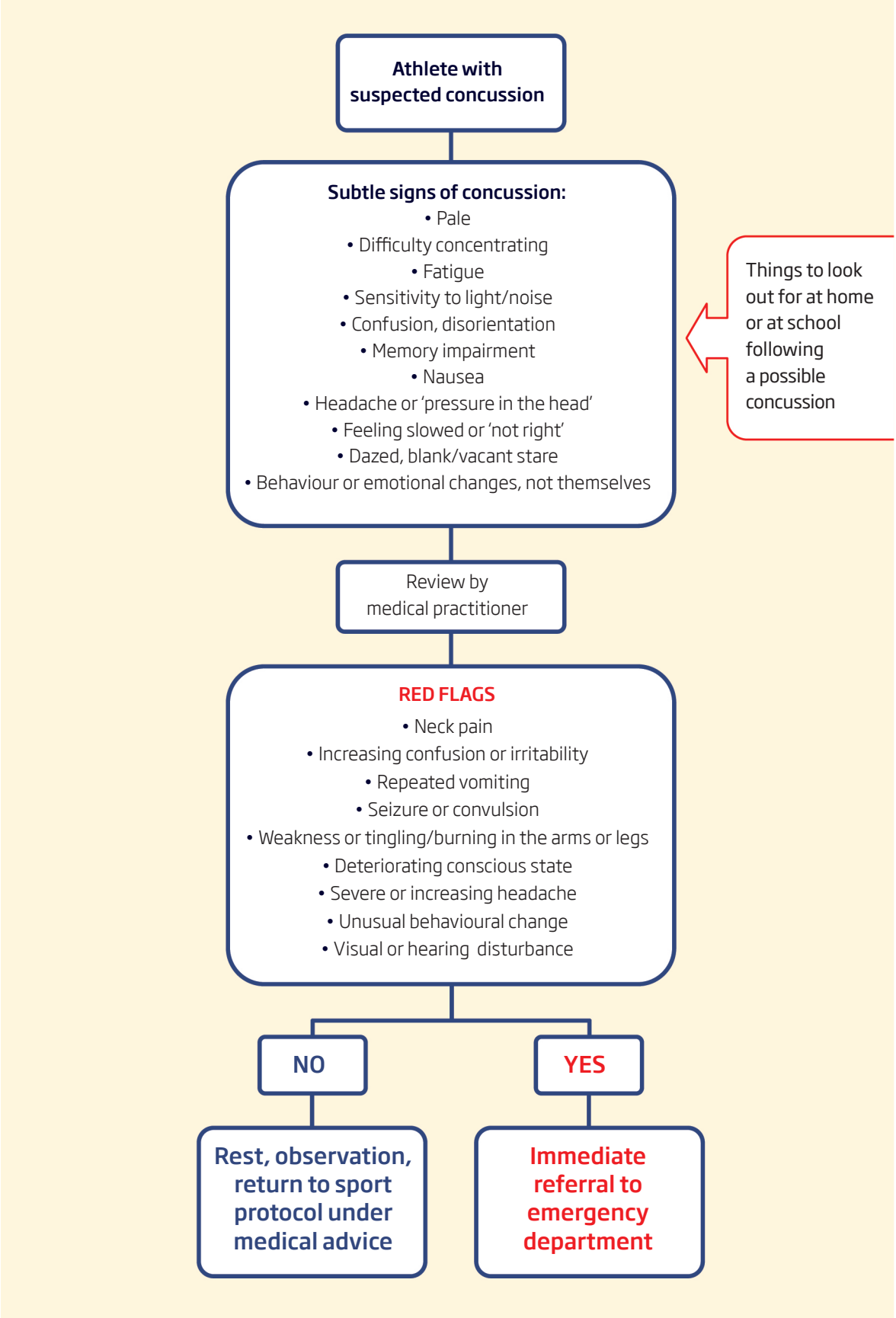


Diagram 5: Medical assessment of concussion – on field

