

Sports-Related Concussions

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Concussions are an inherent part of collision sports such as football and soccer. As a subset of traumatic brain injury, concussions are neurometabolic events that cause transient neurologic dysfunction. Following a concussion, some athletes require longer neurologic recovery than others. Education and intervention aimed at prevention and management can minimize the long-term sequelae of sports-related concussions.

The Centers for Disease Control and Prevention (CDC) estimates that 45 million children and adolescents aged 5-19 years participate in organized or recreational sports [1]. While sports promote positive physical, intellectual, and social development [2], sports participation also poses risk of injury, including orthopedic injury and traumatic brain injury (TBI). An estimated 5-10% of children and adolescents sustain a sports-related concussion with an associated emergency department presentation, and a large but less quantifiable number are injured but do not present to the emergency department [3]. Out of 50,000 deaths per year nationwide from TBI of any etiology, an estimated 900 deaths per year result from sports and recreational activities [4]. In 2013, there were 8 sports-related concussion fatalities from football nationally, all at the high school level [5]. Such statistics raise acute concern about the health and safety of elementary school, high school, and collegiate athletes who receive a sports-related concussion, as such injuries can impair academic and cognitive development [6].

Definition of Sport-Related Concussion

Sports-related concussions have been classified as a subtype of mild TBI. Concussions occur from an external force or blow to the head or body that causes an alteration in neurologic functioning, with impairment in concentration, working memory, and executive functioning [7, 8]. Additional problems that can occur include headaches, insomnia, emotional lability, dizziness, and fatigue (See Table 1).

The prototypical recovery pattern following a single, uncomplicated sports-related concussion is full or near complete symptom resolution in the first 1-2 weeks following injury, although some symptoms may persist for several weeks. Animal research on concussions by Giza and Hovda [9] posits that there is a neurometabolic cascade, with a mismatch in glucose metabolism and regional cerebral blood flow, which creates an energy crisis at the cellular level. In the

majority of these animal studies, the neurometabolic crisis restores to homeostasis in about 7 days, without irreversible damage at the cellular level [9].

However, emerging data from experimental studies of concussed athletes suggest that the animal neurometabolic model may be insufficient to model sports-related concussion neuropathology in humans. Traditional neuroimaging techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) fail to reveal signs of a typical, noncomplicated sports-related concussion, but newer neuroimaging measures used in research (diffusion tensor imaging, functional MRI, magnetic resonance spectroscopy, quantitative electroencephalography, and event-related potentials) show abnormal brain activity and anomalies for weeks or months following a sports-related concussion [10-12]. The 2014 report on sport-related concussions in youth from the Institute of Medicine of the National Academies [13] concluded that, while the clinical significance of these abnormalities was unclear, these newer techniques provide compelling tools that can be used to image cerebral disruption that may be responsible for prolonged post-concussive symptoms in certain athletes, or they may suggest a longer period of post-injury physiological vulnerability than is currently appreciated.

Risk Factors for Prolonged Recovery

One of the strongest predictors of prolonged recovery is a history of previous concussions, especially 3 or more. Other identified risk factors for a complicated, prolonged recovery

Physical	Headache, balance problems, dizziness, visual problems, fatigue, sensitivity to light and noise.
Cognitive	Difficulty concentrating, difficulty remembering, feeling mentally "foggy," feeling slowed down, answers questions slowly.
Emotional	Irritability, sadness, more emotional, nervousness, lability.
Sleep	Drowsiness, sleeping more than usual, sleeping less than usual, difficulty falling asleep, difficulty staying asleep.

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ery include premorbid or comorbid factors. Premorbid factors include a history of birth trauma, pediatric head injury, seizures, migraines, neurodevelopmental disorders, attention deficit hyperactivity disorder, or learning disabilities. Preexisting sleep disorders, motion sickness, or mood disorders (including depression or anxiety) can prolong recovery. Comorbid mood disorders and psychosocial stress also complicate recovery. Predictors of prolonged recovery that can be observed on the field include loss of consciousness, retrograde or anterograde amnesia, and a greater number of symptoms present post-injury. Table 2 summarizes risk factors for prolonged recovery following a sports-related concussion.

Factors Associated With Increased Concussion Risk

Age and Sport

Age accounts for a significant variance in the incidence of concussions, as does the particular sport or athletic activity being performed. Boys and girls aged 10-14 years have

the highest rates of emergency department visits associated with sports-related TBI [4]. Among the 10-14 year age group, the sport and recreational activities producing the most concussions include bicycling, football, and playground activities. For the 15-19 year age group, participation in formal school sports shifts the etiology of concussions from recreational activities to organized sports. Football and soccer have the highest concussion rates, and collision/contact sports such as hockey, lacrosse, and basketball generally have higher concussion rates than non-contact sports such as track and volleyball. For the 4-9 year age group, playground and bicycling accidents are the leading activities associated with concussion risk.

