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Understanding Sport-Related Concussion: A Comprehensive Overview

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Abstract

This paper provides a comprehensive overview of sport-related concussions, highlighting the critical importance of understanding their mechanisms, diagnosis, and management. Sport-related concussion is a frequent and complex pathology whose physiopathological mechanisms are not completely understood yet. Concussions, a subset of traumatic brain injuries, are prevalent in contact sports and pose significant risks to athletes' long-term health. The review covers the pathophysiology of concussions, emphasizing the biomechanical forces involved and the resultant neurological disruptions. Athletes seldom report concussive symptoms, which makes the diagnosis a challenge. Therefore, diagnostic challenges are explored, with a focus on clinical assessment tools, neuroimaging, and biomarkers. Additionally, the paper discusses current management strategies, including return-to-play protocols, and the role of education in concussion prevention. The review underscores the need for ongoing research to enhance diagnostic accuracy, improve treatment outcomes, and establish more effective prevention strategies, ultimately aiming to safeguard athletes' well-being.

Key words: concussion, sport-related concussion, mild traumatic brain injury, closed head injury, athletic injuries,

Introduction

Sport-related concussion (SRC) is a subset of mild traumatic brain injury (mTBI) induced by a blow to the head or another part of the body with force transmitted to the head.[1] It is a significant public health concern, with an estimated 1.6 to 3.8 million sports-related traumatic brain injuries occurring annually.[2] While much of the focus has been on sports like football, where male participants aged 15 and older are primarily studied[3], private high school student athletes are also at risk of experiencing concussions.[4]

Sport related concussions have become such a serious concern that an international workgroup of leading researchers and clinicians was formed to guide policy, clinical practice, and future research.[5] Consensus statements by this workgroup and the resulting awareness have led many sports to introduce new rules and mandatory requirements around player safety, assessment, management, and monitoring of concussion injuries and protective equipment.[6]

Concussions are prevalent in various sports, with over half of all concussions being related to sports activities.[7] Youth sports contribute significantly to high rates of mild traumatic brain injuries, with a substantial number of concussions occurring outside of organized sports.[8] The majority of concussions are treated outside of emergency departments, indicating that the actual number of sports-related concussions may be much higher.[9]

Proper management of concussions is crucial, as returning to play on the same day as the injury is strongly discouraged.[10] Tools like the Sport Concussion Assessment Tool (SCAT) have been developed to aid in evaluating sport-related concussions.[11] Additionally, understanding factors that influence concussion reporting, such as positive and negative influences among secondary-school athletes, is vital for improving detection and management.[12]

Epidemiology of concussion in sports

44 million children and 170 million adults participate in sports related activities and there are approximately 3.8 million sports related concussions per year.[13] Twenty percent of traumatic brain injury resulting in a loss of consciousness occurs during sports activity.[14] Approximately 300 000 sport-related traumatic brain injuries resulting in a loss of consciousness occur each year.[14] Most of these injuries are concussions.[15, 16] Contrary to common belief, more than 90% of concussions do not involve a loss of consciousness, which, combined with the absence of objective biomarkers, can make them challenging to diagnose.[6] Therefore, the actual number of sport-related concussions occurring annually is much higher. Studies of children and adolescents have suggested that 26% of closed head injuries in children occur during athletics,[17] and this is likely to be an underestimate, because many children with sport-related concussions do not seek medical attention.[18, 19]

Pathophysiology of concussion

There is no clear pathological definition to distinguish concussion from other types of traumatic brain injury (TBI), and the injuries leading to concussion are biomechanically like other types of TBI. Therefore, there is no a priori reason to think that concussion and mild TBI could be distinguished pathologically.[20] Therefore, SRC is considered a mild traumatic brain injury (mTBI) resulting from biomechanical forces that are directly or indirectly transferred to the head, causing the brain to shift or move inside the skull.[21] This may be associated with a blow to the skull; however, direct impact to the head is not required.[22] Subsequent changes at the neurometabolic level ensue and lead to a cascade of events at the cellular level, best characterized as an efflux of potassium and a co-occurring influx of calcium through cell membranes.[23] As the concentration of extracellular potassium increases, it triggers neuronal depolarization, which is followed by neuronal suppression.[24] In response to widespread depolarization, sodium-potassium adenosine triphosphate pumps (responsible for maintaining a

homeostatic electrochemical gradient across the cell membranes of axons) increase their activity to restore a normal resting potential.[25] In the process, these pumps become hyperglycolytic, drastically increasing the brain's demand for glucose and oxygen, which, in combination with reduced cerebral blood flow,[26] results in a supply-demand mismatch, or "energy crisis." Given the functional nature of this injury, it should not be of surprise that traditional imaging techniques (eg, computerized tomography) have not been successful in identifying/ diagnosing concussion but are used to rule out more severe pathology (eg, intracranial bleed or skull fracture).[5] While the average recovery time is 7-10 days, the altered metabolic state and diminished blood flow may last for weeks and during this period the neural tissue is more susceptible to further injury.[27]