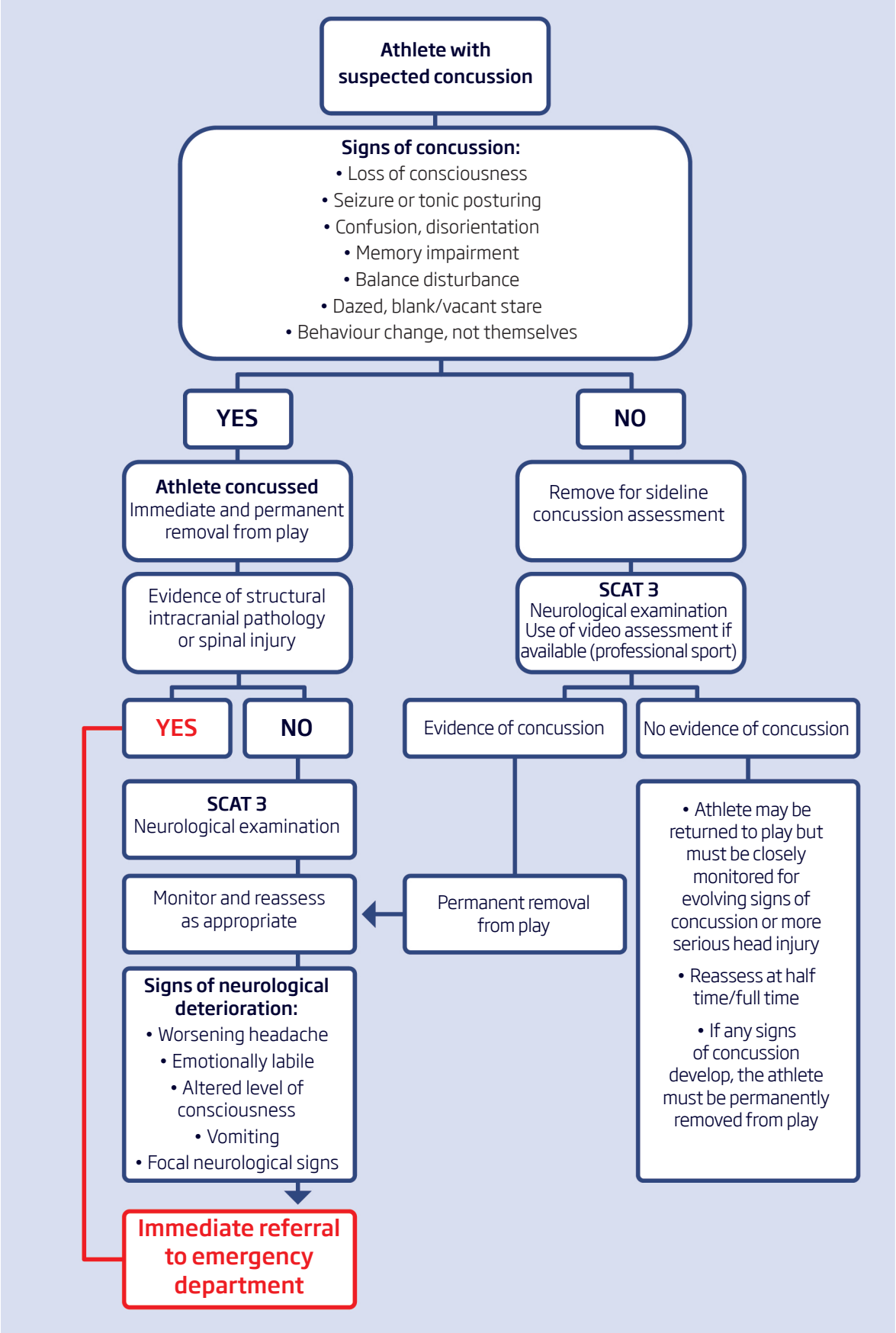
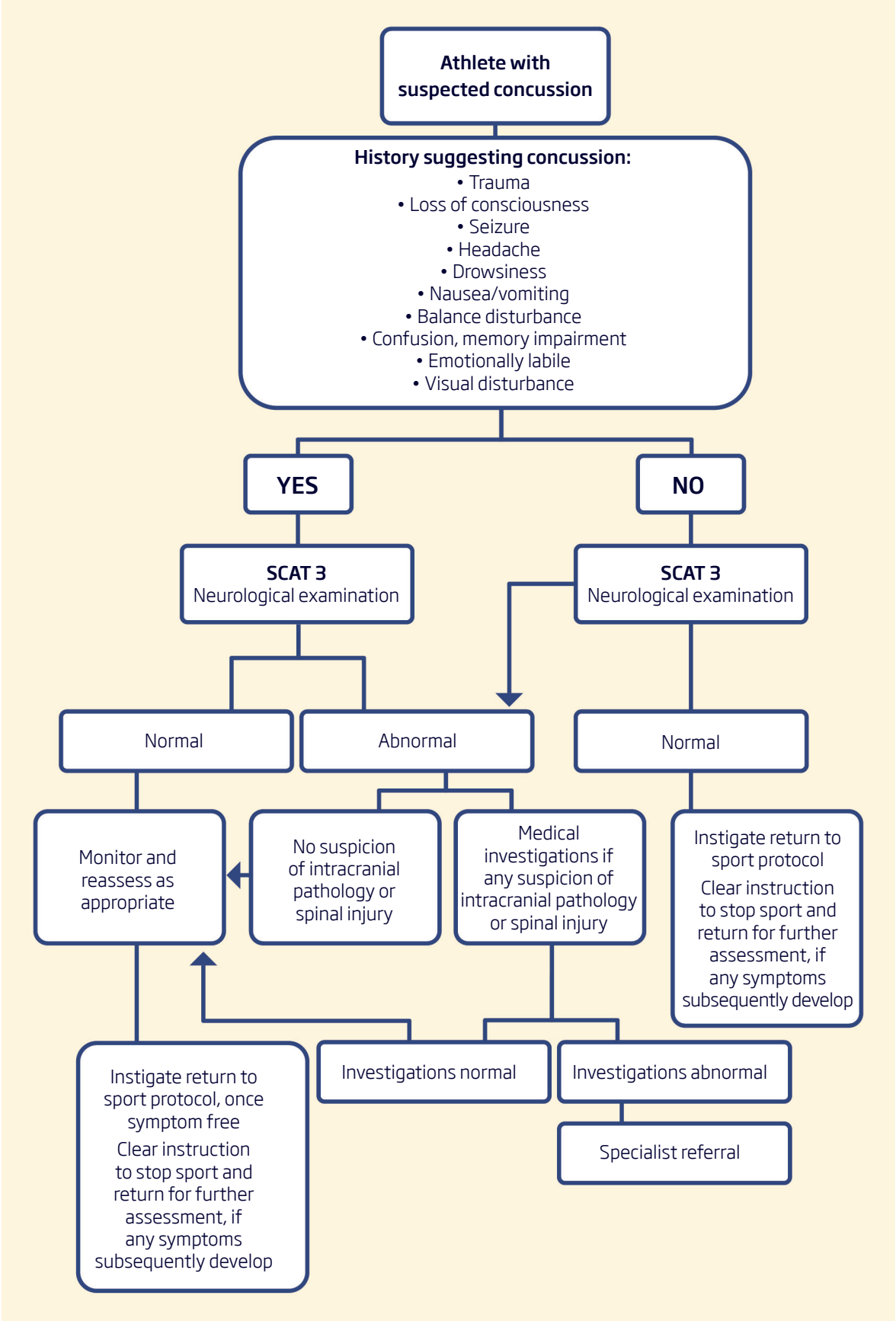


