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Effects of Football-related Concussions on Cognitive Function

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Abstract

In literature review, I examine the current research on football-related concussions and their effects on cognitive performance. A concussion is defined as a blow to the head which results in injury to the brain. Concussions are often difficult to diagnose as they do not leave any radiological variation that can be measured via MRI. Concussions were first observed in boxing during the 1920s, but research on concussions has been slow to gain momentum until recently. As empirical research has gained prominence, both short- and long-term effects of concussions have come to light. Significant cognitive effects of concussions include depression, links to neurodegenerative diseases, memory impairment, and decreases in cerebral blood flow (Didehbani, Cullum, Mansinghani, Conover, & Hart, 2013; Guskiewicz et al., 2007; Maugans, Farley, Altaye, Leach, & Cecil, 2012). The improvements being made in sports to help

fix these problems include changing rules for greater safety, improved concussion assessment techniques, and better safety equipment (Halpin, 2013; Lear & Hoang, 2012; Linendoll, 2013). The potential impacts of this concussion research on football are still largely unknown, but considering the popularity of the sport, the impacts will likely be insignificant.

Keywords: concussion, football, TBI, brain injury

A concussion is a type of traumatic brain injury (TBI). They occur when a bump or blow to the head is received and they can affect the way the brain functions. Concussions can be difficult to diagnose, as no radiological variations (such as those that would be seen in an MRI) are typically found in subjects who have sustained a concussion (McCrea, Perrine, Niogi, & Hartl, 2013; Mitka, 2007) Because of this lack of measurable damage, concussions are more difficult to define than most other types of brain injury (McCrea et al., 2013). The symptoms of concussions are varied, but some of the most common are brief retrograde amnesia (difficulty remembering events immediately prior to the injury), posttraumatic amnesia (difficulty recalling events immediately after the injury), difficulty maintaining balance, and difficulty focusing the eyes (Lau, Kontos, Collins, Mucha, & Lovell, 2011; McCrea et al., 2013). Concussions can also include loss of consciousness; however, even when a person remains conscious, the concussion may still be damaging. Additionally, studies have shown that athletes who have suffered one concussion are more likely to suffer another in the future; the greatest period of risk being within 60 days of the first incident (McCrea et al., 2013). This increased risk is an important factor when considering recovery times for athletes who

receive concussions. However, like most injuries, the severity of concussions is something that doctors and psychologists learned over a long period of time, rather than all at once.

Concussion-like symptoms were first observed in professional boxers in 1928 by Harrison Martland (McCrory, 2011). Martland observed a "punch-drunk" state when boxers had suffered severe blows to the head. These boxers seemed to be confused about where they were, they had difficulty balancing, and their movements were jerky and hesitant (McCrory, 2011). These symptoms later became known as *dementia pugilistica*, a type of chronic traumatic encephalopathy (CTE). CTEs are currently suspected to be a direct result of multiple concussions; however, a direct causal relationship has not yet been determined (Tremblay et al., 2013). In recent years, these symptoms were noticed in other sports, especially those with a high level of physical contact. Experts estimate that 1.6 – 3.8 million Americans suffer a mild TBI per year, with up to 20–30% of these occurring as a direct result of sports (Lincoln et al., 2011; McCrea et al., 2013). Unfortunately, difficulties arise when trying to obtain a better estimation, as many concussive events go unreported due to the work ethic of many athletes and a desire to continue play in a competitive atmosphere (Mitka, 2007). Athletics provide such a notoriously competitive environment that it can be difficult for athletes to report an injury that could affect their playing career. Players may even knowingly risk long-term damage because of the allure of multi-million dollar professional contracts in the National Football League (NFL).

Because of the dangers of concussions, both reported and unreported, efforts have been made to reduce the number of concussions suffered by athletes. Many sports leagues have implemented measures for diagnosis and assessment to lower concussion risks for their athletes. The usefulness of these measures is still under discussion, and currently no universally accepted system exists (Schneiders, Sullivan, Gray, Hammond-Tooke, & McCrory, 2010). The most commonly used system is the SCAT-2, or Sport-Concussion Assessment Tool-2, which has been adopted by most professional sports leagues and many high school teams (McCrea et al., 2013). This system is actually a conglomeration of several other systems that have proven effective over the years, such as the Glasgow Coma Scale, the Standardized Assessment of Concussion and the Balance Error Scoring System (McCrea et al., 2013). Because it contains so many different analysis tools, the SCAT-2 test is

considered to be the most comprehensive of the common concussion tests and is continually being revised and improved (McCrea, et al., 2013). While the SCAT-2 is accepted by most athletic programs, there are still many other viable and effective concussion assessment tools being used.

