

CHRONIC TRAUMATIC ENCEPHALOPATHY AND THE FUTURE OF FOOTBALL

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Abstract

Concussions and non-fatal Traumatic Brain Injuries (TBIs) have gained significant media and scientific attention after recent research has continuously shown these injuries to be cognitively damaging, and possibly fatal. Some long-term impairment from TBIs can now be attributed to Chronic Traumatic Encephalopathy (CTE), which develops at least in part because of TBIs. Significant overlap between CTE and the neurodegenerative process of Alzheimer's disease (AD) has been identified, such as the deposit of tau protein. The National Football League (NFL) is at the center of this controversy because of the rough, high-impact contact and hitting that is essential to the sport of football. The NFL is now giving non-fatal TBIs and concussions more attention after combatting a lawsuit filed by former players experiencing long-term cognitive deficiencies. While research to better understand the pathology of CTE continues, future programs, such as Return to Play (RTP) guidelines, must more effectively prevent and treat concussions in professional athletes, and especially in youth athletes.

Introduction

Concussions are becoming a major publicity issue for the NFL, as research prompts more parents to question whether or not their children should play football. The league is assuring these worried parents that football is safe; however, the issue is not that simple. Advances have been made in recent years in the study of concussions and their potential long term consequences. It is known that a serious condition exists as a result of head injuries, called Chronic Traumatic Encephalopathy, or CTE. Some of its symptoms mimic those of neurological disorders. This alarming reality has incited media attention and a push for change in the NFL. The league has responded by settling their lawsuit and making minor changes to their rulebooks. This paper will review the most current literature about CTE and existing policies for concussion prevention, discuss the future, and make suggestions for safer football.

Concussion and Traumatic Brain Injury (TBI)

Concussions and mild TBIs are one in the same; there is no difference between the terms, other than the fact that "concussion" is more commonly used in sports (Perskind, Brody, Cernak, McKee, & Ruff, 2013). Concussion has been discussed at three meetings of the International Conference on Concussion in Sport. The third conference was held in Zurich in November 2008, where concussion was defined as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (McCroy et al., 2009). These such forces are often a result of a hard hit to the head, a common practice in American football. The immediate symptoms of a concussion are often headache, faintness, confusion, mood change, sleepiness, and unconsciousness (Saffary, Chin, & Cantu, 2012).

The Centers for Disease Control and Prevention estimates that over 207,000 people are treated for sports and recreation-related (SR-related) non-fatal TBIs in hospital emergency departments each year. Football accounted for over 22,000 of these SR-related TBIs, the organized sport with the highest number of

TBIs occurring (CDC, 2007). Over 64% of the total SR-related TBIs occurred within the age group of 5-18, despite more adults participating in recreation and sports than children (CDC, 2007).

According to the NFL Injury Report, 147 total concussions were reported in the 2013 season. During each week of play, at least one player was taken off the field because of a head injury or concussion (NFL, 2013). In a study by Solomon & Haase, data was collected from 159 NFL players about concussions and demographics, which led to insights about occurrence of concussions in a typical player's career in the NFL. The number of reported concussions was positively correlated with participants' age. The expected number of concussions increased by 9.1% for each one-year increase in age. Therefore, the authors expected the number of concussions in an NFL player to double from age 22 to age 30 (Solomon & Haase, 2008).

Athletes who experience a concussion should seek immediate medical attention. Researchers have highly suggested that athletes keep a detailed clinical history of their concussions and treatments (McCroy et al., 2009). Although short-term symptoms and effects of concussion are widely known, the long-term consequences are just recently being unfolded. It is not firmly established how many concussions must occur before long-term damage begins. However, individuals who experience one concussion closely followed by another (within weeks) may develop second-impact syndrome (SIS) (Cobb & Battin, 2004). SIS is very serious and can occur if the first concussion does not heal before a second concussion occurs. This incidence causes the brain to swell rapidly, which in turn causes widespread damage. Although SIS is rare, youth are particularly susceptible, and the result is typically fatal (Cobb & Battin, 2004).

Concussion Prevention and Treatment in the NFL

In 2011, 75 retired NFL players filed a worker's compensation complaint against the NFL, accusing the league of negligence regarding their suffered TBIs (Gust, 2012). The players claimed that the league knew about the dangers of concussions and the relationship to CTE, but failed to protect its players from the damage. This lawsuit was consolidated with others filed by thousands of other former players suffering from cognitive impairment, headaches, and depression, amongst other serious symptoms. It was settled in 2013 when approximately 4,500 players agreed to a \$765 million payout to provide compensation for each player and fund future research (Feder, 2013). In January 2014, the judge overseeing this settlement rejected it. One of her reasons for this was that she did not think \$765 million was enough to cover the damages (Belson, 2014).