Diagram 6: Medical assessment of concussion – off field

(for emergency departments and medical clinics)



3. OVERVIEW OF LITERATURE

Definition

Concussion is a type of brain injury. It is recognised as a complex injury that is a challenge to evaluate and manage. The Concussion in Sport Group (CISG) has hosted four International Consensus Conferences since 2001. Each consensus conference has published a statement summarising the findings of the group. Consensus statement recommendations from the most recent conference in Zurich in 2012 have guided clinicians and others managing sport-related concussion since that time[1]. As defined by the international consensus statement, concussion is 'a complex pathophysiological process affecting the brain, induced by biomechanical forces'. It generally results from a knock – often to the head, face or neck but may be anywhere in the body – which transmits an impulsive force to the head. Concussion commonly involves short-lived impairment of neurological function. Concussion is an evolving injury that may change over the first few hours and sometimes over a few days. In most cases symptoms have resolved seven days post injury[2].

The International Consensus Group considers concussion to be a subset of mild traumatic brain injury[1]. As discussed below, epidemiological data, particularly hospital data, does not distinguish between traumatic brain injury and mild traumatic brain injury or concussion.

Epidemiology

Sport-related concussion is a public health concern in Australia. Precise data on the incidence of sport-related concussion in Australia is lacking. Potential limitations to obtaining accurate data on incidence include lack of recognition of the symptoms, under-reporting by athletes and failing to seek medical advice. If traumatic brain injuries are looked at as a whole, this group represents a major cause of hospitalisation especially for the young and middle aged with rates of up to 280 per 100,000[3]. A study examining the annual rate of hospitalisations for sport-related concussions in Victoria demonstrated a significant increase in frequency from 443 per year in 2002-03 to 621 in 2010-11, an increase of 60.5 per cent over the nine-year period[4]. This was not explained by increased participation, since rates of concussion per 100,000 participants also increased significantly during this time (38.5 per cent). Hospitalisation rates for concussion across different sports have been examined, and when adjustments were made for participation rates, the sports with the highest concussion rates are motor sports (181.8/100,000), equestrian (130.3/100,000), Australian Football (80.3/100,000), all codes of rugby (49.9/100,000), and roller sports (44.8/100,000)[4].

Sport-related concussion rates in the United States are estimated to be up to 3.8 million per year[5]. The condition is thought to be underreported, making the actual incidence of concussion in the community difficult to quantify[6]. This problem is further complicated by the lack of an objective laboratory or diagnostic test for concussion and the reliance on more subjective methods of diagnosis.

Aside from the health concerns, concussions and traumatic brain injuries represent a significant economic cost to the community. There are few figures available for hospital costs specific to concussion as a subset of traumatic brain injury. The costs for hospital admissions involving traumatic brain injury in Australia however were $184 million in the year 2004-05[3]. The majority of traumatic brain injuries occur in the 15-64 year age group, representing the group most likely to be in the workforce[3]. Victorian data for nine years 2002-2011 estimated that hospital costs related to hospital admissions for sport-related concussions to be $1,993,867 per annum[4]. These figures represent only a portion of the economic costs involved, given that they relate specifically to the hospital costs and do not reflect costs to the individual and income and productivity losses.