Diagnosis of Sport-Related Concussion

The potential complications and long-term consequences of repetitive Sport-Related Concussion (SRC) emphasize the importance to reliably diagnose and efficiently manage SRC to protect athletes from developing long-term neurologic and behavioral deficits. While this is evident in classic risk disciplines like American football or ice hockey, general awareness is only slowly shifting towards soccer too, despite the sport's popularity all over the world. With concussion symptoms being heterogenous and often mild, head trauma in soccer is frequently underdiagnosed, and potential consequences are neglected.[28] Concussion can result in a range of symptoms that may vary greatly in quality, severity, and duration. They can often be very nonspecific in nature and overlap with preexisting medical conditions.[29] Many conditions present with similar symptom manifestations such as, dehydration, exercise-induced fatigue and attention-deficit disorders to name a few. A few athletes also report concussion-like symptoms at baseline with nearly 60% of uninjured collegiate athletes noting symptoms on a baseline assessment.[30, 31] Additionally, the contextual factors present on the sideline may influence the athlete's willingness to report their symptoms honestly. Athletes are highly motivated, committed individuals and societal pressures can cloud their decision making. The desire to play through injury to demonstrate commitment to the team, pressure from coaches, teammates or others, and fear of a diminished role because of injury are some of the factors that play a large role in the athlete's disposition and their willingness to share information.[32] In addition, concussion can have a delayed presentation. Some symptoms are present at the time of head impact; however, other symptoms may develop over the first several hours or even days after injury. All these factors can make the symptomatic assessment of concussion challenging.[29]

Diagnosis is primarily based on symptomatology and requires less than 30 minutes of loss of consciousness, memory loss of less than 24 hours and a GCS score of 13-15.[33] Depending on the severity of the injury, loss of consciousness may occur followed by a brief period of amnesia, but loss of consciousness is seen in less than 10% of patients who suffer a concussion. The loss of consciousness is precipitated by the rotational forces at the junction of the midbrain and thalamus resulting in a transient disruption of the reticular activating system.[34] Sport-related concussion result in a multitude of symptoms that often evolve over time during the acute time frame.[32] Clinical findings in patients with concussion include headache, dizziness, difficulty concentrating, inattentiveness, confusion/disorientation, drowsiness, nausea/vomiting, blank stare, sensitivity to light, blurred vision, double vision, slow/incoherent speech, impaired verbal learning and memory, impaired balance/ coordination, slowed reaction time, emotional liability, sensitivity to noise, numbness/tingling, sleeping difficulties, loss of consciousness, and amnesia.[35, 36, 37]

For standardization, different diagnostic tools have been established, with the "Sport Concussion Assessment Tool" (SCAT) being the most frequently used one, first established in 2004.[38] Just recently, this tool has been updated to SCAT-5, comprising different assessment stages.[39] However, the utility of SCAT5 decreases significantly 3-5 days postinjury. Neuropsychological testing such as pen-and-paper tests and computerized tests can be helpful to provide an objective measure of brain function.[25]

The five steps of on-field assessment of the concussed athlete, using the Sport Concussion Assessment Tool—SCAT (5th edition) (modified from Davis, 2017)

1. Red flags: warning signs to evaluate for serious injury

The most important is to find indicators (red flags symptoms) of more serious injury. These red flag symptoms may include focal neurologic symptoms, altered level of consciousness, postural or positional component to headache, progressively worsening headache, or intractable vomiting with headache. If red flags are present, neuroimaging is needed to evaluate for structural abnormalities that need to be addressed. A postural or headache exacerbated by being upright may indicate a low-pressure headache due to cerebrospinal fluid (CSF) leak after injury.[40] An MRI Brain with and without contrast and MRI Spine without contrast would be appropriate in this situation to look for signs of a CSF leak, including pachymeningeal enhancement or spinal extradural fluid collections.[41] In general, neuroimaging studies should be reserved for patients with concussion who have LOC, GCS <15 at 2 hours or less than 14 at any time, post-traumatic amnesia, post-traumatic seizure, focal neurologic deficit, clinical deterioration of condition, and suspected skull fracture.[42, 43, 44]

2. Observable signs: including loss of consciousness, motion or coordination disorders, disorientation or confusion, facial injury

3. Standardized memory assessment: Maddocks questions

- 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?