The SCAT-2 test not only helps diagnose concussions, but also helps doctors and coaches estimate the potential damage of those concussions. The effects of TBIs vary greatly with severity of the blow, as well as the number of concussive events an athlete has experienced (DeBeaumont, Henry, & Gosselin, 2012). Athletes are able to recover rather quickly from a single concussion, but begin to risk more permanent damage after sustaining multiple concussions (DeBeaumont et al., 2012). Unsurprisingly, certain sports have a higher rate of concussions than others, with football accounting for up to 63% of sports-related concussions (DeBeaumont et al., 2012; Mitka, 2007). With such potential danger to athletes, further research must be conducted to increase our knowledge of concussions.

While the long-term effects of concussions are still being researched, the medical community universally agrees that these injuries can cause permanent brain damage. This damage is especially apparent in an athlete's later years

(Tremblay et al., 2013). Sports programs around the nation have been attempting to minimize the danger of concussions for years, though the awareness of these hazards has been increasing only recently (DeBeaumont et al., 2012; McCrea et al., 2013; McCrory, 2011). It was not until 2009 that the NFL began requiring players to be cleared by a physician before returning to play after a concussion, and many other sports associations were similarly slow to react (Didehbani et al., 2013). The effects of concussions are both very real and very serious. They lead to long-term cognitive deficiencies, which are more visible as athletes increase in age and the number of concussions suffered (Guskiewicz et al., 2007; McCrea et al., 2013). These deficiencies can include depression, greater risks of neurodegenerative diseases such as Alzheimer's, and memory impairment, a contributing factor of which may be reduced blood flow to the brain (Didehbani et al., 2013; Guskiewicz et al., 2007; Maugans, Farley, Altaye, Leach, & Cecil, 2012). This decreased blood flow to the brain is thought to be one of the primary contributors to many of the effects of concussions.

As researchers began to see how severely detrimental concussions can be, they also began to look at how they can affect the brain in the long-term. Information from the Center for Disease Control and Prevention (CDC) shows that

in the year 2000, medical costs of TBIs in America were nearly $60 billion (as cited in McCrea et al., 2013). Concussions account for a significant 75% of this total cost (McCrea et al., 2013). The cost is greater when considering the health concerns of TBI victims. Until the last 5–10 years, most research on the long-term effects of concussions focused on the most severe cases, while overlooking the potential damage of multiple, mild concussions (Guskiewicz et al., 2007). Awareness of these mild concussions is increasing, and more medical researchers continue to conduct studies that shed greater light on the subject. Additionally, research has been done which shows that after receiving a mild concussion, 80–90% of athletes are able to recover and be symptom-free after a period of just 10–14 days (Didehbani et al., 2013; McCrea et al., 2013). However, the recovery period is often prolonged when the victim is younger (early teens) or when the victim has sustained multiple concussions. This "recovery" merely includes the visible, manifest symptoms of concussions, and not the energy-deprived state of the brain discussed later. In this review I will first treat the cognitive deficiencies linked to concussion, and then the improvements that have been made to help address these problems.

Cognitive Effects

Concussions have been linked to several prominent cognitive problems. Additional studies are discovering more regarding these effects, their severity, and some potentially linked problems. The cognitive effects I address in this literature review are depression, links to neurodegenerative diseases, memory impairment, and decreased cerebral blood flow.

Depression

Depression is one of the most well-documented and researched long-term effects of concussions. These symptoms first came to light after the suicide of several prominent, retired athletes (Didehbani et al., 2013). Research conducted in 2007 showed that retired NFL players who have sustained three or more concussions are three times more likely to suffer from depression than athletes who have never had a concussion, while those who have had one or two concussions were 1.5 times more likely to suffer from depression (Guskiewicz et al., 2007). The researchers also suggested that this trend is not specific to the NFL, but can be applied across all sports where concussions are a risk. Because these symptoms have been discovered in retired athletes, it is possible that many current athletes continue to play after receiving concussions because they may not

realize the severity of the concussions' consequences in their later quality of life. Even with education regarding the severity of concussions, players may decide that the money and fame that the NFL promises is worth the risk.

