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REVIEW

Management of sports-related concussion in the emergency department

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Abstract

Sports-related concussion is a common presentation to the emergency department, with increasing evidence of short and long-term morbidity. The heterogeneity of symptoms and clinical outcomes, alongside a lack of familiarity with current guidance, can present significant challenges to clinicians. This article presents an overview of the current literature concerning assessment and management of sports-related concussion in the emergency department and outlines a framework for graduated return to activity as based upon the current national guidance.

Key words: Athletes; Brain concussion; Brain injury; Sports; Traumatic

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Introduction

Sports-related concussion, which may affect professional and amateur athletes, is a common reason for a patient presenting to the emergency department (Bryan et al, 2016). In the USA, it has been reported that in patients aged 0–18 years alone there are between 1 million and 1.9 million sports-related concussions per year (Bryan et al, 2016). Although the majority of patients with sports-related concussion do not attend hospital, a significant minority will attend the emergency department, with fewer admitted to hospital (Bryan et al, 2016). Therefore, it is important for clinicians working in the emergency department to be familiar with the presenting symptomatology, potential complications and current national guidance concerning sports-related concussion.

Concussion can be used synonymously with mild traumatic brain injury, with traumatic brain injury defined as 'an alteration in brain function, or other evidence of brain pathology, caused by an external force' (Menon et al, 2010). Sports-related concussion may result in neurological symptoms in keeping with mild traumatic brain injury, such as loss of consciousness or post-traumatic amnesia. However, more commonly, there may be minimal objective clinical biomarkers following sports-related concussion, with this heterogeneity in presenting symptomatology representing a challenge for the assessing physician. The high risk of repetitive head injuries, and subconcussive (asymptomatic) impacts that are thought to potentially still contribute to long-term risks, make sports-related concussion an important cause of head injury (Mez et al, 2017).

Over recent years, there has been increasing evidence of the acute and subacute symptoms following sports-related concussion, preventing a return to both sporting activities and impacting on athletes' wider health-related quality of life (McLeod et al, 2013). There has also been increasing evidence of significant long-term consequences of repetitive head impacts sustained in the sporting environment, most notably in relation to risk of neurodegenerative disease in later life, including chronic traumatic encephalopathy (Mez et al, 2017; Russell et al, 2021; 2022). Aiming to reduce the risk to players of non-elite (grassroots) sport, the UK government has released guidelines for the management of sports-related concussion; the first country to do so on a national level (UK Government, 2023). These build on guidance introduced in Scotland (sportscotland, 2023).

This review summarises these national guidelines and the wider academic literature concerning the clinical features, symptom progression, methods of assessment, and treatment strategies of sports-related concussion to better inform clinicians about its management in the emergency department.

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Clinical features and recovery time

Following head impact there can be a wide variety of symptoms. Patients may have obvious clinical signs such as a loss of consciousness, but the majority of patients will not. The variety in symptomatology and severity of symptoms can present challenges for assessing clinicians, especially in time- and resource-pressured environments. The acute symptoms of sports-related concussion are heterogeneous, and are grouped under multiple domains as summarised in Table 1. Symptoms or signs in one or more domain are thought to indicate a sports-related concussion.

While it used to be believed that symptoms would resolve within 1–2 weeks of injury in most patients, there is growing evidence that for a significant proportion of patients it takes longer (Hallock et al, 2023). For example, a study of patients in a community concussion clinic found less than half (45%) of patients showed clinical recovery within 14 days, with 77% showing recovery within 4 weeks and 96% showing recovery within 8 weeks (Kara et al, 2020). Around 10–20% of patients with sports-related concussion will have a prolonged recovery, with ongoing symptomatology months to years following injury (McCrea et al, 2013; McAllister et al, 2023). Individuals with loss of consciousness or amnesia following injury, previous psychiatric history, history of attention deficit hyperactivity disorder or migraine, injury sustained in practice rather than competition, previous concussions or more severe acute symptoms have all been found to have greater risk of prolonged injury (McCrea et al, 2013; Miller et al, 2016). Female athletes have been found to have a greater burden of post-concussional symptoms, prolonged recovery, and worse overall outcomes following sports-related concussion compared to male athletes (Koerte et al, 2020).