Evolving research suggests that the length of recovery varies based on age. In organized sports, 90% of collegiate athletes return to baseline cognitive functioning within 2 weeks. High school athletes take longer to recover, with only 50% recovering in 7-10 days, and 90% returning to baseline within 4 weeks. For the youngest athletes, many sports or recreational activities are informal and are not

organized for reporting injuries, so both incidence and recovery data for this group are based upon estimates. However, there is growing consensus that younger children with sports-related concussions may experience greater deficits and may need a longer time to recover [14]. Thus there appears to be an inverse relationship between age/level of sport participation and symptom resolution time; specifically, professional athletes recover the quickest, followed by collegiate athletes, high school athletes, pre-adolescents, and children. The consensus among multiple studies is that conservative management of concussions is recommended for athletes of high school age or younger [7, 8]. Conservative management for younger athletes would include longer removal from play, an extended period

of asymptomatic rest and restricted physical exertion, and reduced cognitive and academic demands, with careful monitoring by parents, teachers, and coaches.

Sex

Football is the greatest concussion generator for males, and soccer is the greatest concussion generator for females. Notably, females are at higher risk for sustaining concussions across all ages and sports. For sports with the same rules for each sex, females have almost twice the incidence of sports-related concussions [15]. Hypothesized reasons for this higher risk include physiologic differences such as reduced skull thickness, smaller neck muscles, and hormonal influences. Additionally, some studies suggest that

TABLE 2.
Risk Factors for Prolonged Recovery Following a Sports-Related Concussion

Factor	Modifier
Symptoms	Number, duration (>10 days), severity.
Signs	Prolonged loss of consciousness (>1 minute), amnesia.
Temporal	Frequency: repeated concussions over time. Timing: injuries close together in time. Recency: recent concussion or traumatic brain injury.
Threshold	Repeated concussions occurring with progressively less impact or slower recovery after each successive concussion.
Age	Child and adolescent (<18 years).
Comorbidities and pre-morbidities	Migraine, seizures, mental health disorders, attention deficit hyperactivity disorder, learning disabilities, sleep disorders.
Medication	Psychoactive drugs, anticoagulants.

Source: Adapted from McCrory et al [8].

females may be more willing to report symptoms than males [15]. However, the most prevalent concussion symptoms are similar across both sexes. Approximately 97% of females and 95% of males report headaches post-concussion. Dizziness and vestibular dysfunction are endorsed by about 77% of both sexes. Concentration difficulties are reported by 51% of males and by 47% of females. Regarding more prolonged sports-related concussion symptoms, headaches and concentration difficulties are more persistent in female athletes [16].

Consequences of Sports-Related Concussions

Consequences of sports-related concussions can be divided into short-term or long-term consequences, or they can be categorized by whether their effects compromise neurocognitive, emotional, physical, or academic functioning. The aforementioned data highlight factors associated with prolonged recovery following a sports-related concussion, which is often referred to as post-concussive syndrome (PCS). Various diagnostic systems quantify the length of symptom duration and the degree of resulting impairment required to meet diagnostic criteria for PCS.

Long-term post-concussive sequelae are termed refractory PCS, and are seen in 10-20% of concussed athletes between the years of kindergarten through 12th grade. These student-athletes require more comprehensive evaluation by a multidisciplinary team of physicians, neuropsychologists, and vestibular therapists with training and experience in the assessment and treatment of concussions. Neuropsychological assessment and biopsychosocial evaluation can help to make the differential diagnosis, identify factors that are prolonging symptoms, and target appropriate interventions to maximize recovery. Premorbid and comorbid neurologic risk factors can increase the potential for refractory symptoms following a sports-related concussion [17].

Typical physical consequences of a sports-related concussion include headache, dizziness, fatigue, and sleep disturbance. When prolonged, these symptoms can have a secondary impact on attention, memory, and learning efficiency, and there can be tertiary effects on academic progress or job performance. Neurocognitive sports-related concussion symptoms can directly impact learning. Behavioral and emotional dysregulation are also common post-concussion consequences, with emotional flooding and reduced impulse control or frustration tolerance. When these are not recognized as post-concussion symptoms, they can engender negative responses from parents, teachers, or peers. Finally, restrictions on return to play (RTP) can have a negative impact on an athlete's sense of identity, peer group inclusion, and perceived control. Positively, most athletes exhibit resiliency and return to baseline.

Minimizing the Risks of Sports-Related Concussions and Subsequent Injury

While prevention of sports-related concussions is the ultimate objective, this goal is currently unattainable. Concussions are a naturally occurring event in collision sports such as football and hockey. Therefore, current prevention efforts are aimed at minimizing the incidence and severity of sports-related concussions.