According to the NFL's website, helmets have always been worn by their players, dating back to the 1920s. However, at the league's inception in that decade, helmets were no more than soft leather hats. In 1939, the John T. Riddell Company created the first plastic helmet, but it wasn't until 1943 that the NFL mandated the use of a helmet, and not until 1949 that the league officially adopted the Riddell design. In the years following, padding, then air bladders, were added to the inside of helmets to soften the impact. The first polycarbonate helmet emerged in 1986, and this material is still used today. The most significant efforts to increase awareness and safety were made in the 2000s, when Riddell made the Revolution helmet (NFL, 2012).

In 2011, Battle Sports Science developed their Impact Indicator technology. NFL players using this product wear a chinstrap embedded with sensors and software used to detect Head Injury Criterion (HIC). An impact measured at 240 HIC indicates a 50% probability of concussion, and will turn the green light on the chinstrap to a red light. If another player, a coach, or an official sees a red light, the player will be taken off the field for evaluation (Battle Sports Science).

Although the Impact Indicator is a clear advancement from the 1920s safety equipment, critics of this product fear that it may give a false sense of security. This device does not prevent or diagnose concussions. It is intended to curb the incidence of TBI and give an early warning (Battle Sports Science). However, players may blindly trust the green light on their device, rather than listening to their instincts about injuries. David Halstead, a sports impact researcher, argues that whiplash can cause TBI, which would go completely undetected by the chinstrap device (Goldman, 2011). The same false sense of security described by Halstead

regarding the Impact Indicator can also apply to the use of helmets. Risk compensation phenomenon suggests that athletes wearing a helmet play more dangerously, based on the mistaken belief that helmets protect their heads from all injury (Hagel & Meuwisse, 2004).

The NFL has made recent attempts at concussion prevention by adding and changing some rules in the game, as outlined on their website (2012). Defenseless players are not to be hit above the shoulders. The league defines a defenseless player as a player who does not have time to position himself to brace for impact. Before this change, players were allowed to hit another player as soon as the opponent's feet touched the ground. The NFL has also made it illegal to position a player directly across from the snapper during a field-goal attempt, because the snapper is considered to be in a defenseless position. Additionally, if a player loses his helmet, the ongoing play is immediately stopped (NFL, 2012).

Stricter Return to Play (RTP) procedures for concussion sufferers have recently been created by the NFL. Evaluations will always be made before players are allowed to play their next game. Independent neurologists will be consulted each time a player suffers a concussion (NFL, 2012) perhaps because team doctors may present a bias towards their players' readiness to play for their team.

Concussion Prevention and Treatment in Youth Football

Although the NFL is the only professional football league in the United States, high school football players are the largest group of people playing the sport in the country (Johnson, 2012). For educational and health reasons, just as much research focus should be placed on youth SR-related concussions as it is for the NFL.

Helmet technology has indicated that one high school player can experience about 900 head impacts per season, many of which are subconcussive (Broglio et al., 2011). A study of high school football players by Talavage et al. (2010) revealed that traditional methods for assessing concussions and smaller impacts may be insufficient. They discovered a category of players who did not report suffering from a concussion or its symptoms, but still experienced significant cognitive impairments such as poor visual working memory. This indicates that even the inevitable nonconcussive bumps to the head, if repetitive, can cause neurocognitive damage (Talavage et al., 2010). Much of this damage can easily go undetected if proper prevention methods aren't in place.

Similarly to the NFL, many states and youth football organizations implement RTP guidelines as a means of concussion prevention. The first law mandating RTP guidelines was called the Lystedt Law, named for a high school football player who became permanently disabled from SIS (Johnson, 2012). Although RTP methods are an improvement from a complete lack of guidelines, these methods most likely are not allowing a concussed player to fully recover before returning.

Chronic Traumatic Encephalopathy

Pathology

In 1928, Martland coined the term "punch drunk", referring to cognitive impairments and gait problems exhibited in boxers (McKee et al., 2009). The first official term for the progressive neurological deterioration now known as CTE was "dementia pugilistica", by Millspough in 1937 (McKee et al., 2009). There is a growing number of confirmed cases of CTE, all identified post-mortem. There is also a growing number of suspected cases of CTE. As of 2012, there were 68 confirmed cases (Baugh et al., 2012). TBI is the most well-established cause of CTE (McKee et al., 2009; Shively, Scher, Perl, & Diaz-Arrastia, 2012). Biological factors such as genetics may play a role, but have not been as well-established.