The literature concerning the long-term effects on cognitive function is mixed. Some evidence demonstrates no difference in athletes who were concussed at 3 months following injury compared to healthy controls, with cognitive impairment improving within the first month following injury (McCrea et al, 2013; Henry et al, 2016). However, evidence from the wider literature concerning mild traumatic brain injury has suggested that there is ongoing cognitive impairment at a year following injury (Schneider et al, 2022).

There is increasing evidence about the impacts of repetitive concussion or sub-concussive impacts (Mez et al, 2017; Russell et al, 2021; 2022). In the acute and subacute period following injury, athletes who have sustained a concussion are at greater risk of sustaining a second concussion, with increased vulnerability to second concussion suggested during

Table 1. Symptoms and signs of sports-related concussion

Symptom	Signs
Physical symptoms	■ Headache ■ Dizziness ■ Visual changes
Physical signs	■ Loss of consciousness ■ Pre- or post-traumatic amnesia ■ Neurological deficit
Behavioural changes	■ Irritability ■ Low mood ■ Emotional lability
Cognitive impairment (Hallock et al, 2023)	■ Decreased reaction time ■ Processing speed ■ Attention ■ Memory ■ Executive functioning ■ 'Brain fog' or 'feeling slowed down'
Sleep/wake disturbance	■ Insomnia ■ Excessive drowsiness

Adapted from Hallock et al (2023); UK Government (2023)

the first 7–10 days following the primary injury (McCrea et al, 2009). However, even more separate, discrete events are important, with longer-term cognitive deficits associated with three or more life-time mild traumatic brain injuries (Lennon et al, 2023).

A rare syndrome called 'second impact syndrome' has been described, whereby patients may have severe and potentially fatal neurological consequences following a repeat head injury while recovering from a previous concussion (Bey and Ostick, 2009). Catastrophic oedema may occur particularly in younger athletes; the cause of which is unclear.

Chronic traumatic encephalopathy

Chronic traumatic encephalopathy is a specific neurodegenerative pathology associated with repetitive head trauma (Mez et al, 2017). It was first described by Martland (1928) as the theory of punch-drunk, described as 'repeated blows on the head or jaw which cause multiple concussion haemorrhages', where symptoms in the late stage 'often mimic those seen in diseases characterised by the parkinsonian syndrome'. Over the next 80 years multiple case reports and case series reported similar findings, with the thought of this being a boxing-specific phenomenon (Hay et al, 2016). However, over the last decade there has been increasing evidence of chronic traumatic encephalopathy in non-boxing athletes exposed to multiple concussive and sub-concussive impacts. The most high profile studies concerns American football players (Mez et al, 2017), with similar findings in rugby union (Russell et al, 2022), and from repetitive heading of a football over a professional career (Russell et al, 2021). Other neurodegenerative diseases have been associated with professional sports, including motor neurone disease (Russell et al, 2022). Changes consistent with chronic traumatic encephalopathy have been described in autopsy studies of young individuals with repetitive exposures to head injury, supporting the hypothesis that the processes driving chronic traumatic encephalopathy-related neurodegeneration are established years before clinical presentation.

Whether chronic traumatic encephalopathy was caused by sports-related concussion or not has been controversial. However, the increasing evidence in this area has led to the National Institutes of Health (National Institute of Neurological Disorders and Stroke, 2023) and the Centers for Disease Control and Prevention (2021) acknowledging that the evidence fulfils Bradford Hill criteria for chronic traumatic encephalopathy, at least in part, to be caused by repetitive head injury (Nowinski et al, 2022). Rigorous assessment and management of concussion is important to reduce this risk (Geddes et al, 1999; Lee et al, 2023).

Clinical assessment and diagnostic tools

Following suspicion of sports-related concussion, athletes should be immediately removed from the activity; as the UK guidance states: 'If in doubt, sit them out'.

Initial assessment may be performed by an appropriate on-site healthcare professional or via the NHS by calling 111. The first priority should be to ensure that a player does not need to attend the emergency department to be assessed for a significant brain injury. The 'red flag' symptoms, as recommended by the National Institute for Health and Care Excellence (2023) head injury guidelines, are shown in Table 2.

