The Short- and Long-term Effects of Sports-Related Concussions: A Literature Review

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Abstract

Concussions are one of the most common injuries in sports, particularly contact sports. Public interest in the effects of sports-related concussions has grown over the last 10 to 20 years, and policy changes have occurred as the result. The aim of this literature review was to identify the short- and long-term effects of sports-related concussions and consequently, the policy changes that have occurred in organized sports. Analysis of the literature suggests that sports-related concussions have had a significant impact on individuals in the short term, including academic performance after injury, as well as in the long term, putting them an increased risk for cognitive impairment, Alzheimer's disease (AD), and depression. More research is necessary to identify recent epidemiological data concerning sports-related concussion incidence, treatment, and prevention.

Introduction

Participation in organized sports is often encouraged for young people because of the social and physical health benefits it provides; however, many of the more popular sports carry a high risk of injury. Sports-related concussions account for a significant proportion of all sports injuries (5–9%), with an estimated 1 million to 4 million sports-related concussions sustained each year within the United States, as per the CDC. Although not all mild traumatic brain injuries (mTBIs) qualify as concussions, all concussions are considered mTBIs (1).

Full-contact sports, such as football, soccer, and ice hockey, are more likely to result in concussions compared to non-contact sports, such as volleyball and swimming (2). Research now indicates that most sports-related concussions sustained in men's sports are through player contact, whereas equipment or apparatus contact is the leading cause of those sustained in women's sports (3). Numerous studies have noted that axonal injury is a potential biological mechanism for mTBIs (4–5). Upon sustaining a concussive brain injury, rapid depolarization occurs due to the disruption of cell membranes and axonal stretching. The release of several neurotransmitters follows, and the reestablishment of ionic balances depletes energy stores and presents at the clinical level as post-concussive symptoms (5).

The 5th international conference on concussion in sport, held in Berlin in October of 2016, modified its previous definition of a sports-related concussion to include the consensus that the acute clinical signs and symptoms of such injury reflect more of a functional disturbance opposed to a structural injury that can be view using neuroimaging (6). Despite this decision, subsequent studies have continued to find strong evidence to support the use of several imaging techniques in identifying structural damage after mTBIs (7–8). The objectives of this review are to explore the short- and long-term effects of sports-related concussions and the policy changes in collegiate and professional sports organizations resulting from this growing body of knowledge.

Methods

An examination of the literature was conducted to identify the short- and long-term effects of concussions incurred from participation in organized sports. Potential articles were identified using Google Scholar, as well as from access granted through the Geisinger Commonwealth School of Medicine Library online. Keywords screened for included: sports + concussion, traumatic brain injury. The goal was to focus on new findings from articles published within the last 10 years that would build upon findings from five-year-old studies; however, articles published within the last 20 years were included to piece together a more complete picture.

Results

The short-term symptoms and effects of sports-related concussions

Most findings related to the short-term effects of sports-related concussions are from the adolescent to young-adult population, since youths are more frequently involved in organized sports compared to adults (2). Head impact exposure data collected from a single season of high school varsity football suggests that even when concussions are not clinically diagnosed, cumulative head impacts during this time period can still result in changes to the brain (9). Diffusion tensor imaging (DTI) has revealed widespread white matter microstructure changes in post-concussive adolescents up to two months after injury (10). One specific area of white matter that is more sensitive to loss of structural integrity due to sports-related concussions, as detected by DTI, is the area in the superior temporal lobe that contains projection fibers connecting the medial geniculate body of the thalamus to the primary auditory cortex (11). As such, severe damage to this area would likely translate into auditory or vestibular impairment, however, deficits in balance and cognition are not always observable immediately after or even up to 24 hours after a high-impact concussion (12). In contrast to these observations, it has also been claimed that trauma to the corpus callosum caused by falx cerebri displacement from lateral impacts may have a significant impact on an individual after a mTBI, however, evidence suggests that different impacts and mechanisms of injury can result in injury to many different brain structures (13).

High school athletes with a history of concussions are more than nine times more likely than athletes with no concussions to have multiple acute symptoms of concussion on the field immediately following an additional head impact (14). The most common symptoms of concussions include headaches and dizziness, and the same electrophysiological deficits have been found in both symptomatic and asymptomatic concussed athletes (1, 15). Tests of attention, concentration, processing speed, and mental flexibility produce worse, or impaired, results for youth athletes with a recent concussion compared to those either without or with a history of one previous but not recent concussion, demonstrating how the effects of sports-related concussions remain even after acute symptoms resolve. These same studies have also shown no distinction between youth athletes who have sustained a sports-related concussion within the last week and those who have a history of two or more previous concussions without current resulting physical or cognitive dysfunction (16).

The severity of a concussion, as studied in high school football, is not only determined by one force or the location of impact, but rather a combination of rotational acceleration, linear acceleration, and the location of impact, with “blindside” impacts producing the greatest risk of concussion (17). Although there is still debate about the precise pathophysiology of concussions, there is strong evidence supporting a window of recovery in which a subsequent mTBI will cumulatively affect the metabolic depression observed in the brain (18). While the use of mouthguards reduces the overall risk of orofacial injuries, their effect on concussion incidence is not as strong (19). Examination of brains from teenage athletes who died between one day and four months after sustaining impact concussions in contact sports revealed numerous post-traumatic pathologies consistent with microvascular injury, blood-brain barrier (BBB) disruption, and secondary neuroinflammation, with one case meeting the diagnosis criteria for early-stage chronic traumatic encephalopathy (CTE) (20). This finding is especially significant since CTE can only be diagnosed by autopsy after death, and as a result, is more often associated with much older adults.