Studies have shown that brief periods of depression can follow a concussion, but the severity of the depression is nowhere near the level that has been measured later in life (Guskiewicz et al., 2007). The diagnosis of depression is serious enough on its own, but even more serious is that 16.7% of the athletes surveyed by Didehbani et al. (2013) expressed the presence of suicidal thoughts and desires. This is a substantial deviation from the norm—research on suicide in the general population suggests that about 3.7% of the adult U.S. population suffers from suicidal ideation (Crosby et al., 2011). Researchers postulate that these depressive symptoms are due to the lesions that can be sustained by the brain from severe (or multiple mild) concussions (Guskiewicz et al., 2007). While depression and suicidal thoughts are a serious cause for alarm, researchers have also studied the potential link of these symptoms to other serious diseases.

Neurodegenerative Disease

Studies have also shown that TBIs are a potential risk factor for the manifestation of several neurodegenerative disorders, which include Alzheimer's disease and Parkinson's disease (Guskiewicz et al., 2007). Clinically diagnosed depression is not common among Alzheimer's patients; however, having a depressed mood is common preceding the onset of Alzheimer's. Additionally, researchers of one study believe that concussions may not be a cause of these disorders, but simply cause earlier or more severe manifestations of them (Guskiewicz et al., 2007). While the links between concussions and neurodegenerative disease have been approached, little additional research has been done.

Memory Impairment

Depression was one of the first discovered long-term effects of TBI, but many new cognitive dysfunctions have been uncovered or better understood within the last 10 years of research. Guskiewiczet al. (2007), in addition to finding a strong correlation between concussions and depression, also found that many former football players suffer mild-to-severe memory impairment in their later lives. The study focused on 2552 former football players, with 1513 responding to the questionnaire on concussion history. Of those 1513 responses, 58% of players reported having sustained one or two concussions, and 34% reported having three or more concussions. Of the players with one or two

concussions, 11% (102 players) reported significant memory loss, and of those with three or more concussions, 31% (185 players) reported memory problems. While this data is based on the players' perception of their injuries, the relationship it implies is a cause for concern. Research in this area of memory loss is continually being done, though much of this research is performed outside the realm of former athletes.

Decreased Cerebral Blood Flow

A recent study published in the American Academy of Pediatrics' journal shows a possible cause of these cognitive issues (Maugans et al., 2012). Children aged 11 to 15 years were studied at various stages after receiving a concussion and the results showed a decrease in volume of cerebral blood flow after sustaining a concussion (Heger, 2008; Maugans et al., 2012). The patients were studied within 72 hours of a concussion, 14 days after, and 30 days or more after the blow (Maugans et al., 2012). The control, or normal amount of blood flow to the brain, is 48 mL per minute, while those who have suffered a concussion within 72 hours decreased to 38 mL of blood flow per minute, without any discernible damage visible to an MRI (Maugans et al., 2012). This is a decrease of over 20% in the amount of blood the brain is receiving.

These effects are not permanent. The study shows that 27% of the patients were recovering toward the normal values after 14 days, and 64% after 30 days (Maugans et al., 2012). However, the study only included a very small sample size (N=9) and was conducted on children in a very specific age group. Additional studies in this category would be beneficial in discovering whether these effects differ based on age of the victims or their stage of mental development. Are the effects greater on a child whose brain has not fully developed? Or is it better if the concussion is suffered by a child who can recover more quickly than someone older? Also, are these negative effects of concussions caused by this decreased blood flow, or are they caused by additional, unknown damage? These questions could be answered with further research and help increase understanding of the effects of concussions on cerebral blood flow.

Improvements

As researchers continue to learn more about how concussions affect the brain, sports programs and companies continue to try to prevent concussive injury. Various methods exist to help reduce the number of concussions suffered by athletes. The most prominent of these ways include the implementation of safety-oriented rules,

construction of adequate concussion assessment tools, and creation of better safety equipment.

Rule Changes

While safety standards have been implemented slowly over the years, important improvements have been made. In 2013, the NCAA Football Rules Committee implemented a new rule in efforts to help improve safety of the players. The rule stipulates ejection of players who lead a tackle with their heads against a defenseless player (Halpin, 2013). This rule has been put in place in hopes of reducing the number of injuries of all kinds, but especially head injuries (Halpin, 2013). While it has sparked a large amount of controversy, the rule is well-intended and an important step towards making a highly dangerous sport slightly less so. Staples (2013), a well-known sports columnist, believes that the Rules Committee has not just the opportunity, but the obligation to reform the sport, regardless of the controversy it may spark. Staples (2013) goes so far as to say that the sport needs saving from itself, or people will stop participating in it. Additionally, other rule changes have been made, including moving kickoffs up five yards in efforts to reduce the number of statistically dangerous kickoff returns.