There are a variety of assessment tools to assist in the acute assessment of concussion following head impact, often designed for use pitch side. The most common of these is the Standard Concussion Assessment Tool- 5th edition (SCAT5), a tool designed specifically to assist healthcare professionals in assessment of suspected sports-related concussion (Echemendia et al, 2017). The SCAT5 combines objective neurocognitive assessment with the athlete's subjective self-evaluation of symptoms. First, athletes are assessed with a four-step immediate or on-field assessment tool, including initial red flags, observable signs, a memory assessment (Maddocks questions that are often modified dependent on sport being assessed) and assessment of Glasgow Coma Score and cervical spine. The second step provides a framework for a more comprehensive off-field assessment, including salient past medical history, symptom evaluation, cognitive screening, neurological screen with balance assessment and delayed recall, with total scores provided for each section.

The SCAT-5 is recommended for use in a variety of head injury assessment guidelines by multiple sporting bodies (World Rugby, 2022). World Rugby (2022) recommend a three-stage process with an off-field assessment, assessment within 3 hours of the incident, and assessment

Table 2. Red flags indicating those who should be referred to the emergency department for hospital assessment

Patient	Clinical signs or symptoms
All patients should be referred if:	Glasgow Coma Score less than 15
	Any loss of consciousness because of the injury
	Focal neurological deficit since injury
	Suspicion of skull fracture or penetrating head injury
	Amnesia (pre or post injury)
	Persistent headache since the injury
	Any vomiting since the injury (clinical judgement should be used for those <12 years old)
	Seizure since the injury
	Any previous brain injury
	High energy head injury
	History of bleeding or clotting disorder
	Current drug or alcohol intoxication
	Safeguarding concerns
	Ongoing concern by the professional about the diagnosis
In the absence of the above, consider referral if:	Irritability or altered behaviour
	Visible trauma to the head of concern to the assessing clinician
	No one able to observe the patient at home
	Ongoing concern from the patient or patient family/carer concerning diagnosis

From National Institute for Health and Care Excellence (2023)

36–48 hours following injury. Multiple assessment points are used because symptoms may evolve and develop over time, with longitudinal assessment often key in diagnosis of sports-related concussion. It is important to note that the SCAT5 and other assessment tools are for assessment alongside clinical judgement, and should not be used as stand-alone mechanisms for the diagnosis of sports-related concussion (Echemendia et al, 2017).

In the emergency department, the primary step in assessing sports-related concussion should be a comprehensive history, with assessment of mental/cognitive status and neurological examination. This includes assessment of pre-morbid factors that may be associated with worse outcome, such as the environment the concussion was sustained in, pre-existing mental health disorder and previous concussion history (McCrea et al, 2013; Miller et al, 2016). Particular care should be taken to evaluate the longitudinal symptom trajectory (worsening or improving), especially if there is delayed presentation to the emergency department. Although rare, patients attending hospital with a sports-related head injury may have a more severe brain injury, with potentially clinically important findings on acute neuroimaging. Therefore, all patients require assessment in relation to local guidelines and clinical decision rules concerning the requirement for neuroimaging following head injury. In the UK, this is in reference to the National Institute for Health and Care Excellence (2023) head injury guidelines. It is also important for clinicians to be aware of the risk of coexistent extracranial injury following head injury, such as cervical spinal injury or maxillofacial injuries.

While commonly used by sports physicians outside of the hospital setting, assessment tools such as the SCAT5 may be used in hospital to augment clinical assessment. However, the length of time required to perform the assessment can be challenging in the time-critical environment of the emergency department, with some suggesting that an altered and quicker version would be better suited to emergency department assessment (Mistry and Rainer, 2018).

Non-specialist assessment in hospital should include baseline Glasgow Coma Score, mental status and neurological assessment, including vestibulo-oculomotor function, peripheral nervous system, coordination, gait and balance, and neuropsychological assessment. In professional sporting environments, clinicians will often perform a more detailed neuropsychological assessment in conjunction with clinical assessment. This can be conducted either in person by trained medical/neuropsychology staff, or with the assistance of computerised cognitive evaluation tools such as the immediate post-concussion assessment and cognitive testing (ImPACT) (Kontos et al, 2014). These tools can augment clinical assessment to facilitate comprehensive neuropsychological assessment (Lovell, 2002). In some cases, athletes may perform 'baseline' pre-season testing as well as testing post injury, with comparison between the measurements facilitating individualised assessment of cognitive impairment and aiding in return-to-play decisions when athletes return to baseline. Although there is some evidence regarding the use of computerised neurocognitive testing batteries for patients in the emergency department (Lunter et al, 2019), this is not commonly available outside of clinical research.