Pathophysiology

The pathophysiology of concussion is unclear. Theoretical models are based on animal research and some functional neuroimaging studies. Evidence points toward a series of interrelated changes that result in impaired neuronal function[7-10]. The proposed physiological changes were initially described by Giza and Hovda in 2001 and were updated in 2014[7,8]. These papers propose that biomechanical forces sustained result in disruption of neuronal cell membranes and axonal stretching causing indiscriminate flux of ions through now unregulated channels and defects in the physical membranes. This in turn causes depolarisation and potassium efflux and calcium influx which will then lead to the indiscriminate release of excitatory neurotransmitter glutamate. ATP dependant membrane ion pumps become overactive in an attempt to restore the resting membrane potential and this increases glucose demands and results in a temporary depletion of intracellular energy reserves and increase in ADP. There may also be a reduction in cerebral blood flow during this time that can worsen the energy supply shortage. The intracellular calcium influx is thought to persist for longer than the other perturbations and may result in mitochondrial dysfunction due to sequestration of calcium within. This would further aggravate energy supply issues. The changes are also thought to result in increased free radical production and this process may be implicated in some of the longer term symptoms associated with concussion[11].

Functional imaging studies have been used to assess alterations with concussion, including magnetic resonance spectroscopy (MRS), diffusion tensor imaging and positron emission tomography (PET) scanning. A 2014 review of the use of MRS in sport-related concussion suggested that MRS can effectively detect neurochemical changes associated with concussion and may be useful in a research setting to detect changes consistent with concussion and monitor progress beyond recovery of symptoms[12]. Function MRI (fMRI) has found differences in functional brain activation pattern up to two months post-concussion in concussed athletes compared to controls. This is despite other clinical and neuropsychological testing being normal between the groups[13]. A small study looking at diffusion tensor imaging in concussed adolescent athletes demonstrated white matter changes in the concussed group. This correlated with findings suggestive of concussion on the SCAT[14]. PET scans have demonstrated changes in cerebral metabolism of glucose in some regions of the brain in military veterans with post concussive symptoms compared to controls. This suggests metabolic abnormalities may be implicated in post-concussive symptoms[15]. These neuroimaging modalities in concussion are currently limited to a research setting. Increased availability and further research would be required before they could be reliably implemented in a clinical setting.

An improved understanding of the pathophysiology of concussion will allow more accurate diagnosis and evidence-based management of the condition. It may provide enhanced appreciation of the long term consequences of concussion and particularly recurrent concussion, to inform risk profiling and mitigation.

Assessment of suspected sport-related concussion

The diagnosis of concussion can be difficult. There is no specific diagnostic test which confirms the presence or otherwise of concussion. Diagnosis of concussion relies on clinical assessment of symptoms and signs including cognitive and behavioural disturbance.

In some instances, it will be obvious that there has been a significant injury where the athlete loses consciousness, has a seizure or has significant balance difficulties. Symptoms of concussion however can be very subtle and may present as nothing more than the athlete reporting that they do not 'feel right'. Symptoms commonly reported by concussed athletes include visual disturbance, feeling 'foggy', lethargic or slow, having sensitivity to light or noise, feeling dizzy or nauseous, or headache.

Signs of concussion are also variable and may be difficult to detect. The athlete may appear normal apart from appearing vacant, dazed or stunned. The athlete may be disoriented and unable to recall team plays, scores, who the opponent is or be disoriented in terms of place and time. Parents, coaches and attending medical personnel need to be alert for evidence that an athlete is behaving unusually or out of character, exhibits signs of disorientation, clumsiness or loss of balance. Amnesia is common in the setting of concussion. The athlete may ask questions repeatedly about what happened or what the score is. Concussed athletes will often have difficulty concentrating and answering specific questions.

It is critical that all individuals dealing with potentially concussed athletes understand that concussion is an evolving phenomenon. Subtle symptoms and signs often become far more significant in the hours and days following the injury.

Due to the evolving nature of the injury and the varied and potentially subtle symptoms and signs, a minimum criteria for the diagnosis has been published based on a review of the literature[16]. The recommendations include an assessment looking at a variety of domains – loss of consciousness, symptoms, cognition, neurobehavioural symptoms, and balance – with any abnormality being a potential sign of concussion[1, 16]. Due to the complexity of the injury and the diagnostic challenge it can present, one of the outcomes from the series of International Conferences on Concussion was the development of the Sport Concussion Assessment Tool aimed at improving identification, clinical assessment and diagnosis of sport-related concussion.

