

The Significance of TBI Prevention in the NFL's Future

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HN-300-E

9 December 2019

Increasing knowledge regarding traumatic brain injuries (TBIs), such as concussions, has brought about significant changes to the game of football with the safety of the players in mind. Although individuals frequently recover from the acute symptoms of TBIs, there are often chronic repercussions, in which the structure and function of the brain are permanently altered. The chronic effects of TBIs and great vulnerability of football players to these injuries bring into question whether the physicality of the game or the safety of the players is of greater importance. The NFL's increasingly protective stance on concussions, following a period of hidden data and denial, demonstrates the importance of player safety to the National Football League (NFL) over ratings and viewers. Additionally, the cohesive involvement of different groups such as the NFL, NFL Players Association (NFLPA), medical professionals, engineers and biomechanists, and coaches to decrease future occurrences demonstrates the significance of concussion prevention. Although some athletes and viewers may oppose this perspective, as it will result in deviation from football's intended nature, the NFL and other involved groups have proven the safety of the players essential to the game due to the significant effects and high prevalence of traumatic brain injuries in the NFL.

A TBI is defined as “an alteration in brain function, or other evidence of brain pathology, caused by an external force.”¹ Collisions that occur during the sport of football can provide rapid linear or rotational acceleration (change of velocity) of the brain, resulting in this damage. TBI can lead to both primary and secondary injury. Primary brain injury is that directly resulting from the external force on the brain, and secondary injury evolves over time, as a result of the primary injury, causing structural changes to the brain on the cellular and subcellular level.¹ TBIs can lead to debilitating, neurodegenerative brain diseases caused by various pathways. Neurodegeneration is the process by which both the structure and function of neurons, the

primary functional unit of the nervous system, are altered, often leading to cognitive disabilities. Recently, one of the most controversial topics concerning the NFL has been football's role in the development of Chronic Traumatic Encephalopathy. Chronic Traumatic Encephalopathy (CTE) is a neurodegenerative brain disease, linked to TBIs, that has recently been found to be common in NFL athletes. A positive correlation has been identified between the development of CTE and age of first football exposure, duration of play, number of collisions, and linear and rotational acceleration of collisions.²

Although there is much evidence linking football exposure to TBIs and neurodegenerative disease, there has been objection to recent adjustments made to the game with the interest of player safety in mind. There are many individuals who question the severity and prevalence of these diseases in the sport of football. Others believe that there has been too large of a shift from the physical nature of the game and that these changes will catalyze further alterations, leaving the game unrecognizable. Individuals who believe this view the preservation of the game to be of greater importance than the safety of players. Regardless of the motive to disregard the importance of head injury prevention, a definite concern of the NFL is how their ratings, viewers, and sponsors will be affected by these changes, as this is the source of their income. However, medical research, statistics, and the NFL's changing stance on these injuries stress the far greater importance of head injury prevention than maintenance of the sport's physicality.

Concussions are the most frequently occurring TBI and are especially prevalent in the sport of football. Concussions result from a sudden change in velocity of the brain and cause both primary and secondary brain injuries. If an external force causes the brain to move within the skull and make contact with its bony surface, a concussion may result.¹ Additionally, when

inertial forces cause sudden linear or angular acceleration of the brain, straining, shearing, and compression of tissue may result in a concussion.¹ Primary concussive injuries are those resulting from such forces. Secondary concussive injury, such as traumatic hematomas (accumulation of blood outside the brain's blood vessels) and cerebral edema (swelling of the brain) can result in elevated pressure within the skull, lack of oxygen delivered to the brain, and further cell death.¹

Although these acute symptoms alone are concerning, concussions can lead to the activation of enzymes within damaged neurons, causing multi-path cascades that result in further cellular death. The forces experienced by the brain during a concussion cause a disturbance in the structure of neurons, resulting in a great release of neurotransmitters (the chemical substance allowing neurons to communicate).¹ Excitatory amino acids (a type of neurotransmitter), such as glutamate, cause calcium ions outside of the neuron to diffuse into the cell, and as a result, additional calcium ions are released from stores within the cell.¹ Additionally, the disturbance in neurons causes cell membrane defects, resulting in a furthered influx of calcium ions into the cell.¹ The change in homeostasis of calcium ions leads to various events within the neurons, such as the activation of two groups of enzymes, caspase and calpain cysteine proteases.¹ The activation of the caspase protease causes the diminishing of cytoskeletal proteins, which give the cell its shape, resulting in programmed death of neurons.¹ Calpain proteases cause rapid, passive cellular death, due to energy deficiency and failure to maintain homeostasis.¹ Calpain proteases can also lead to an inflammatory response, that results in cellular death.¹ Concussions do not only involve the consequences of primary and secondary injuries, but as a result of neuronal disruption, imbalances in the homeostasis of calcium ions catalyze pathways that result in further cellular death.