Future diagnostic advances include the use of serum biomarkers to indicate those with more severe injuries or that are at higher risk of prolonged recovery, or advanced neuroimaging techniques using magnetic resonance imaging to assess structural brain damage not typically seen on computed tomography (Meyer et al, 2020). Although these show promise, they remain largely in the research environment with various steps required before widespread clinical adoption.

Management

On initial assessment in hospital, the main decision concerns the requirement for acute neuroimaging or admission for neuromonitoring. Most patients with sports-related concussion do not require these, and are highly likely to be discharged to the community (Bryan et al, 2016). Therefore, the principles of ongoing management from the hospital largely concern adequate safety netting for worsening symptoms, symptomatic management and clear advice concerning return to activities. In reference to specific management guidance the UK government, in conjunction with experts and key stakeholders in the field, have developed specific guidance concerning the assessment and management of sports-related concussion (UK Government, 2023).

Patients should be made aware of the common symptoms that may occur following concussion (Table 1), alongside adequate safety netting over red flags that would require return to hospital. This can be provided both verbally and through written information forms. Patients can be signposted to online information resources such as those provided by charities such as Headway (https://www.headway.org.uk/), or the UK national guidance on sports-related concussion (UK Government, 2023). It should be clearly explained that the majority of patients will recover within a short time period, but that improvement may take time, with explicit advice about when to seek further help if worsening or no improvement.

Aside from graduated return to activity, there is limited evidence of efficacy for specific treatments in the acute phase following injury. Treatments such as simple analgesia (paracetamol or ibuprofen) for headaches (Petrelli et al, 2017) or reduction of screen time (Macnow et al, 2021) improve the acute symptoms following injury. In relation to screen time, it is suggested that the greatest benefit is in reduction rather than abstinence (Cairncross et al, 2022). Overall the evidence suggests that a reduction of screen time is beneficial, but harm is unlikely to occur from small amounts of use.

Around 10–20% of patients will have persistent symptoms following sports-related concussion, lasting beyond the normal timescale for recovery (McCrea et al, 2013; McAllister et al, 2023). In patients with persistent post-concussive symptoms following sports-related concussion, there is evidence of symptomatic benefit with the use of psychotherapeutic interventions such as cognitive behavioural therapy, behavioural medicine and cognitive rehabilitation (Conder et al, 2020). Therefore, specialist neurorehabilitation services should be considered in patients with persistent post-concussional symptoms. UK guidance states that if symptoms do not improve or worsen following 14 days then patients should seek medical advice through NHS 111, and see their primary care physician if symptoms have

not resolved by 28 days (UK Government, 2023). Although professional athletes often have access to private rehabilitation services, it can be difficultyfor amateur athletes to access these services. The process for patients to access these will differ across different health systems and clinicians should be aware of the local processes, to better inform patients how to access them should this be required.

The effects of sports-related concussion are not limited to sport, with impacts on patients' activities of daily living, alongside education and occupation (McLeod et al, 2013; Neelakantan et al, 2020). For non-professional athletes, the priority of recovery should be the return to normal education or work activity rather than focusing solely on sport. A graduated return to activity and sport is currently recommended to help with successful return to normal activity and avoid a repeat concussion in the subacute phase following injury (UK Government, 2023). Following a short rest period (24–48 hours) individuals should gradually increase the level of activity in a set and regimented way, while staying below the symptom exacerbation threshold. Individuals should progress through incremental steps, with increasing demands at each step in relation to both study or work and sporting life. Each step is gradual, and the individual should drop back to the previous asymptomatic level if concussion-related symptoms recur. Individuals should not return to activity where there is a risk of head injury unless they have been symptom free at rest for 14 days. The minimum time to progress to return to competitive sport is recommended as 21 days from injury, and only if there are no symptoms at rest in the preceding 14 days and symptom free during training.