Encephalopathy is a broad term referring to brain disease, and CTE is a more narrow diagnosis that distinguishes repetitive trauma as a cause. Other types of encephalopathy cases can be attributed to various reasons, including infections, drugs, toxins, or anoxia (*Encephalopathy causes*, 2012). The neuropathology of CTE is still being researched, but experts have determined a few clear signs of CTE in autopsy, mainly

cerebral atrophy. More specific neuropathological signs include enlarged lateral ventricles, atrophied fornices, a thinned corpus callosum, and scarring on the cerebellum (McKee et al., 2009). Notably, Neurofibrillary Tangles (NFTs), misfolded tau proteins, are accumulated as a result of CTE. The tau protein build-up makes it difficult for nerve cells to make connections with other nerve cells, which will eventually kill the cells (McKee et al., 2009; Omalu, Hamilton, Kambouh, DeKosky, & Bailes, 2010; Shively et al., 2012).

The pathology of CTE has been compared to neurodegenerative diseases such as Alzheimer's disease (AD), which is the sixth leading cause of death in the United States (Hoyert & Xu, 2011). There are several similarities between CTE and AD in both the brain and in clinical manifestation. NFTs and the deposit of tau proteins in the brain has been continuously observed in both diseases, and is considered a primary indication of AD (McKee et al., 2009; Perskind et al., 2013). Additionally, the brain atrophies in the same areas in CTE and AD: the frontal, temporal, and parietal lobes, which function in organization, communication, reading, and writing (Rabins, 2011). Although pathology and symptoms are similar, CTE is known to progress more slowly and the patterns of atrophy are distinct (Perskind et al., 2013).

CTE Clinical Symptoms and Case Study

Three stages of the clinical progression of CTE symptoms were described by Corsellis, Bruton, & Freeman-Browne (1973). The first stage is primarily associated with psychotic symptoms, including emotional disturbances, depression, and mood swings. This is supported by findings in a study by Guskiewicz et al. (2007) which suggest an increased risk of clinical depression as a result of repetitive SR-related head injuries. The second stage is characterized by memory loss, social instability, erratic behavior, and the first signs of Parkinsonism. Significant cognitive abnormalities, dementia, and severe manifestations of Parkinsonism, including speech and gait problems, appear during the third stage (Corsellis, Bruton, & Freeman-Browne, 1973).

Each case of CTE is unique. To understand the broad range of symptoms, researchers complete case studies. Dr. Ann McKee of Boston University Medical School has been actively documenting case studies since she reported observations of her first CTE brain in 2009. She examined the brain of former NFL linebacker John Grimsley, who died at the age of 45 from an accidental self-inflicted gunshot wound. His wife stated that he suffered three concussions in college and eight concussions in his NFL career, but only one was documented. His cognitive decline began at age 40, when his short term memory, concentration, organization, ability to juggle tasks, attention, planning, problem solving, and judgment all suffered. He would ask questions repeatedly and ask to rent a movie he had already seen recently. John had trouble shopping alone and preparing his tax information. He developed severe anger and hostility and began to consume more alcohol at the end of his life (McKee et al., 2009).

McKee prepares and stained slides of brains post-mortem to compare them. She is able to identify areas of NFTs by staining the tangles brown. John Grimsley's brain showed severe signs of atrophy compared to a normal brain. There were massive numbers of NFTs specific to CTE, so many that they could be seen on slides without a microscope. His frontal lobes, amygdala, and hippocampus were dramatically changed as well. McKee found this damage to be completely abnormal for a 45 year old brain and attributes all of the damage to the concussions John suffered.

Discussion

Why Play?

Because of the growing literature examining the dangers of concussions, it is interesting to note the reasons people continue to put themselves at risk for dementia and premature death. The answers may lie within social psychology. American society enjoys football in-part because it enjoys violence (Anderson & Kian,

2012). Additionally, masculinity plays a large part in handling injuries and risk or injury. Football players may begin to hear the command, “be a man” at a young age. There is a social pressure placed on boys and men to play football to sustain masculinity. Furthermore, it may not be “manly” to remove oneself from the game because of injury. Players can be expected to ignore their pain and overcome it, especially a closed head injury, which does not show obvious outward symptoms to onlookers. It appears that John Grimsley did just that, because the vast majority of his concussions were not reported.