The resulting symptoms of concussions correspond to the damaged area of the brain. Due to human anatomy, and the biomechanics of how the brain moves within the skull, the most frequently injured region of the brain resulting from concussion is the frontal lobe, which deals with motor learning and higher-level thought.¹ Other regions often affected include the temporal lobe (deals with memory, hearing, smell, and speech comprehension), the brain stem (controls basic life functions, such as breathing and heart rate, and the transmission of messages from the brain), the basal ganglia (deals with coordination, sequential movement, and motor learning), and the diencephalon (which relays sensory information to other parts of the brain and works with the limbic system to generate emotions).¹ The most common symptoms of concussion involve cognitive disfunctions. This includes deficits in attention, short term memory, learning, information processing, speech and language functions, problem solving, and impulse control.¹ Personality changes, such as impulsivity, irritability, affective instability, and apathy, also frequently result from concussions.¹ Concussions affect an individual's overall cognitive and social functions. Therefore, not only would it be irrational and dangerous to allow a player to participate with any of the cognitive impairments resulting from concussion, but having to live with these impairments as a human being has a drastic effect on the individual's quality of life and ability to function in society. Additionally, research shows that concussions catalyze mechanisms that result in permanent brain damage.

Although the previously described symptoms are often acute, concussions can also have chronic effects on the cellular level, greatly influencing brain function in the long term. TBIs cause the clustering of various molecules that drive chronic, neurodegenerative disorders, such as the development of Alzheimer's Disease, Parkinson's, and frontotemporal dementias.³ Amyloid beta, a protein involved in the development of Alzheimer's Disease, has been found to be present

in cortical plaque, and amyloid beta precursor protein can be found within neurons, just ten hours after a severe TBI.³ The most notorious neurodegenerative disorder linked to the participation in football is Chronic Traumatic Encephalopathy (CTE). CTE is a neurodegenerative disease, driven by the accumulation of tau proteins, that can result from a single TBI or repetitive, mild TBIs (mTBIs).³ Tau proteins are a microtubule-associated protein that “can undergo excessive phosphorylation and accumulate intracellularly as neurofibrillary tangles.”³ Although these proteins are essential for normal cell function, accumulation of phosphoryl groups can cause tau proteins to entangle one another and build up within the brain. The resulting accumulation of tau can lead to CTE, and tau build up is an indicator of Alzheimer’s Disease, Progressive Supranuclear Palsy, Corticobasal degeneration, and Pick Disease.³ Although there are minimal symptoms associated with repetitive mild TBIs in the short term, the brain becomes more susceptible to injury with each impact.³ CTE is more closely related to these repetitive mild TBIs.³ Symptoms of CTE include those resulting from concussions, but with an aspect of permanence, in addition to psychological changes. Some of these psychological changes include increases in impulsivity, depression, apathy, anxiety, and feelings of hopelessness, explosivity, verbal violence, physical violence, and suicidality.² All of these symptoms were found to be present in above 50% of individuals with mild CTE.² Concussive damage to the brain is both debilitating in the short term and can affect long term quality of life.

The overwhelming prevalence of concussions in the NFL is equally as alarming as their effects. The mechanics involved in the sport of football, alongside the high forces and velocities involved at the professional level, make the players increasingly vulnerable to obtain a TBI. Research conducted by Nathanson et al. analyzed and assessed data regarding concussion frequency throughout the 2012 and 2013 NFL regular season.⁴ There was an average occurrence

per game of 0.61 concussions, and there was found to be 6.61 concussions per 1,000 athletic exposures.⁴ This means that if an athlete was to participate in 1,000 athletic exposures (games, practices, etc.) he would suffer an average of 6.61 concussions. It was also concluded that defensive backs, tight ends, and wide receivers had the highest incidence rates of concussions per athletic exposure.⁴ Defensive backs had 11.76 concussions, tight ends had 11.11, and wide receivers had 9.79 concussions per 1,000 athletic exposures.⁴ Running backs, quarterbacks, and offensive linemen were in the 6-8 range, and linebackers, fullbacks, and defensive linemen had less than four concussions per 1,000 athletic exposures.⁴ The high frequency of TBIs in the NFL is undeniable, and position-wise statistics can be utilized in the future to develop new strategies for keeping the most susceptible players safe.