Some of the football codes including Australian Football League (AFL), National Rugby League (NRL) and Australian Rugby Union (ARU) are trialling criteria for mandatory removal of athletes from sport following head trauma. These criteria are intended for use initially at the elite level and would provide a decision-making algorithm for doctors to determine the requirement for removal from sport. The criteria are subdivided into those that require 'immediate removal and no return to sport' and those indicating 'immediate removal from sport for further assessment' with concussion assessment tools. The utilisation of these criteria remains in the trial phase. Clinical features, following head trauma, that would mandate 'immediate removal and no return to sport' are proposed to include loss of consciousness, no protective action in fall to ground directly observed or on video, impact seizure or tonic posturing, confusion, disorientation, memory impairment (e.g. fails Maddocks questions – see below), balance disturbance (e.g. ataxia), athlete reports significant, new or progressive concussion symptoms, dazed, blank/vacant stare or not their normal selves or behaviour change atypical of the athlete.

Where resources allow, sporting organisations should optimise the use of modern technology such as instant video replay, to enhance the ability to detect and manage concussion.

Evidence-based assessment tools

The Sport Concussion Assessment Tool 3 (SCAT 3) is the third version of the internationally recommended assessment tool and an outcome of the Zurich 2012 International Consensus Conference on Concussion. The SCAT 3 is designed for use by medical professionals to assist in the diagnosis of concussion. It is freely available online at *bjsm.bmj.com/content/47/5/259.full.pdf*. It is not intended to replace clinical judgment which remains the cornerstone of diagnosis for this condition. The tool encompasses a sideline assessment to be used at the time of the concussion, which includes a brief history of the injury, a Glasgow Coma Score and a series of questions known as Maddocks questions. These questions have been validated for use in concussion and are more sensitive in this context than the standard orientation questions[18]. The questions assess athlete orientation (in time and place) as an indicator of concussion. The questions have been modified within the SCAT 3. The questions should be preceded with the preface: 'I am going to ask you a few questions, please listen carefully and give your best effort.'

The modified Maddocks questions are:

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

The remainder of the SCAT 3 is for use off the field, as a sideline concussion assessment, in the medical room, or in the consulting room after a referral for suspected concussion has been made.

Additionally the Child SCAT 3 was also developed from the Zurich 2012 meeting of the Concussion in Sport Group. It is a modified version of the SCAT 3 for children aged 5-12 years. The key differences are that the symptom evaluation is written in language more appropriate for this age group and the severity score is marked out of three rather than six. The child SCAT 3 also includes a parent's report of symptoms and severity. The cognitive assessment is slightly simplified and the balance testing excludes the single leg stance.

The Pocket Concussion Recognition Tool is a simplified summary of the key signs and symptoms that should raise concern about a possible concussion. The tool is designed for use by any member of the community, unlike the SCAT 3 which is only intended for use by medical professionals. The tool is aimed at identifying concussions. Once a possible concussion is identified, the card advises that the person must be removed from sport immediately and not be allowed to return to activity until they are assessed medically. This tool also lists 'red flags' that should prompt emergency medical review.

Neurocognitive testing can assist in the diagnosis and monitoring of concussion. Such testing is increasingly becoming computer-based. There are several products available for qualitative neurocognitive testing. These products aim to quantify various aspects of cognitive function including speed of psychomotor processing, learning and memory, vigilance and attention. Neurocognitive testing provides more objective assessment of a patient's neurological function compared to patient reported symptoms scoring, which are often under reported[6]. This testing is also more detailed than the abbreviated cognitive component of the SCAT 3. As with other diagnostic tools, it should not be used in isolation but may form one part of the clinical history and examination. Computerised neuropsychological tests such as ImPACT (impacttest.com) or Axon (axonsports.com) are validated for use in concussion and are an easily accessible resource for use in clinics. A fee is usually charged to the patient for each test undertaken. Formal neurocognitive testing is recommended in the case of prolonged concussive symptoms[1].

Management

There is a high degree of consistency between concussion management policies emanating from major organisations including the Concussion in Sport Group Consensus Statement, the American Academy of Neurology, the Centre for Disease Control and professional sporting organisations.

Acute assessment of the concussed athlete at the time of injury should observe normal protocols of first-aid treatment. Where the athlete is unconscious or incapable of providing intelligible responses, cervical spine injury should be assumed and treated appropriately with in-line immobilisation, until cervical spine injury can be excluded. Attention to airway, breathing and circulation should be followed as indicated.

Athletes suspected or confirmed as suffering concussion should be removed from the sporting environment and should not be allowed to return to physical activity until they have been assessed by a medical practitioner. Referral to a medical practitioner should occur as a matter of priority. Where suspicion remains or concussion is confirmed, the athlete must not return to sport on the day of injury.

Given that concussion is an evolving injury, the athlete should be observed by a competent adult for several hours following the concussion. Symptoms suggesting requirement for urgent medical review include deteriorating neurological function, worsening nausea, vomiting, recalcitrant severe headache and loss of consciousness.

The current principles of concussion management involve rest until symptoms have resolved before gradual increase in cognitive activity and then physical activity[16,18]. This is based on observational studies that have demonstrated improved performance on post-injury testing and reduction in symptoms after prescribed cognitive and physical rest[19]. Animal models of concussion pathophysiology also demonstrate worsened metabolic changes associated with activity in the early phases after an injury[20].