Speed of progress through the steps will differ between patients, with the aim of gradually getting back to normal life and sport. Figure 1 demonstrates the stages of graduated return to activity as suggested by the UK guidance.

Conclusions

Following sports-related concussion, patients may experience a variety of symptoms, with significant effects on sporting performance, activities of daily living, education and

Stage	Activity
Stage 1	Relative rest period
Stage 2	Gradually introduce daily activities
	Gradually return to normal daily activities outside of work/education Increase mental activities such as reading
	Light physical activity, simple daily activities such as short walks or simple chores
Stage 3	Increase tolerance of activities
	Adding in home-based work/education activity in small blocks
	Walking or stationary cycling for 10–15 minutes. No high intensity or weight resistance training
Stage 4	Return to study and work/training
	Consider part-time or reduced activities
	Training in chosen sport when not experiencing symptoms at rest. Gradually increase in intensity. No contact training and avoid activities with risk of head impact
Stage 5	Return to normal work/education/training
	Return to full activity
	Unrestricted training. When free of symptoms at rest for 14 days commence training involving head impact
Stage 6	Return to competition
	Only if symptom free at rest for 14 days and symptom free during training

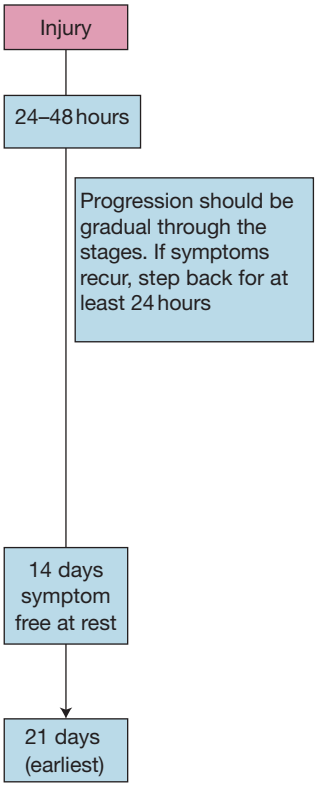

Figure 1. Example of a graduated return to activity (education/work) and sport programme. Adapted from UK Government (2023).

Key points

- There is a wide variety of symptoms following sporting head injury that can have a significant impact on patients' activities of daily living.
- A subset of patients following sports-related concussion will have ongoing symptoms for months to years following injury.
- Repetitive head injuries are associated with worse clinical outcomes, with growing evidence for and increased risk of neurodegenerative disease in later life.
- Hospital assessment should first assess for the risk of more severe injury requiring acute neuroimaging and make a full assessment of potential coexistent extracranial injury.
- Following sports-related concussion, all patients should be given clear advice and a planned graded return to activity.

occupation. There is increasing evidence of neurodegenerative processes associated with repetitive concussions or sub-concussive impacts. Clinicians should be familiar with the variety of symptoms associated with sports-related concussion, the important factors in a patient's history and examination findings, potential complications and the expected recovery time. Using the sports-related concussion-specific UK guidelines clinicians should provide advice concerning graduated return to activity or sport, alongside information when to seek further medical help concerning ongoing symptoms.

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Conflicts of interest

DPW declares no conflicts of interest. VFJN reports holding a grant with Roche Pharmaceuticals on biomarkers which is unrelated to this article. VFJN was a member of the Update Committee for the below NICE Guideline and represented the Royal College of Emergency Medicine to review the UK Concussion Guidelines for Grassroots Sport.

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References

Bey T, Ostick B. Second impact syndrome. West J Emerg Med. 2009;10(1):6–10

Bryan MA, Rowhani-Rahbar A, Comstock RD, Rivara F. Sports- and recreation-related concussions in US youth. Pediatrics. 2016;138(1):e20154635. https://doi.org/10.1542/peds.2015-4635

Cairncross M, Yeates KO, Tang K et al. Early postinjury screen time and concussion recovery. Pediatrics. 2022;150(5). https://doi.org/10.1542/peds.2022-056835

Centers for Disease Control and Prevention. Repeated head impacts. 2021. https://www.cdc.gov/traumaticbraininjury/concussion/repeated-head-impacts.html (accessed 29 June 2023)