For many years, studies of sports-related concussions focused more on male athletes than female athletes, however, in recent years, studies have expanded to look at both populations. Female athletes experience higher rates of sports-related concussions than male athletes when looking at sports that have teams for both sexes (21). Additionally, female athletes have longer recovery times (21–22). Despite strong evidence supporting these sex-linked differences, the explanation has proven much more diverse. One proposed theory is that estrogen has a neuroprotective effect in males but not in females; however, there is still a need to explore this theory further (23).

The long-term effects of sports-related concussions

There is a considerable body of evidence to support that the effects of sports-related concussions also do not resolve with the conclusion of a person’s involvement in organized sports. Synaptic plasticity is compromised in athletes with a history of multiple sports-related concussions and the risk for cognitive impairment increases with each cumulative concussion after a certain threshold (24–25). As a result, an individual who sustains multiple concussions in their youth is at a significant risk for long-term damage. In addition, the NCAA Concussion Study found that collegiate athletes with a history of at least three concussions had a risk of future concussions three times greater than athletes with no previous concussions (26). The more concussions an individual sustains, the more likely they are to both sustain additional hits and increase the severity of their long-term impact.

Younger age of first exposure to American football correlates with worse executive function and behavioral regulation later in life, as well as increased odds for clinical depression (27). Similarly, the number of sports-related concussions was determined to be a good predictor for symptoms of common mental disorders later in life (28). However, other data shows the cognitive and motor system changes observed in retired athletes who sustained their last sports-related concussion more than 30 years ago were very similar to those found in athletes 3 years post-concussion (29). Another study found that regardless of the time since the last concussion was sustained, the duration of the cortical silent period under transcranial magnetic stimulation (TMS) was significantly prolonged in athletes with a history of concussions, signifying an inhibition of motor cortex neurons (30). This increase in intracortical inhibition disrupts the normal balance needed for typical function. Athletes with a history of multiple sports-related concussions were measured to have significantly increased GABA-induced intracortical inhibition, which correlated with their degree of altered plasticity (24).

Data from retired professional football players with a history of concussion, especially recurrent concussion, suggest this type of TBI may be a risk factor for late-life memory impairment and AD (31). Not only is there an increased prevalence of mild cognitive impairment (MCI) and dementia among aging retired NFL players with cognitive deficits compared to players without cognitive deficits, but there is an increase in the prevalence of depression correlated with white matter dysfunction in those retired players compared to the same age group in the general population (32–33).

The total structural impact of sports-related concussions on the brain often cannot be evaluated until after death. Postmortem evaluation of brains from former NFL players revealed nearly all the samples studied had frequently severe CTE pathology (34). The changes in white matter associated with combined aging and sports-related concussions include anomalies affecting major inter- and intra-hemispheric, as well as projection fiber tracts. The degenerative effects of aging are likely increased by the structural injuries of sports-related concussions (35). Retired athletes with a history of sports-related concussions have previously been found to have enlarged ventricles compared to those with no concussions, suggesting an impairment in cerebrospinal fluid (CSF) circulation (36).

Policy changes in response to these effects

It is now widely accepted that sports-related concussions can have detrimental effects, even if those specific changes are still being understood. The first concussion statute, the Lystedt Law, was enacted in 2009 because of the unfortunate and catastrophic injury sustained by a middle school football player allowed to return to play after he had a concussion earlier in the game (37). Over the next 5 years, similar laws were implemented in all U.S. states (37). More recently, there has been considerable focus on implementing concussion policies at the collegiate and professional levels.

The NCAA enacted its Concussion Policy and Legislation in 2010, requiring all member institutions to have a concussion management plan (38). The Division I Concussion Safety Review Process was initiated in 2015 and requires member schools to submit their concussion safety protocol for review by a committee (39). While athletes might benefit more from the implementation of a single concussion policy across all NCAA member teams or more consistency in the contents of the various protocols, there is currently more of a focus on ensuring all schools have a plan in place.

The NBA concussion protocol, implemented in 2011, must be followed by all teams and is enforced by the league. Players, coaches, and medical staff are provided with concussion education and players who have sustained a concussion are required to meet several criteria before returning to play. These criteria include presenting without concussion-related symptoms, evaluation by a physician, and completion of a stepwise exercise protocol without the return of symptoms (40).

The NFL concussion protocol was implemented in 2009, updated in 2014, and similar to the NBA, all NFL teams must follow the overarching rules enforced by the league (41). The NFL has reported an overall decline in concussion rates over the last several seasons (42). Despite initial evidence supporting the efficacy of these concussion reduction strategies, there is still a strong need for updated data on the incidence of sports-related concussions across all collegiate and professional sports to draw conclusions about the efficacy of these policies.

Conclusion

The symptoms of sports-related concussions present during the acute phase of injury, however, even after these resolve, chronic or long-term effects may develop. The severity of long-term effects increases with repeated head impacts, and the risk of future impacts increases with each successive injury. While the immediate impacts of a sports-related concussion mostly affect a person's physical presentation or cognition temporarily, a history of sports-related concussions puts a former athlete at higher risk for AD and depression later in life. Collegiate and professional sports organizations, such as the NCAA, NBA, and NFL, have implemented new concussion protocols or policies over the last several years, but it remains to be seen whether enough has been done to improve or mitigate not only the short-term, but also the long-term effects of sports-related concussions. To determine the best course of treatment, more research is necessary to identify the specific physiological mechanisms of sports-related concussions. For now, the best strategy is prevention.

Disclosures

The author has no relevant financial or other competing interests to disclose.

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