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Concussion and the Adolescent Athlete

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Abstract

Traumatic brain injury (TBI) is a complex and debilitating neurological injury that places a significant financial and emotional burden on both families and medical providers. Accumulating evidence suggests that mild TBI or concussion remains grossly underdiagnosed, as compared with more severe TBI, due to a poor understanding of the clinical signs and symptoms involved with a head injury. Notably, pediatric head injury may be associated with the subsequent development of serious, long-term neurological consequences, emphasizing the need for improved diagnosis and acute medical intervention. The purpose of this minireview is to summarize the association between participation in youth athletics and the occurrence of concussions, a primary source of mild TBI in the adolescent population, with the goal of increasing awareness within the nursing profession for this clinically important yet underdiagnosed form of brain injury.

Traumatic brain injury (TBI) is a leading cause of death and disability across all population demographics. Over 57 million people worldwide live with the neurological consequences of a TBI, including 10 million people who require hospitalization (Zitnay et al., 2008). Within the United States, over 1.7 million Americans experience TBI annually, resulting in 275,000 hospitalizations and 52,000 deaths (Bramlett & Dietrich, 2004; Langlois, Rutland-Brown, & Thomas, 2004; Nortje & Menon, 2004). The incidence of TBI has increased more than 5% within the past decade, producing an annual economic impact of ~$60 billion due to medical expenses and the cost of lost productivity (Faul, Wald, & Coronado, 2010; Thurman, 2001; Zitnay et al., 2008). TBI represents a heterogeneous group of injuries that exhibit a variable, complex pathophysiology and produce a range of long-term sequelae that include emotional disturbances, cognitive difficulties, language disturbances, and other neurobehavioral issues (Faul et al., 2010; Zitnay et al., 2008). The Centers for Disease Control and Prevention broadly defines TBI as “a bump, blow or jolt to the head or a penetrating head injury that disrupts the normal function of the brain” (Binder, Corrigan, & Langlois, 2005; Faul et al., 2010); however, patient outcomes vary widely depending on the severity of the initial trauma. Moderate to severe TBIs, which are frequently caused by motor vehicle accidents or falls, may induce loss of consciousness and confusion, whereas mild TBI (mTBI) is often associated with more mild deficits and/or the lack of overt clinical symptoms. The clinical criteria for defining mTBI remain poorly defined; thus, many victims fail to seek and/or receive immediate medical attention and may experience long-term deleterious consequences as a result. Given the public health importance, improved

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awareness and understanding of the signs and symptoms of mTBI are needed to improve patient outcomes.

The Problem

In contrast to other common neurological diseases, such as stroke and Alzheimer disease, TBI is most prevalent in younger populations, with the 0–4-year and 15–19-year age groups experiencing the highest rates of incidence (Mitka, 2010). Overall, TBI is more prevalent than breast cancer, AIDS, multiple sclerosis, and spinal cord injury combined; however, these data reflect only the number of neurotrauma patients seeking emergency medical treatment and overlook an increasing number of mTBI victims (e.g., concussions) who fail to obtain medical evaluation. As a result, TBI is now commonly regarded as a "silent epidemic."

Despite the prevalence within society, a relatively modest percentage of research effort has been devoted to the mechanistic understanding and treatment of TBI; however, approximately 22%–29% of all wounded soldiers from the Operation Iraqi Freedom and Operation Enduring Freedom experienced at least one reported TBI, making this the "signature wound" in current military personnel (Bradshaw, 2008; Okie, 2005). These recent findings in the Armed Services have resulted in a renewed interest in understanding the clinical pathophysiology of TBI and have raised awareness to this type of injury. On the basis of the prevalence of mTBI in soldiers, in 2009, the Department of Veterans' Affairs put forth clearly defined clinical guidelines for TBI that included a defined characterization of TBI, as summarized below:

> A traumatically induced structural injury and/or physiological disruption of brain function as a result of an external force that is indicated by new onset or worsening of at least one of the following clinical signs, immediately following the event: 1. any period of loss of or a decreased level of consciousness (LOC), 2. any loss of memory for events immediately before or after the injury (post-traumatic amnesia (PTA), 3. any alteration in mental state at the time of the injury (confusion, disorientation, slowed thinking, etc), 4. neurological deficits (weakness, loss of balance, change in vision, praxis, paresis/plegia, sensory loss, aphasia, etc) that may or may not be transient, 5. intracranial lesion. (Management of Concussion/ mTBI Working Group, 2009)

Although important for ensuring adequate care to veterans, these studies have served another important purpose in that public awareness for TBI within civilian populations has been significantly heightened. To maintain focus and limit the scope of this mini-review, the following sections will present current data on sports-related TBI in the adolescent athlete because this topic is of clinical import to many nurses, trainers, and other emergency room medical personnel.

Concussion—A Form of mTBI

Historically, TBI represented an all-encompassing term covering the complete spectrum of neurotrauma, ranging from mild to severe head trauma (Faul et al., 2010); however, this broad definition does not adequately differentiate between mTBI and severe head injury. Throughout the literature, the terms *mTBI* and *concussion* are used interchangeably (Tanielian, 2008); however, *mild* simply refers to the

> An ever-growing body of evidence suggests that concussion, or mild traumatic brain injury (mTBI), in young individuals is an often unrecognized or overlooked, underreported, and inadequately treated problem in pediatric and adolescent neuroscience.

severity of the initial insult rather than providing a predictor of the long-term sequelae (Grady, 2010). In contrast, the term *concussion* is more often used when communicating with mTBI patients or with families of patients because ~33% of Americans are unfamiliar with the term TBI or equate this with the more severe forms of injury (Langlois, Marr, Mitchko, & Johnson, 2005). To provide further clarity and consistency within the medical community, the Academy of Neurology defines concussion as "a trauma-induced alteration in mental status that may or may not involve loss of consciousness and whose hallmark is confusion" ("Practice Parameter: The Management of Concussion in Sports (Summary Statement)," 2011). Furthermore, in a 2008 consensus statement from the International Symposium on Concussion in Sports, concussion was defined as "complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces." This sports concussion may or may not involve a loss of consciousness and generally reflects functional disturbances rather than structural damage or injury. This results in the absence of abnormalities on standard structural neuroimaging (McCrory et al., 2005).

Sports Concussions and the Adolescent Athlete

Concussions are an increasingly common sports-related injury. The Centers for Disease Control and Prevention estimates that ~135,000 children between the ages of 5 and 18 are treated in the emergency room each year for concussion as a result of participation in sports-related activities (Faul et al., 2010); however, these numbers may represent significant underestimates because recent reports indicate that ~300,000–3,800,000 sports-related mTBIs occur annually, with children aged 14–19 exhibiting three times more TBI in 2007 as compared with 1997 (Buzzini & Guskiewicz, 2006; Halstead & Walter, 2010; Mitka, 2010). It remains unclear whether the increased presentation of concussed adolescents in the clinic represents a true increase in the number of injuries or whether this reflects an increased awareness of the signs and symptoms of concussion. Given the potentially dire long-term consequences of concussion, these data indicate an alarming number of adolescents experiencing head injuries during participation in sporting activities.

Participation in youth sports and sports-related activities has risen dramatically over the past several decades, given the increased number of programs for both male and female youths. Furthermore, the recognized benefits of physical fitness resulted in more adolescent involvement in competitive sports. Paralleling this trend of increased sports participation, reports of mTBI as a result of involvement in a sporting event have also increased, particularly in contact sports such as football and ice hockey (Mitka, 2010). Despite improvements and more widespread use of protective equipment (e.g., improved helmet design), which reduce the incidence of concussion, a large number of concussions occur each year, indicating a large public health need to better understand the risk factors and symptoms and signs of a concussion.