Conder A, Conder R, Friesen C. Neurorehabilitation of persistent sport-related post-concussion syndrome. NeuroRehabilitation. 2020;46(2):167–180. https://doi.org/10.3233/NRE-192966

Echemendia RJ, Meeuwisse W, McCrory P et al. The sport concussion assessment tool 5th edition (SCAT5): background and rationale. Br J Sports Med. 2017;51(11):848–850. https://doi.org/10.1136/BJSPORTS-2017-097506

Geddes JF, Vowles GH, Nicoll JA, Révész T. Neuronal cytoskeletal changes are an early consequence of repetitive head injury. Acta Neuropathol. 1999;98(2):171–178. https://doi.org/10.1007/s004010051066

Hallock H, Mantwill M, Vajkoczy P et al. Sport-related concussion. Neurol Clin Pract. 2023;13(2):e200123. https://doi.org/10.1212/CPJ.0000000000200123

Hay J, Johnson VE, Smith DH, Stewart W. Chronic traumatic encephalopathy: the neuropathological legacy of traumatic brain injury. Annu Rev Pathol Mech Dis. 2016;11(1):21–45. https://doi.org/10.1146/annurev-pathol-012615-044116

Henry LC, Elbin RJ, Collins MW, Marchetti G, Kontos AP. Examining recovery trajectories after sport-related concussion with a multimodal clinical assessment approach. Neurosurgery. 2016;78(2):232–241. https://doi.org/10.1227/NEU.0000000000001041

Kara S, Crosswell H, Forch K et al. Less than half of patients recover within 2 weeks of injury after a sports-related mild traumatic brain injury: a 2-year prospective study. Clin J Sport Med. 2020;30(2):96–101. https://doi.org/10.1097/JSM.0000000000000811

Koerte IK, Schultz V, Sydnor VJ et al. Sex-related differences in the effects of sports-related concussion: a review. J Neuroimaging. 2020;30(4):387–409. https://doi.org/10.1111/jon.12726

Kontos AP, Braithwaite R, Dakan S, Elbin RJ. Computerized neurocognitive testing within 1 week of sport-related concussion: meta-analytic review and analysis of moderating factors. J Int Neuropsychol Soc. 2014;20(3):324–332. https://doi.org/10.1017/S1355617713001471

Lee EB, Kennedy-Dietrich C, Geddes JF et al. The perils of contact sport: pathologies of diffuse brain swelling and chronic traumatic encephalopathy neuropathologic change in a 23-year-old rugby union player. Acta Neuropathol. 2023;145(6):847–850. https://doi.org/10.1007/S00401-023-02576-Y

Lennon MJ, Brooker H, Creese B et al. Lifetime traumatic brain injury and cognitive domain deficits in late life: the PROTECT-TBI cohort study. J Neurotrauma. 2023. https://doi.org/10.1089/neu.2022.0360

Lovell MR. The relevance of neuropsychologic testing for sports-related head injuries. Curr Sports Med Rep. 2002;1(1):7–11. https://doi.org/10.1249/00149619-200202000-00003

Lunter CM, Carroll EL, Housden C et al. Neurocognitive testing in the emergency department: a potential assessment tool for mild traumatic brain injury. Emerg Med Australas. 2019;31(3):355–361. https://doi.org/10.1111/1742-6723.13163

Martland HS. Punch drunk. JAMA. 1928;91(15):1103–1107. https://doi.org/10.1001/JAMA.1928.02700150029009

Macnow T, Curran T, Tolliday C et al. Effect of screen time on recovery from concussion: a randomized clinical trial. JAMA Pediatr. 2021;175(11):1124–1131. https://doi.org/10.1001/JAMAPEDIATRICS.2021.2782

McAllister TW, Broglio SP, Katz BP et al. Characteristics and outcomes of athletes with slow recovery from sports-related concussion: a CARE consortium study. Neurology. 2023;100(14):e1510–e1519. https://doi.org/10.1212/WNL.0000000000206853

McCrea M, Guskiewicz K, Randolph C et al. Effects of a symptom-free waiting period on clinical outcome and risk of reinjury after sport-related concussion. Neurosurgery. 2009;65(5):876–883. https://doi.org/10.1227/01.NEU.0000350155.89800.00