4. Glasgow Coma Scale

Response	Scale	Score
Eye opening response	Spontaneous	4 points
	Response to verbal command	3 points
	Response to pain	2 points
	No eye opening	1 point
Verbal response	Oriented	5 points
	Confused	4 points
	Inappropriate words	3 points
	Incomprehensible sounds	2 points
	No verbal response	1 point
Motor response	Obeys commands	6 points
	Localizing response to pain	5 points
	Withdrawal response to pain	4 points
	Flexion to pain	3 points

	Extension to pain	2 points
	No motor response	1 point
Minor Brain Injury: 13-15 Moderate Brain Injury: 9-12 Severe Brain Injury: 8-3		

5. Cervical spine assessment: neck pain, pain free movement, limb strength, and sensation

While the diagnosis of concussion is subjective, based on clinical assessment, there is exciting new research on blood biomarkers associated with astroglial (glial fibrillary acidic protein, S -100 calcium binding protein B) and axonal (tau, ubiquitin C-terminal hydrolase 1) injury. The biomarkers have been demonstrated to accurately detect when a TBI has occurred and may be able to predict the severity of an injury.[45, 46, 47]

Treatment

The traditional management of concussion mandated complete physical and cognitive rest until all symptoms have resolved for several days.[48,49] The treatment of concussion remains symptomatic therapy. There are targeted therapies for the most common symptoms experienced. The range of symptoms experienced by each patient will vary from person to person and cross multiple domains of medicine. Therefore, a multidisciplinary approach is quite important. The overarching goal in management of these patients is to provide symptomatic treatment, provide recommendations for return to mental and physical activity, and prevent reinjury while the brain is healing.[29] Cognitive rest includes reducing activities such as reading and video games that require concentration and attention to avoid overtaxing a functionally injured brain.[50, 51]

Headache is the most common and debilitating symptom after a concussion.[52] Posttraumatic headache (PTH) results in pain and an inability to participate in rehabilitation. Patients with PTH can present with a myriad of associated clinical features that mimics a specific primary headache disorder, and specific therapies should be tailored to those clinical features. A migraine-like PTH is most common.[53, 40] Targeted treatment recommendations for posttraumatic migraine should start with adherence to a well-regulated schedule of sleep, proper diet and hydration, exercise (eg. noncontact/nonrisk exertion), and stress management. Cardiovascular exercise that is graduated as the patient develops tolerance is often recommended.[54, 55] If necessary, analgesics such as ibuprofen and paracetamol (acetaminophen) may be used for the treatment of headaches.[48, 33] Prolonged use of these medications should be avoided as this may result in rebound headaches. Nonsteroidal anti-inflammatory drugs or aspirin should be avoided because of the theoretic risk of intracranial hemorrhage.[25]

The vestibular clinical profile is often characterized by symptoms of dizziness, mental fogginess, nausea, difficulty tolerating complex and busy environments (eg, grocery store or school cafeteria), feelings of anxiety and panic, and a sense of detachment. Quick or sudden movements of the head will often trigger or exacerbate symptoms.[21] Nausea, if severe, can be treated with ondansetron.[56] The athlete may often be provoked with horizontal and/or vertical gaze stability and optokinetic sensitivity.[21] Neurocognitive data may highlight a pattern that shows impaired processing speed and reaction time, in lieu of relatively intact memory scores. Risk factors for this clinical profile may include preexisting vestibular disorders and a personal history of car/motion sickness.[57]Furthermore, athletes who report on-field signs/symptoms of dizziness, which may indicate vestibular dysfunction, have been shown to have protracted recovery times.[58] After significant structural causes have been excluded, vestibular rehabilitation therapy should be initiated if symptoms persist for more than 10-14 days.[58, 59] Targeted treatment pathways indicated for vestibular dysfunction almost always include a referral to a neuro-vestibular therapist who can provide the athlete with an individualized set of exercises to rehabilitate these issues.