A common problem with sports-related concussion is that the symptoms often appear mild, leading to the refusal of appropriate medical treatment by the youth; however, it is equally likely that the athlete, coaches, and/or parents do not fully understand how a concussion manifests. As such, the injured athlete, who may experience an impaired sense of self-awareness due to the concussion or disregard the severity of the injury due to a competitive drive to continue, declines medical attention and seeks to return to action, where they are vulnerable to a second head injury (Buzzini & Guskiewicz, 2006; Grady, 2010; Guskiewicz et al., 2003; Halstead & Walter, 2010; McCrea et al., 2003; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004; Mitka, 2010). Given the recognition of the acute symptoms (e.g., confusion, anterograde or retrograde amnesia, dizziness, nausea) and the growing appreciation of the long-term, irreversible neurological consequences that develop in the days, weeks, and months after a concussion, early diagnosis and medical intervention are of utmost importance (Grindel, Lovell, & Collins, 2001; McCrea et al., 2004; Pellman &

Viano, 2006; “Practice Parameter: The Management of Concussion in Sports (Summary Statement),” 2011; Williamson & Goodman, 2006). The importance of this is further illustrated by data suggesting that high school athletes require longer recovery periods from concussion as compared with adults (Field, Collins, Lovell, & Maroon, 2003).

Football as a Primary Source of mTBI—Lessons From Professional Athletes

Concussions occur in nearly all adolescent sporting activities; however, athletes participating in combative sports are not surprisingly at the highest risk for sustaining concussion (Grady, 2010; Meehan, d'Hemecourt, & Comstock, 2010; “Practice Parameter: The Management of Concussion in Sports (Summary Statement),” 2011). In 1994, the National Football League (NFL) recognized that concussions represented a major issue in athletes, resulting in the formation of a committee to study the issue of concussion in professional football players. On the basis of the recommendations of the NFL, helmets and mouthpieces were redesigned to provide improved safety and helmet-to-helmet contact was banned (Pellman & Viano, 2006). However, in the past several years, a large number of former NFL players reported neuropsychiatric disorders, including increased aggression, erratic behavior, and suicidal tendencies (Solomon, Ott, & Lovell, 2011). Although the precise causes of these neurological deficits remain under intense investigation, repetitive mTBIs over the career of the athlete (which may have been undiagnosed or unappreciated at the time of the injury) may result in the development of chronic traumatic encephalopathy (CTE), a progressive degenerative disease that is related to dementia pugilistica in boxers. Indeed, very recent postmortem brain analysis demonstrated this devastating condition in at least a dozen former professional athletes, including retired NFL players, as well as numerous former ice hockey players in the National Hockey League (Kusinski, 2011; Schwarz, 2010a). Perhaps more troublesome and most relevant to the present review, a 21-year-old collegiate football player with no prior history of depression suddenly experienced an emotional collapse and committed suicide. Postmortem analysis of his brain revealed the development of early-stage CTE (Schwarz, 2010b). Although a causative link between CTE and suicide remains speculative in this individual, this case study suggests that even amateur athletes may be susceptible to the long-term consequences of concussion.

The sobering studies presented in the preceding section on professional athletes illustrate that adolescent athletes who participate in contact sports may be at risk for concussion and subsequent neurological deficits. In response to the emerging data on concussion, the National Collegiate Athletic Association, the primary governing body of athletics for over 1,200 colleges and universities within the United States, commissioned a study focused on the incidence of concussion and recovery times for returning to play for college football players (Guskiewicz et al., 2003).

This study looked at the incidence of concussion in all levels of collegiate athletes (divisions I–III, including scholarship and nonscholarship athletes) and determined that linebackers (a defensive player who delivers violent, high-impact tackles to stop the advancing offensive player) experienced the highest rate of concussions at 0.99 concussions per athlete exposure, whereas wide receivers (an offensive player responsible for catching passes, typically does not involve significant contact) exhibited the lowest incidence at 0.53 concussions per exposure. Interestingly, it was determined that athletes experiencing a concussion had a higher risk of experiencing additional concussions (placing these athletes at a higher risk of developing CTE and other long-term neurological deficits). Furthermore, these players experienced longer recovery times after the first concussion and displayed cerebral dysfunction, even in cases that lacked loss of consciousness, confusion, or amnesia (Guskiewicz et al., 2003; McCrea et al., 2003).