McCrea M, Guskiewicz K, Randolph C et al. Incidence, clinical course, and predictors of prolonged recovery time following sport-related concussion in high school and college athletes. J Int Neuropsychol Soc. 2013;19(1):22–33. https://doi.org/10.1017/S1355617712000872

McLeod TCV, Bay RC, Valier AR, Lam KC, Parsons JT. Health-related quality of life following sport-related concussion in interscholastic athletes. Br J Sports Med. 2013;47(5):e1. https://doi.org/10.1136/bjsports-2012-092101.48

Menon DK, Schwab K, Wright DW, Maas AI. Position statement: definition of traumatic brain injury. Arch Phys Med Rehabil. 2010;91(11):1637–1640. https://doi.org/10.1016/J.APMR.2010.05.017

Meyer J, Bartolomei C, Sauer A, Sajatovic M, Bailey CM. The relationship between fluid biomarkers and clinical outcomes in sports-related concussions: a systematic review. Brain Inj. 2020;34(11):1435–1445. https://doi.org/10.1080/02699052.2020.1802780

Mez J, Daneshvar DH, Kiernan PT et al. Clinicopathological evaluation of chronic traumatic encephalopathy in players of American football. JAMA. 2017;318(4):360–370. https://doi.org/10.1001/JAMA.2017.8334

Miller JH, Gill C, Kuhn EN et al. Predictors of delayed recovery following pediatric sports-related concussion: a case-control study. J Neurosurg Pediatr. 2016;17(4):491–496. https://doi.org/10.3171/2015.8.PEDS14332

Mistry DA, Rainer TH. Concussion assessment in the emergency department: a preliminary study for a quality improvement project. BMJ Open Sport Exerc Med. 2018;4(1):e000445. https://doi.org/10.1136/bmjsem-2018-000445

National Institute for Health and Care Excellence. Head injury: assessment and early management. 2023. https://www.nice.org.uk/guidance/ng232 (accessed 15 August 2023)

National Institute of Neurological Disorders and Stroke. Focus on traumatic brain injury research. 2023. https://www.ninds.nih.gov/current-research/focus-disorders/focus-traumatic-brain-injury-research (accessed 29 June 2023)

Neelakantan M, Ryali B, Cabral MD et al. Academic performance following sport-related concussions in children and adolescents: a scoping review. Int J Environ Res Public Health. 2020;17(20):7602. https://doi.org/10.3390/IJERPH.17207602

Nowinski CJ, Bureau SC, Buckland ME et al. Applying the Bradford Hill criteria for causation to repetitive head impacts and chronic traumatic encephalopathy. Front Neurol. 2022;13:938163. https://doi.org/10.3389/fneur.2022.938163

Petrelli T, Farrokhyar F, McGrath P et al. The use of ibuprofen and acetaminophen for acute headache in the postconcussive youth: A pilot study. Paediatr Child Health. 2017;22(1):2–6. https://doi.org/10.1093/pch/pxw011

Russell ER, MacKay DF, Stewart K et al. Association of field position and career length with risk of neurodegenerative disease in male former professional soccer players. JAMA Neurol. 2021;78(9):1057–1063. https://doi.org/10.1001/JAMANEUROL.2021.2403

Russell ER, MacKay DF, Lyall D et al. Neurodegenerative disease risk among former international rugby union players. J Neurol Neurosurg Psychiatry. 2022;93(12):1262–1268. https://doi.org/10.1136/JNNP-2022-329675

Schneider ALC, Huie JR, Boscardin WJ et al. Cognitive outcome 1 year after mild traumatic brain injury: results from the TRACK-TBI study. Neurology. 2022;98(12):E1248–E1261. https://doi.org/10.1212/WNL.0000000000200041

sportscotland. Scottish sports concussion guidance. 2023. https://sportscotland.org.uk/clubs/scottish-sports-concussion-guidance/ (accessed 29 June 2023)

UK Government. UK concussion guidelines for grassroots sport. 2023. https://www.sportandrecreation.org.uk/policy/research-publications/concussion-guidelines (accessed 29 June 2023)

World Rugby. Head injury assessment (HIA) protocol. 2022. https://www.world.rugby/the-game/player-welfare/medical/concussion/hia-protocol (accessed 29 June 2023)