The optimal duration of the period of rest is not clear, but 80-90 per cent of concussions fully resolve within 7-10 days[1]. After the acute period following the injury, those with persistent rest symptoms who can tolerate short duration of light exercise may benefit from a closely monitored and graduated physical rehabilitation program[21].

Any athlete with a suspected or confirmed concussion should not be allowed to drive and should remain in the company of a responsible adult. They should further be advised to avoid alcohol and avoid medications unless medically prescribed. Concussed athletes should specifically avoid aspirin, anti-inflammatory medications, sleeping tablets or sedating pain killers.

Any athlete with suspected or confirmed concussion should be referred immediately to the nearest emergency department if they develop any of the following clinical features:

- neck pain
- increasing confusion or irritability
- repeated vomiting
- seizure or convulsion
- weakness or tingling/burning in the arms or legs
- deteriorating conscious state
- severe or increasing headache
- unusual behavioural change
- double vision.

Children and adolescents

Sport concussions are common in children and adolescents[22]. Concussion warrants special consideration in this age group and a more conservative approach to diagnosis and management is recommended[1]. The physical, cognitive and emotional differences in this group require that assessment tools be targeted to this population[23]. The development of the child Sport Concussion Assessment Tool (SCAT 3) at the International Consensus Conference on Concussion is intended to address these concerns. Children and adolescents seem to be more vulnerable to concussion due to a variety of factors including decreased myelination, poor cervical musculature, and increased head to neck ratio[23]. The role of cerebral blood flow alterations in the pathophysiology of concussion may be more significant in children than in adults[24]. There is also some evidence that components of cognitive function relating to executive functioning may be impaired in adolescents with concussion for up to two months after injury[25]. The implications of this are not clear and further studies are required to confirm or refute this data.

The guidelines surrounding management of concussion from the Concussion in Sport Group Consensus Statement include prioritising complete return to school and learning before commencing return to physical activity. Modification of school attendance and activities may be required, allowing an increased period of asymptomatic rest and extending the graduated return to play or sport. A more cautious return to sport protocol is recommended when concussion modifiers (discussed below)[1] are evident. World Rugby recommend that children and adolescents 18 years or younger not return to contact training or play for at least two weeks after resolution of concussion symptoms.

Investigations

There are no reliable radiological or blood investigations that assist with the diagnosis of uncomplicated concussion. Where symptoms persist for a prolonged period of time (more than seven days) or where there is evidence of deteriorating neurological function, CT or MRI of the head may be indicated to exclude other serious pathology such as fracture or intracranial bleed. There are no biomarkers which indicate the presence or otherwise of uncomplicated concussion.

Neurocognitive testing can form part of the clinical assessment process but such testing in isolation is not sufficient to diagnose or exclude concussion.

Concussion modifiers

A number of 'concussion modifiers' have been identified which the clinician should take into account when assessing the athlete with concussion[1]. These factors may be associated with prolonged recovery of symptoms or worse outcome.

The evidence relating to loss of consciousness and prolonged recovery is inconclusive. Although some studies have found no association between loss of consciousness and prolonged recovery,[26, 27] one study found there was an association between loss of consciousness of more than one minute and more than seven days out from sport[28].

One study looking specifically at high school and college sport-related concussion found that loss of consciousness was associated with prolonged duration of symptoms, defined as greater than seven days. While there is no clear evidence that loss of consciousness or post-concussive seizure is associated with a worse outcome, prolonged loss of consciousness (more than one minute) or prolonged seizure (more than one minute) following head trauma should raise suspicion of more serious injury such as intracranial haemorrhage.

Previous concussion is a risk for further concussion and the clinician should take a conservative approach where there is a history of repeated concussion or concussions occurring in close time proximity[29, 30]. Recurrent concussion is sometimes associated with reduced threshold for concussion and this should alert the clinician to potential increasing vulnerability to further concussive episodes.

Children appear to have a lower threshold for the concussion injury compared to adults and take longer to recover from a concussion injury[25, 31]. Age-appropriate assessment and a more cautious approach to return to play or sport should be adopted with children and adolescents less than 18 years of age[1, 23, 32].

Some studies report increased occurrence of depression and anxiety following head trauma[33, 34]. The assessing clinician should be mindful of comorbidities including pre-existing mental illness such as depression, migraine, learning disability, attention deficit hyperactivity disorder (ADHD) or sleep disturbance. Similarly, a high level of vigilance should be observed in a situation where the athlete is taking medication such as psychoactive drugs or anticoagulant medication. The majority of concussions resolve within 7-10 days[1, 2]. The requirement for medical investigation and re-evaluation to assess mental and cognitive health should be considered where there are a high number of concussive symptoms, the concussive symptoms are of highs of severity or the symptoms are prolonged in duration[1].