A structured exercise plan can also supplement and provide the athlete with certain workouts to further aid recovery.[21]

Sleep disruption generally will improve with proper sleep hygiene. Melatonin may be considered in those patients with severe sleep disruption not responding to sleep hygiene. Physiotherapy may be useful for persistent balance problems while cognitive behavioral therapy may be useful for mood changes.[60]

The anxiety/mood clinical profile includes an overall increase in anxiety, ruminative thoughts, hypervigilance and hypersensitivity toward symptoms, feeling over- whelmed, sadness, and/or hopelessness. In fact, anxiety has been identified as one of the most common psychiatric manifestations of concussion.[61] Antidepressants are the most prescribed medications for post-concussion syndrome (PCS). Although they are not FDA approved for this use, some selective serotonin reuptake inhibitors (SSRI) have an off-label use to address PCS symptoms.[62]

The ocular-motor clinical profile is often characterized by frontally based head- aches, fatigue, difficulty with visually demanding tasks (eg, reading, mathematics, and lengthy computer work), pressure behind the eyes, and difficulty with attention/concentration.[21] Targeted treatment for the ocular clinical profile may begin with a referral to a vestibular therapist, as they are trained to assess for and provide exercises to retrain the athlete's ocular functioning. If the athlete requires a higher level of care, an evaluation by a trained neuro-optometrist who can initiate a course of vision therapy may be indicated.[63, 64]

Return to play

For athletes who return to sports following a concussion, rapid integration back into sports may worsen symptoms and prolong recovery.[65] The National Athletic Trainers' Association recommends that injured athletes be prohibited from returning to play before they are symptom-free during both rest and exertion and until results of the neuropsychological tests have returned to preinjury levels, regardless of grading of concussion.[66] Returning an athlete to play is a clinical decision. Tools, such as brief computerized cognitive testing, should not dictate return to play. Before providing medical clearance and returning to contact sports, it is recommended to reestablish baseline measures of oculomotor, vestibular, and cognitive function.[29] Once an athlete is asymptomatic at rest, he or she may start light physical exertion. If asymptomatic during that trial, the exertion is increased 24 hours later. Exertion and sport participation is incrementally increased each day until the athlete can fully participate without symptoms. This progression usually takes 1 week. If at any point during the progression the athlete becomes symptomatic, the athlete must rest 24 hours, and then complete the last step of the progression that he or she was able to complete without symptoms.[5] These graduated programs to resume activity aim to ensure the concussed athlete can only participate in sports when restored from concussion symptoms.[5, 67, 68] In the advanced rehabilitation phases of the return to sport protocol, a "push through symptoms" is possible, if symptoms are prolonged. Ensuring a sufficient period of absence from sports participation protects the athlete from the aggravating consequences of repetitive concussions.[28] The patient and family should be informed that a prior history of concussion is a risk factor for future concussion and prolonged recovery.[29]

Prevention Strategies

Preventing sport-related concussion is very difficult. Prevention includes the use of helmets when bicycling, skiing, snowboarding, or motor biking, placing age limits on certain types of contact sports, good sportsmanship respecting the rules of the sport, encouragement of fair play, and banning of certain dangerous sport activities.[5, 69] Although helmets are often discussed as a means of preventing concussion, this is not the purpose of their design.[70] Current helmets have at best, a limited effect.[71, 72] Part of the difficulty of creating a helmet that improves protection against concussion is material limitations. Helmets have not been proven to protect from rotational acceleration of the brain and do not limit the amount of "brain slosh".[73, 74] By bracing the neck muscles before impact, an athlete decreases the resulting acceleration that the head experiences.[75, 76, 77] Therefore, it has

been suggested that strengthening the neck musculature may decrease the risk of concussion. Many concussions, however, occur when the athlete does not anticipate the impact, which makes increased musculature of questionable value.[78, 79]

Conclusion

In conclusion, understanding sport-related concussions is paramount to protecting the health and safety of athletes across all levels of competition. This comprehensive overview has outlined the complex nature of concussions, from their underlying mechanisms to the challenges in diagnosis and management. Despite advancements in clinical assessments and treatment protocols, significant gaps remain in our knowledge, particularly regarding long-term effects and optimal prevention strategies. Continued research is essential to develop more accurate diagnostic tools, refine management approaches, and implement effective preventive measures. By fostering a deeper understanding of sport-related concussions, stakeholders can better mitigate risks, promote safer athletic environments, and ensure the long-term well-being of athletes.

Author's contribution

Conceptualization, JK; methodology, JK, AN, MB; software, BM, AL, AR, KZ, RT; check, AL, AR; formal analysis, AN, BM, KZ; investigation, AL, MD, RT; resources, MB, KS, KZ; data curation, KS, AN; writing – rough preparation, JK, AN, MB; writing-review and editing, MD, KZ; visualization, MB; supervision, RT, MD; project administration, KS

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