Current Concepts in Sports-related Concussion

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ABSTRACT

Increasing concern over the acute and long-term consequences of sports-related concussion has generated widespread interest and attention. This article provides an overview of concussion in athletes, including diagnostic and management considerations, and highlights the clinical challenges associated with repeated minor head trauma in sports.

KEYWORDS: Sports-related concussion, mild traumatic brain injury, athletes

Table 1. Symptoms of Concussion

Physical	Cognitive	Behavioral
Headache	Memory problems	Increased emotions
Nausea/Vomiting	Difficulty concentrating	Sadness
Visual disturbance	Fogginess	Depression
Dizziness/Vertigo	Feeling slowed down	Anxiety
Impaired balance	Confusion	Irritability
Sensitivity to light/noise		
Fatigue		
Sleep disturbance		

INTRODUCTION

Sports-related concussion has become a growing concern in recent years and has generated considerable discussion within the scientific and athletic communities. Perhaps no other issue in sports medicine has received as much attention in the media as the potential long-term consequences of concussion in athletes. An estimated 1.6 million to 3.8 million concussions occur annually in the United States (1), but many more may go unrecognized or unreported. Although significant advances have been made over the last decade, the assessment and management of concussion remains a challenging endeavor.

PATHOPHYSIOLOGY

Concussion is defined as a complex pathophysiologic process resulting in transient neurologic dysfunction following a biomechanical insult to the brain, with or without loss of consciousness (2). It falls on the mild end of the traumatic brain injury (TBI) spectrum. There is considerable evidence to implicate linear and rotational acceleration forces at the moment of impact, causing deformation of neuronal membranes and axonal stretching. The resulting neurometabolic cascade involves ionic imbalances and local metabolic dysfunction (3). These physiologic disturbances are transient but render the brain more vulnerable to repeat injury, possibly with longer lasting effects.

EVALUATION AND RETURNING TO PLAY

The acute clinical effects of concussion result from neuronal dysfunction. They include balance and cognitive impairment, and any of more than 20 symptoms ranging from headache and "fogginess" to irritability (**Table 1**). Diagnosis is made when an athlete presents with the typical constellation of findings following either direct or indirect trauma. The focus of initial care is on the evaluation for cervical spine injury or neurosurgical emergency. The next step in evaluating and managing concussion involves recognition of the injury and removal from play. A systematic neurologic exam and assessment of symptoms, cognition, and balance will often lead to the correct diagnosis. However, sports-related concussion is not always easy to identify. While novel technologies are being developed to measure biomechanical forces, the magnitude of head impact does not necessarily predict clinical injury. Furthermore, the various symptoms of concussion are nonspecific, sometimes resulting in a diagnostic dilemma. This is complicated by the fact that athletes may not recognize the significance of their symptoms or will conceal symptoms in an effort to continue playing. Symptom checklists, such as the Sideline Concussion Assessment Tool (version 3, aka SCAT3) (2), are useful in the sideline evaluation after injury and have been adapted to assist in the office-based evaluation of concussion. Unless there is concern for structural brain injury, CT or MRI is often unnecessary. Traditional neuroimaging is expected to be normal in concussion, reflecting the more functional nature of the injury.

Same-day return to play should not be allowed at any level of sport for an athlete with diagnosed or suspected concussion. Following the Zackery Lystedt Law in Washington State in 2009, all fifty states have now enacted some form of concussion legislation in an effort to increase awareness and improve athlete safety. Rhode Island's School and Youth Programs Concussion Act (Chapter 16–91) mandates education for all coaches and volunteers involved with interscholastic

athletics; it requires immediate removal from play for suspected concussion, and written clearance for return to sports must be provided by a licensed physician (4).

After eliminating life-threatening injury and diagnosing concussion, safely returning an athlete to sports is a critical piece of the management paradigm. Grading systems were popular in the diagnosis and management of sports-related concussion in the early 1990s (5). However, these systems were flawed and have been abandoned as the focus shifted from categorizing injury severity to making individual recommendations based on several factors. Although most concussions will resolve within 7–10 days (6), recovery can be unpredictable and some may take significantly longer to improve. The return-to-play decision is complex and requires a very individualized plan. It is well understood that returning an athlete to sports assumes complete resolution of symptoms at rest and with physical activity, in addition to full recovery of cognitive function. Physical rest eliminates the risk of another head injury and allows recovery, though the degree and duration of rest are debatable. The widely used protocol published by the Concussion in Sport group is a consensus approach that outlines a progression of activity from light aerobic exercise to full contact activity (2). Introduction of exercise occurs once the athlete is asymptomatic, and each step identifies a 24-hour period with suggested activity (**Table 2**). Successful completion of each step requires that symptoms are not exacerbated during or after exertion.