Assessment Tools

When the rules that have been put into place to help prevent TBIs fail and an athlete suffers a concussion, guidelines exist that programs must follow before allowing the player to return. The first true system of guidelines was put in place in 1997 by the American Academy of Neurology (Lear & Hoang, 2012). Unfortunately, every case and every player's brain are different, and these one-size-fits-all style guidelines are now considered obsolete; a more individualized approach is needed (Lear & Hoang, 2012).

Today, the most commonly used system is the SCAT-2 system, which uses several different grading systems to address the needs of each individual athlete (McCrea et al., 2013). Coaches and team medical staff use these guidelines to diagnose their players and assess how long their athlete will be unable to play. The length of time a player must wait before returning to play is something that is still under debate by many medical professionals. Unsurprisingly, it too falls under the category of individual adaptation for each player and each case.

Research done by Lear & Hoang (2012) has made strides in helping coaches properly estimate and address the needs of each player's recovery. The reason returning to play is such an important issue to address is the susceptibility of

a concussed player to receive a second concussion. Two primary reasons have been postulated as to why someone who has received a concussion is more likely to sustain another (Heger, 2008). Some of the effects of a concussion are slower reaction times and decreased attention ability (caused by tiny tears in the white matter of the brain), making fast-paced sports much more dangerous due to the player's inability to properly react. The second reason is related to brain chemistry. The sudden movement and acceleration of the brain within the cranium causes the brain's cells to fire, which can use a large amount of energy. In order to replenish the brain's energy supply, the brain remains very active after a concussion. Normally the brain would restore the lost nutrients quickly, but because of the decreased blood flow to the brain, it can leave the brain in this debilitated state for up to an entire year, depending on the severity of the concussion (Heger, 2008; Maugans et al., 2012).

Safety Equipment

Besides simply changing the rules, improvements have been made in the equipment used as well. Riddell, a prominent sports equipment manufacturer, has developed a sensor that can be placed inside of football helmets. The sensor is a lining within the helmet that measures several different forces applied to the helmet – linear force, rotational force, and impact duration and location. This information is sent wirelessly to a handheld unit on the sidelines, and will send an alert on significant hits. While Riddell has stated that this is not a true diagnostic tool for concussions, this new technology is meant to be an extra precaution and help coaches know when their player receives a potentially damaging hit (Linendoll, 2013). This system may be a bit expensive, especially for high school programs with small budgets, but Riddell is working on making this technology cheaper and more available for any program that wants it (Linendoll, 2013). While awareness of the danger of concussions has been slowly accepted among sports associations, progress is being made in making sports safer for the players. Players can never be fully protected from danger, but rules and safety gear can help prevent damage in an industry that is, at its heart, merely entertainment.

Conclusion

While many improvements are being made to reduce the number of concussions football players receive, many athletes are still suffering from these injuries. Experts estimate that sports of all levels cause anywhere from 300,000 to 1,000,000 concussions per year in the United

States (Guskiewicz et al., 2007; Lear & Hoang, 2012). Concussions have both short-term and long-term effects, which are more apparent and severe depending on the number of concussions suffered. These effects are still being researched and studied, but some of the most well-documented of these effects are depression and memory impairment. Along with these, there have been correlations between concussions and significant neurodegenerative diseases such as Alzheimer's and Parkinson's disease. A potential cause of these effects could be the diminished blood flow the brain receives after a concussion is sustained.

The understanding of concussions and their effects is becoming increasingly public and well-known, which has convinced the sports industry to begin to address these dangers. Every year, rules are being implemented in popular sports to increase the safety of athletes. Sports equipment manufacturers are pioneering new safety equipment for the players to wear. Public understanding of the dangers of sports is increasing. While all of these are important steps forward, it remains to be seen where these changes will lead the industry.

It is important to continue to research and learn more about the effects of concussions. Players, coaches, and programs need to continue to seek ways to protect their players. In all likelihood, these improvements will not substantially change the integrity of the sports, at least within the foreseeable future. Fans of these sports can rest assured they will still have the entertainment they love, at a decreased risk to the players who provide that entertainment. As safety equipment and implementations improve, parents and children will still see football as a viable recreational pursuit. As these children get older, the sport gets rougher—but so will the prestige of being a football player. The culture that surrounds football is immense and powerful — even at the high school level, good football players are celebrated and revered. As those players continue to play in college and professional leagues, the possibility for fame increases. As long as this culture of player adulation remains, so will football, and players will continue to risk long-term injury and damage in the pursuit of the fame and fortune that playing in the NFL can bring.

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