Fortunately, as the discussion about CTE becomes more prevalent in the NFL, there have been instances of players taking the risk seriously. A conversation between two NFL teammates, Aaron Rodgers and Donald Driver, demonstrates this. Rodgers hit his head badly in a regular season game in 2010. He seriously considered going back into the game, but Driver was quoted reminding him that his life is more important than a game. Rodgers sat out, his team lost the game, he was diagnosed with a concussion, and he remained out for the next game. After his full recovery, his team won the Superbowl, and he was named most valuable player (Anderson & Kian, 2012). This is a success story of a player placing his health before victory and self-sacrifice. Hopefully, Rodgers has set an example which all players might follow.

The Future of TBIs and Football

Further empirical research about concussions and CTE should be conducted to establish more conclusive evidence about the pathology of the condition. It is still unknown how severe or how repetitive a TBI must be to cause symptoms of CTE. Additionally, as of right now, CTE can only be diagnosed in an autopsy; researchers must be able to understand distinctions about the disease to identify it in living persons. These distinctions should be developed alongside clear criteria for CTE and its various stages. Neurologists working with players should improve on identifying concussions more effectively, and understanding proper recovery time and early warnings of CTE.

The NFL understands that there are gaps in the research, and as outlined in its settlement, is cooperating by funding several projects to answer some of these questions. One such project will be led by Dr. Jeffrey Ojemann at Seattle Children’s Hospital. His researchers will administer MRIs to at least 10 high school football players following the experiences of their first concussions. Levels of gamma-aminobutyric acid, a chemical in the brain useful for cognition and movement, will be monitored (Anderson, 2013 & Belson, 2013). This research will be useful for better prevention and treatment in both youth and professional football.

Although it is beneficial that the NFL is funding future research, money may not be enough to resolve their current challenges with the growing problem of concussions. Changes should be made to the actual safety of the game of football, rather than just the post-concussion protocol. Because of the growing research, football is at a crossroads, and if CTE research can undoubtedly verify the dangers for parents, the sport could one day cease to exist as it does today. It is evident that football is currently too highly valued in American culture to eliminate it entirely. Thus, the benefits of change should be considered.

Youth football, even at a high school level, may one day eliminate tackling. It is dangerous and can likely result in health consequences later in life. Tag and flag football can replace the tackling without changing more than one aspect of the sport. This transition could be difficult for those who do not know or understand the serious consequences of concussions. However, if measures are not taken, school officials may find themselves responsible for serious injuries to their students, who primarily attend school for their education, not football.

It would be ideal to eliminate all tackling above the shoulders in the NFL. However, some have argued that this would cause an increase in bodily injuries such as to the anterior cruciate ligament, referred to as the ACL, in the knee. In order to preserve the way the game is played, the RTP guidelines should be dramatically altered. A more effective retirement package may be created to aid players who have had several concussions and need to stop playing. Independent neurologists should do weekly assessments of all players, regardless of whether or not the player has complained of symptoms. These assessments would

prevent any player from attempting to hide a concussion in order to avoid missing the next game. Although a player may consider it their prerogative to have as many concussions as they would like, it may be in the best interest of the NFL to implement these rules to avoid further lawsuits. The NFL is an employer and should try its best to protect its employees from harm.

The NFL would also benefit from implementing a mandatory educational system for their players about concussions. It would go over the most recent research about how concussions occur, why they can cause long term damage, and what can be done about them. The program should remind players that their helmets do not make them invincible from all injury. This education could make players and their families more likely to understand and comply with RTP guidelines.

Summary and Conclusion

As outlined by research over several years' time, including ongoing projects at highly advanced laboratories, concussions are not to be taken lightly. Second Impact Syndrome is one deadly consequence of concussions, and CTE is another. Yet, CTE is not taken as seriously as it should be, perhaps because it is difficult for people to make decisions that impact their future lives. Football players can be playing in the best game of their career one day, and within a few years, find themselves confused, impaired, and depressed. Family members of people with CTE can attest to the seriousness of the issue, and the strong link with football head injuries.

Trying to alter human behavior and health decision making is one of public health's biggest challenges. Now is an urgent time for the prevention of these unnecessary concussion deaths in professional sports. Youth players look up to the professionals, and it would be wise of NFL players to value their personal health so that the kids do as well. The research on CTE has progressed to the point where it is no longer simply a hunch; concussions are deadly.

Improving the safety of football in regards to head injuries will take time, as will the research on CTE. The overall attitude about the game has to change, from youth football all the way through to professional football. If educators begin by teaching the youth, by the time these young players reach the NFL, they will have had years of serious discussions about concussions. Hopefully, this educated generation of players will value their brains more than the sport of football. Sports are healthy and beneficial when played intelligently, so optimistically, football players in America can migrate in that direction in order live long, healthy lives after their careers.

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