Special considerations in concussion

The issue of concussion has received significant media attention in recent years. The focus of a large part of this attention has been around chronic traumatic encephalopathy (CTE), particularly in retired athletes from the National Football League in the USA[35-38]. CTE is described by McKee et al 2009 as a 'progressive neurodegeneration clinically associated with memory disturbances, behavioural and personality change, Parkinsonism, and speech and gait abnormalities'[36]. McKee describes the neuropathology as being characterised by cerebral and medial temporal lobe atrophy, ventricular enlargement, enlarged cavum septum pellucidum, and extensive deposition of tau protein[36]. While there is significant concern about CTE and its possible relationship to concussion, it is important to note that no causative link has been clearly established. McKee concludes that evidence is 'overwhelming' that repeated head trauma causes the condition. Other researchers have questioned the link between sport-related concussion and CTE due to the current level of evidence published being limited to case reports, case series and retrospective analyses which cannot adequately determine causality or risk factors[17, 39, 40]. There is significant selection bias in many of the reported cases[40]. The potential contribution of confounders, such as genetic predisposition to psychiatric illness, alcohol and drug use or co-existing dementia, is not adequately accounted for in the current literature [17].

Recent public health concerns about CTE have, to a large extent, driven the increased focus on forming best practice guidelines for the identification, diagnosis and management of sport-related concussions with the goal of preventing complications such as CTE. Further research is needed to understand what type of trauma is implicated, how much force is required, and how frequently for the development of pathological changes of CTE. It is also not clear why only some athletes are affected with these symptoms. Properly designed prospective studies, which control for potential confounding variables, are required to improve our understanding of CTE and any potential link to prior concussion[17, 39, 40].

Acute cerebral oedema, or 'second impact syndrome' is another condition that has received a lot of media attention due to its catastrophic outcomes. This condition, along with CTE, appears to have driven much of the public awareness around concussion. Acute cerebral oedema refers to rapid cerebral swelling that can occur when a second concussive injury is sustained during a 'vulnerable' period when the brain has not recovered from an initial insult. Animal models have demonstrated that there is a period of vulnerability during which

further injury can result in significant axonal injury with associated ion channel damage[10]. It is thought that a second impact may not be needed for the swelling to develop. The condition is rare and the only available literature consists of case studies which are inadequate to provide a good understanding of the mechanisms and risk factors. Further research is needed to better understand the pathophysiology and risk factors for 'second impact syndrome'.

Education and prevention

Improved education and awareness is critical to improving diagnosis and management of concussion. Such education must include all stakeholders – athletes, parents, coaches, teachers, and health-care professionals.

A number of studies have demonstrated that general knowledge about concussion is inadequate. Athletes are included in this group, with a recent study indicating that high-school aged National Football League (NFL) athletes in the United States were not able to identify some of the key symptoms of concussion[41]. This finding suggests there are difficulties in identifying potential concussion. Furthermore only a small percentage of these athletes were able to indicate possible consequences of poorly managed or misdiagnosed concussion from a list including brain haemorrhage, coma and death.

In a large survey conducted in 2012 of community-based Australian coaches and trainers in Australian football and rugby league concussion knowledge was found to be poor, indicating that key messages are not reaching community level sport[42].

Studies looking at effectiveness of concussion education programs have found that without clear guidance on the content of the material these programs can be ineffective[43]. Under-reporting of concussion by athletes still appears to be a problem and legislation alone, without education of the athletes, has been shown to be ineffective in addressing this problem[44].

In addition, concussion knowledge among health-care workers should be improved with provision of readily accessible information and resources to those managing concussion. Internationally sourced data suggests that training and education on concussion at medical school is suboptimal.[45]

Education programs must target the various groups involved in sport-related concussion in order to effectively improve awareness and understanding in the community. Athletes themselves need to have a good understanding of concussion in order to appreciate the importance of reporting symptoms and complying with rest and return to sport advice. Parents and coaches must also be able to recognise the symptoms and signs of concussion in order to detect concussions at the community sport level where there is no medical supervision present.

Measures which may assist in preventing concussion include the use of protective equipment and rule changes in high-risk sporting codes. While use of protective equipment would seem to provide a simple and accessible means of preventing concussion, evidence suggests the use of helmets, mouth guards or other protective devices to prevent concussion offer little if any benefit. It is important to note that these devices are valuable for the prevention of other types of traumatic head injuries such as skull fracture and subdural hematoma. At present however there is no clear evidence that they assist in prevention of concussion[46, 47].

Sporting organisations in Australia have responded to the increased concern regarding concussion. The four major football codes (Australian football, rugby league, rugby union and soccer) have introduced rule changes in recent years to ensure more thorough clinical assessment of the athlete with suspected concussion and to enforce guidelines around management of the concussed athlete. All sporting organisations should ensure that medical and support staff covering sporting events have adequate education and training in immediate and long-term management of concussion.