Table 2. Graded Return to Play Protocol

Stage	Activity	Functional Exercise	Objective
1	No activity	Complete physical and cognitive rest	Recovery
2	Light activity	Low-intensity aerobic exercise Walk, swim, stationary bike	Increase heart rate
3	Sport-specific	Simple sport-related exercise Skating, running	Add movement
4	Training	Noncontact sport-related training drills Resistance training	Coordination and cognitive load
5	Full contact practice	Resume normal activity/practice	Restore confidence & Assess function
6	Return to play	Resume competitive game play	

Adapted from Consensus Statement on Concussion in Sport (2).

In addition to physical rest, cognitive rest is recommended as a cornerstone of concussion management and is also consensus-based (2). Cognitive rest entails limiting activities of attention and concentration, including schoolwork and video games, which may exacerbate symptoms and delay recovery. It often involves varying levels of academic accommodations (and sometimes removal from school) in an effort to allow recovery and preserve school performance. Although guidelines for "returning to learn" lack a strong evidence base, there is increasing attention to the need for a student-athlete's gradual and structured return to the classroom. The American Academy of Pediatrics emphasizes the importance of this and provides strategies for a productive transition back into the academic setting following concussion (7).

NEUROPSYCHOLOGICAL TESTING

Neuropsychological assessment first entered the scene in the late 1980s when it was discovered that sports-related concussion results in an acute decline in neurocognitive function. Traditional paper and pencil testing was cumbersome and gave way to computerized neurocognitive testing in the 1990s as a tool to more objectively evaluate concussion. Neuropsychological testing adds diagnostic value over symptom reporting alone (8), and computerized neurocognitive testing is now an important piece in the evaluation and management of concussion. Formal testing examines memory, attention, reaction time and other executive functions commonly affected by mild TBI. It allows for detection of subtle cognitive deficits, which can persist beyond symptom resolution. It is most useful to have a baseline evaluation for comparison following injury, but testing can be beneficial in the athlete without pre-injury data as well. Computerized neurocognitive testing is inexpensive, widely available, and has demonstrated reliability and validity (9). Nevertheless, it must be understood that such testing is only a single tool in the comprehensive evaluation of concussion and should not stand alone or be considered mandatory.

FEARED CONSEQUENCES

Although the neurometabolic disturbances and symptoms of concussion are often short-lived, there are acute and long-term consequences related to unrecognized or recurrent injury. A very conservative approach to managing concussion has evolved based on our knowledge of three major (and often controversial) clinical concerns: second impact syndrome, post-concussion syndrome, and chronic traumatic encephalopathy.

Second Impact Syndrome

The phenomenon of second impact syndrome, first popularized in the mid-1980s, remains a frequently cited concern when returning athletes to play. It refers to a second impact that occurs prior to recovery from an initial concussive injury, leading to loss of cerebral autoregulation, diffuse cerebral edema, and permanent neurologic disability or death. However, there is little evidence to support its existence and it is, at most, an exceedingly rare entity (10). Participation in contact and collision sports will always present a risk for catastrophic head trauma, but the reference to second impact syndrome as a reason for caution is debatable.

Post-concussion Syndrome

Post-concussion syndrome (PCS) is another major concern and represents the most practical clinical challenge following sports-related concussion. The definition of PCS in the medical literature is inconsistent, but it is generally understood to be the persistence of cognitive, physical, or emotional symptoms well beyond the expected time frame for recovery (11). Post-concussion syndrome is considered when concussion symptoms last more than six to twelve weeks following injury, and some experts argue that PCS is the manifestation or unmasking of psychiatric illness rather than the neurological injury itself. Severity of injury does not always correlate with symptoms, but a large symptom burden might predict a prolonged course. Pre-existing migraine headaches and learning difficulties may also herald a lengthy recovery. There is evidence to suggest a period of vulnerability following concussion, and repeated injury during this period can exacerbate symptoms and complicate recovery (3). A protracted course following a second concussion before complete recovery is perhaps more concerning than the unlikely second impact syndrome.

Regardless of the underlying pathophysiology, a multidisciplinary and symptom-targeted approach is best for managing PCS. Education of the athlete, family, coaching staff and others in the recovery process is universally important as well. While there are various medical treatments available, evidence is limited, and many therapies remain anecdotal or opinion-based. Pharmacologic therapy is directed toward alleviating symptoms but should not be expected to speed recovery and may cause cognitive or behavioral side effects. Examples include melatonin for sleep disturbance, amitriptyline for headache, selective serotonin reuptake inhibitors for depression, and amantadine for cognitive impairment (12). Unfortunately, because there is little supportive evidence for the use of medications for PCS in athletes, these strategies should be considered only by experienced providers after failure of more conservative measures.