Education

In any prevention effort, education is primary. Education about concussions should be directed toward all persons involved in sports, since early detection and proper management improve outcomes. North Carolina's Gfeller-Waller Concussion Awareness Act mandates education about sports-related concussions for players, parents, coaches, and others involved in middle and high school sports in our state, and it specifies steps that must be taken before an athlete with a suspected concussion can return to practice or play. [Editor's note: The Gfeller-Waller Act is discussed further in the sidebar by Bloom on pages 90-91.] Positively, the Gfeller-Waller Act has been voluntarily adopted by many of the private school sports associations in North Carolina. Free educational materials on sports-related concussions can be accessed from the Matthew Gfeller Sport-Related Traumatic Brain Injury Research Center at the University of North Carolina at Chapel Hill (<http://tbicenter.unc.edu>) and from the CDC (<http://www.cdc.gov/concussion/HeadsUp/youth.html>).

Safe Play Guidelines

Prevention of sports-related concussions has benefitted from recent efforts to promulgate safe play guidelines. Many of these efforts use materials that have been widely distributed through the Heads Up: Concussion in Youth Sports tool kit developed by the CDC. Organizations including USA Football and Pop Warner have also established rules

and techniques to minimize injury risk, and USA Football recently adopted new rules for practice and play for high school. Adherence to these rules and techniques of fair/safe play by coaches and players is essential to reduce the incidence of sports-related concussions.

Equipment

Given the recent emphasis on the risk of concussion in sports, equipment and devices advertised to prevent or minimize sports-related concussions are increasingly being marketed. However, scientific study of these products and equipment may not validate their efficacy. Currently, there are no football helmets or other equipment proven to prevent concussions. Rather, high-tech helmets are designed to prevent catastrophic brain injuries such as skull fractures. Nonetheless, newer helmets may help reduce the impact to the player's brain. Also, there is no conclusive evidence to

date that mouth guards or equipment modifications prevent concussions. In fact, aftermarket modifications may make the equipment less safe and can invalidate certification from the National Operating Committee on Standards for Athletic Equipment.

Strength and Conditioning

Good aerobic conditioning before a concussion may minimize recovery time. Additionally, good muscular strength, especially of the neck muscles, has been postulated to reduce concussions, especially when the player is aware that a hit may occur (eg, not a blindsided hit). Finally, sub-threshold aerobic exercise is an intervention for PCS.

Removal, Rest, and Graduated Re-entry

It is essential that a player suspected of having a sports-related concussion be removed from the game and evalu-

ated on the sideline. The presence of a certified athletic trainer (ATC) to perform sideline evaluation is critical, although many public schools in North Carolina do not have ATCs. Preventing an athlete from playing when they still are symptomatic is essential, since 90% of second concussions occur within 7-10 days of the first concussion.

Best practice guidelines identify physical and cognitive rest as the primary treatment for sports-related concussions. Consensus indicates that 3-4 days of rest is optimal, and longer periods of rest may be counterproductive. During this time, student-athletes are restricted from sports or educational activity, and they should reduce screen time and cognitive stimulation. Rest protocols allow the normal homeostatic process to occur, whereas precipitous return to practice, play, or cognitive activity will prolong symptoms and complicate the recovery process.

When athletes are asymptomatic at both rest and exertion, they can begin a graded exercise challenge following the Graduated RTP Protocol. As they return to learn (RTL), many student-athletes will also require temporary modifications and accommodations that allow for graduated cognitive exertion. Currently, the North Carolina Department of Public Instruction does not have formal post-concussion return-to-school guidelines, but such a policy is being drafted. The need for RTL supports following a sports-related concussion has been endorsed by the American Academy of Pediatrics [18] and the American Medical Society for Sports Medicine [19]. While RTL plans will need to be individually tailored, policy guidelines offer a template for how students can return to school before they have completely recovered from a sports-related concussion. Educational plans appropriate for students with short-term consequences of a sports-

related concussion or persistent PCS can prevent academic decline and the stress this places on student-athletes and their families.

Conclusion

Given the scope of the problem and the potential for adverse consequences following sports-related concussions, there is clear need for systematized statewide efforts aimed at concussion education, management, and prevention. Factors associated with the risk of sports-related concussions include age, sport, sex, and prior concussion. Premorbid neurologic risk factors, comorbid disorders, and younger age have been identified as factors contributing to prolonged recovery. Prevention strategies include education, equipment, strength and conditioning, and safe play guidelines. Early identification, early intervention, implementation of physical and cognitive rest, and graduated RTP and RTL protocols are critical in maximizing recovery following a sports-related concussion. *NCMJ*

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