4. GUIDELINES IN AUSTRALIAN SPORTING CODES

Given the increasing awareness of sport-related concussion and the associated community concern about this condition, many sporting organisations have developed their own guidelines for its management. These guidelines are constantly evolving through ongoing review. There is a high degree of congruency and alignment across the various sporting codes, supported by the latest scientific evidence on concussion diagnosis and management. Readers should refer to sport-specific websites for further information.

Australian Football League

aflcommunityclub.com.au/index.php?id=66

Australian Rugby Union

http://irbplayerwelfare.com/concussion

Basketball Australia

http://www.basketball.net.au/wp-content/uploads/2014/05/Concussion-Guideline.pdf

Boxing Australia

http://boxingnt.org.au/wp-content/uploads/sites/6/2013/07/Boxing-Australia-Ltd-Technical-Competition-Regulations-25.05.2013.pdf

Football Federation Australia

http://www.footballaustralia.com.au/dct/ffa-dtc-performgroup-eu-west-1/FFA%20Concussion%20Guidelines_1jeu1k23rk09q11ybjbcbc0ws5.pdf

National Rugby League

Community Rugby League Guidelines: http://www.nrl.com/About/ReferenceCentre/%20ManagementofConcussioninRugbyLeague/tabid/10798/Default.aspx

Independent concussion doctors

Some Australian professional football codes are considering introducing on field independent concussion doctors to make decisions around concussion diagnosis and return to sport. The premise that it is difficult for the doctor who is embedded within a team to be completely objective in making decisions on concussion is unfounded. Team doctors who know the athlete will be best equipped to detect some of the subtle signs of concussion. The premise that a doctor's professional assessment and diagnosis is influenced by their employment status is also unfounded. In fact, removing the team doctor entirely from the assessment and decision-making could conceivably be detrimental for the athlete.

5. OTHER CONCUSSION RESOURCES

Medical groups and sporting bodies, both nationally and internationally are developing their own guidelines or position statements on concussion. There is a broad acknowledgement of the complexity of sport-related concussion and the challenge this task poses for physicians.

Australian

Brain Foundation Australia

http://brainfoundation.org.au/disorders/concussion

Brain Injury Australia

http://www.braininjuryaustralia.org.au/docs/CONCUSSIONpolicypaperFINAL.pdf

Sports Concussion Australasia Headsmart Sports Concussion Programme

http://www.headsmart.me/

Sports Medicine Australia

sma.org.au/wp-content/uploads/2015/09/SMA-Position-Statement_Concussion-190815.pdf

International

American Academy of Neurology

http://www.neurology.org/content/80/24/2250.full

American Medical Society for Sports Medicine

http://bjsm.bmj.com/content/47/1/15.long

Centre for Disease Control (USA)

http://www.cdc.gov/headsup/index.html

Faculty of Sport and Exercise Medicine UK

http://www.fsem.ac.uk/media-resources/publications/concussion-guidelines.aspx

6. CONCUSSION RESEARCH PRIORITIES

The issue of a potential link between concussion and Chronic Traumatic Encephalopathy (CTE) has caused significant concern in Australia and around the world. Despite claims by some researchers, there is a paucity of evidence supporting a causative link between these two conditions. Potential long-term health ramifications from sport-related concussion need to be an area of focal research attention. The design of research initiatives must be thoughtfully considered to ensure that any data arising from such research is meaningful and reliable. It is crucial to the welfare of Australian athletes that any potential long-term health implications associated with concussion are clearly identified and understood.

Little is known about the biological mechanisms underlying the symptoms and signs of concussion. Improving the understanding of biological abnormalities underlying concussion will improve the certainty with which doctors can advise athletes, parents and sporting bodies regarding prevention, management and safe return to sport. Improved understanding of concussion biology may also lead to the discovery of reliable biomarkers or imaging modalities to assist in indicating the presence or otherwise of concussion, and/or satisfactory recovery from concussion.

A key part of any health initiative must be improving the knowledge and information transfer to those who are most affected by the condition. While most concussion position papers support the role of education, there is little good evidence which indicates what the current level of community knowledge is in relation to concussion. It is important that future research projects seek to quantify current community knowledge on concussion so that interventions which seek to educate athletes and other stakeholders can be assessed for their efficacy and validity.

Children appear to be more susceptible to concussion and appear to take longer to recover from concussion. However, the evidence surrounding the impact of concussion on children, in comparison to adults, is far from clear. There is a need to better understand the variability in concussion susceptibility between different sporting subpopulations. An improved understanding will allow prevention and management strategies to be based on the specific risk profile of particular sporting subgroups, including children.

There have been great advances over the past decade in the clinical tools that are available to clinicians for use in the diagnosis and management of concussion. It is true to say however that no single tool can diagnose concussion or indicate conclusively when it is safe for an athlete to return to sport. It is vital therefore that research continues to focus on improving clinical tools to enable accurate diagnosis of concussion and to inform appropriate return to sport.

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