Rehabilitation techniques play an increasing role in the management of prolonged concussion recovery. Cognitive behavioral therapy may be helpful in managing emotional and sleep disturbances, as well as other physical symptoms such as posttraumatic headache. Neurocognitive rehabilitation may enhance memory, attention and general cognitive performance. Vestibular rehabilitation may help relieve dizziness and improve gait and balance. It has been postulated that prolonged rest may actually be detrimental to recovery. Some experts advocate a supervised and controlled aerobic exercise rehabilitation program for athletes with symptoms lasting beyond three weeks. Gradual progression of exercise at a subsymptom threshold can aid in recovery (13).

Chronic Traumatic Encephalopathy

The third major concern surrounding sports-related concussion involves the cumulative effects of repeated head trauma. The investigation into long-term neuropathologic, cognitive, and behavioral changes is not well established. Some research supports a decline in neurocognitive function with multiple concussions, but other studies have failed to demonstrate cumulative adverse effects (14). Chronic traumatic encephalopathy (CTE) was first described in boxers as dementia pugilistica in the 1930s, referring to boxer's dementia. CTE is a neurodegenerative disease found in individuals with a history of repetitive mild traumatic brain injury. It shares clinical similarities with Alzheimer's dementia and parkinsonism, but diagnosis is made only by distinct changes on post-mortem neuropathologic examination.

Although the risks of developing neurodegenerative disease from boxing have been recognized for decades, researchers and the media have more recently brought attention to this risk in football following several high-profile cases and tragic deaths. CTE generally occurs later in life, long after retirement from sports, and is characterized by an insidious-onset of cognitive decline and behavioral changes. Deterioration of mental health has also been highlighted as a concern. Clinical diagnosis is complicated by the lack of standard criteria, the requirement for autopsy confirmation, and confounders such as substance abuse. Additionally, the exact relationship between sports-related concussion and CTE remains unclear (15). Risk factors within sport are largely unknown, including the significance of repetitive subconcussive head trauma or even a single lifetime concussion. Nonetheless, concerns about the cumulative effects of both concussive and subconcussive impacts are growing, and certain thresholds may predict later-life depression and cognitive impairment (16).

Based on the subacute and chronic consequences of concussion mentioned above, the question of retiring athletes from contact or collision sports is frequently encountered in clinical practice. There are no specific data or criteria on which to base retirement decisions, and each decision is highly individualized. Despite a lack of strict guidelines, it is generally understood that several variables will prompt this discussion: decreasing time intervals between concussions, relatively minor impacts causing or exacerbating symptoms, and increasing symptom burden or duration with each successive injury.

FUTURE DIRECTIONS

Concussion will always be an inherent risk of contact and collision sports. Present and future efforts toward mitigating this risk are focused on prevention, diagnosis, and improved understanding of long-term sequelae. Primary prevention includes enforcement of existing rules and careful consideration of further rule changes. Equipment use and modification is important for injury prevention, but despite manufacturers' claims, there is no conclusive scientific evidence that protective equipment prevents or reduces risk of concussion. Continued efforts toward educating the athletic community about injury recognition and significance, and

the importance of safe return to competition, is essential in limiting adverse outcomes.

Presently, sports-related concussion is a clinical diagnosis. Advances in areas like biomarker research and functional magnetic resonance imaging may someday offer a more objective view of this injury. Development of other technologies, such as force-measuring accelerometers in football helmets, may also change our understanding of head trauma, as may further research into the roles of age, gender, and genetic predisposition as risk factors for injury or long-term complications.

CONCLUSIONS

Our knowledge of sports-related concussion has grown exponentially in the past decade, but it is clear that we have only scratched the surface. Dissemination of information by media outlets has outpaced our true scientific understanding of concussion. This has been productive in educating the public about its significance, and education is integral in mitigating risk. However, it has arguably created unsubstantiated concern in the absence of sound evidence for poor long-term outcomes. The management of sports-related concussion has evolved from grading systems to consensus-based recommendations with a limited base of evidence. Currently, the standard for management incorporates a conservative, individualized approach guided by the principles of physical and cognitive rest, though the role of strict or prolonged rest is being challenged. Complex cases often require a multidisciplinary team consisting of primary care providers, sports medicine specialists, neurologists, mental health professionals, neuropsychologists, and physical therapists.

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Disclosures

None

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