High School Athletics and Concussion

Of the estimated 300,000 sports-related concussions, approximately 250,000 occurred in football players alone (Grindel et al., 2001). Notably, ~3%–6% of all high school football players reportedly experienced at least one concussion; however, it is important to note that these data rely upon surveillance studies and do not include reports by the players, suggesting an underestimation of the actual incidence (McCrea et al., 2004). In support of this assertion, surveys of high school football players found that two thirds of the players would not report or would mask the symptoms of a concussion due to pressure and/or a personal desire to continue playing or due to a belief that the injury was not serious enough to warrant medical evaluation (McCrea et al., 2004; Williamson & Goodman, 2006). In addition, over one third surveyed did not realize that they sustained a concussion until a definition was provided. Thus, when correcting for these confounds of personal reporting of head injury, the true incidence of sports-related concussions in high school football players may approach 15% per season (McCrea et al., 2004). Although football is the primary source of adolescent concussion (Grindel et al., 2001), all high school athletes of both genders are at risk for concussion. Along these lines, reports from the late 2000s indicate that after football, the rate of concussions was next highest in female soccer players. In contrast, volleyball and baseball athletes displayed the lowest incidence of concussion per 1,000 athlete exposures (Halstead & Walter, 2010; Meehan & Bachur, 2009). Because the incidence of concussion is generally calculated from studies involving physician visits or following athletic trainer reports, these reports may largely underestimate the actual number of incidences. As sports medicine professionals generally agree that the incidence of sports-related concussions in the adolescent is significantly underreported, the numbers may represent gross underestimations, particularly in “noncontact sports,” where the presence of qualified medical staff may be absent due to limited budgets (McCrea et al., 2004; Williamson & Goodman, 2006). Furthermore, increased awareness of concussion among medical personnel and the general public may improve reporting of head injury and may provide more accurate data on the prevalence.

Discussion and Summary

An estimated 300,000–3,800,000 sports-related concussions occur annually, suggesting that mTBI in the adolescent athlete is a common occurrence (Halstead & Walter, 2010; Levy, Ozgur, Berry, Aryan, & Apuzzo, 2004). Because serious and irreversible neurological deficits are possible after repeated concussions, a major public health issue clearly exists. Unfortunately, clearly defined clinical definitions and practice guidelines for a concussion remain poorly accepted throughout the medical community, contributing to poor public and professional awareness of this devastating and often undiagnosed injury. Compounding these issues is a lack of accepted structural deficits or biomarkers to definitively diagnose a concussion (McCrea et al., 2004; Streeter, 2011). Thus, concussion remains underdiagnosed, leaving adolescent athletes at a greater risk of subsequent head injuries and poor long-term outcomes (Buzzini & Guskiewicz, 2006; Grady, 2010; Guskiewicz et al., 2003; McCrea et al., 2003, 2004).

Future Directions

Research studies on the effects of concussion and development of CTE are desperately needed to define the clinical course of neurological dysfunction, including prospective studies to delineate the short-and long-term effects of concussions in the adolescent brain (Buzzini & Guskiewicz, 2006). Multiple guidelines and concussion grading systems exist to assess fitness to return to athlete competition in adults; however, these tests lack of sport-wide standardization and are not specific to the adolescent brain (Buzzini & Guskiewicz, 2006; Grindel et al., 2001). Improvements to these assessments, and education of nursing

and other medical professionals, including nonbiased adolescent-specific recommendations, are therefore needed to provide outstanding care of the young athletes, who may be the most vulnerable to the long-term consequences of a concussion.

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