Additionally, a study conducted by Mez et al. displayed the prevalence of CTE among 202 deceased football players.² CTE was diagnosed in 3/14 high school athletes, 48/53 college athletes, and 110/111 NFL athletes.² The average duration of play among athletes who were determined to have mild CTE pathology was found to be 13 years, and 15.8 years for those with severe pathology.² 13 years of participation is a relatively short amount of time, especially for individuals competing in the NFL who began playing at a young age. The most common cause of death among those with mild CTE was suicide (27%), which alongside the symptoms of CTE demonstrates a link to both physical and mental health issues, and the most common cause death among those with severe CTE was neurodegenerative factors (47%).² The prevalence of concussions and neurodegenerative disease among NFL players is evident, and the effects greatly affect their quality of life. Therefore, the health and safety of NFL players should be of utmost importance.

Although studies exemplifying the chronic effects and prevalence of concussions in football have existed for a long period of time, the NFL's protective stance is relatively recent. Increasing public awareness of the harmful effects of concussions, in addition to the prevalence of concussions in football, has raised a plethora of worries for the NFL, including diminished income due to decreased viewers, sponsorship, and youth participation in the sport. A study published in the *New England Journal of Medicine* in 1952 states that football players should no longer participate in the sport after suffering more than three concussions.⁵ This demonstrates that knowledge regarding the dangers of concussions and football has been around for over 50 years. Alongside the increasing awareness of concussions, the commissioner of the NFL, Paul Tagliabue, developed the MTBI Committee in 1994.⁵ The team physician for the New York Jets, Elliot Pellman (rheumatologist), was made the chair of the committee.⁵ Not only was Pellman lacking expertise regarding brain function, but he also had a conflict of interest, as he was a physician for the New York Jets.

Throughout the existence of the MTBI Committee, numerous fraudulent studies were conducted, and the league's negligence was demonstrated.⁵ Further exemplifying the committee and league's lack of comprehension: during a regular season game in 2003, Pellman allowed Wayne Chrebet to reenter a game after suffering a hit that caused the player to lose consciousness.⁵ From 1996-2001, more than half of the players who reported suffering a concussion proceeded to reenter the game.⁵ The majority of players during this time period who reentered games following a concussion reported resolved symptoms almost immediately following the incident.⁵ However, because the symptoms of a concussion are predominantly subjective, and NFL contracts are not guaranteed beyond the current season, it is likely that the players were being dishonest in order to maintain their jobs.⁵ Had the committee not denied the

potential for CTE in football, and educated their athletes on the chronic effects of concussions, the actions of players may have been different. The NFL's questionable past regarding concussions demonstrates the incompetence of various staff members and the league as a whole.

In 2005, a revolutionary article, titled "Chronic Traumatic Encephalopathy in a National Football League Player", was published, and it discussed the findings of the autopsy conducted on diseased NFL hall of famer, Mike Webster.⁵ This study, conducted by Dr. Bennet Omalu, found Webster's brain to be riddled with tau proteins, indicating the presence of CTE.⁵ This was the first documented case of long term cognitive decline in an NFL player, and it catalyzed the changes that are being made in favor of player safety present day.⁵ Omalu and the other doctors involved linked the cognitive deterioration of Webster to numerous occurrences of concussions suffered throughout his long NFL career.⁵ The NFL was outraged with the release of the article, and the organization immediately denied the findings and attempted to discredit the results.⁵ Increased public knowledge of the dangers of football had the potential to hurt the NFL as a business organization, and the league therefore attempted to keep findings under the rug for as long as possible. The MTBI Committee slandered and rejected the relevance and accuracy of Omalu's article, denying the possibility of permanent cognitive disability resulting from multiple concussions.⁵ However, the NFL's knowledge of the danger football poses to long term brain function was apparent through changes to the rules made years after Omalu's findings. Despite kick return units being identified by the NFL as having a low risk for brain injury at the time of the rule change (2011), the kickoff was moved forward five yards in order to reduce the speed of collision between the players and to increase the number of touchbacks.⁵ Although the NFL denied a correlation between long term cognitive deficits and football, the importance of player safety to the future of the game was always understood.

Although the NFL has recently been making an effort to reduce concussion incidences, the league's demonstration of great negligence cannot be excused. Articles discussing the long-term risks of receiving multiple concussions have existed for over 60 years. Despite the existence of evidence demonstrating the dangers of concussions, the NFL did not show an interest in concussion prevention until public awareness increased. The MTBI Committee was therefore developed in 1994, with the purpose of making the NFL appear more concerned with the safety of its players. Despite public belief, the committee conducted numerous faulty studies, with the intention of discrediting previously conducted studies linking football to cognitive decline. Efforts to discredit findings continued, even when a clear link was established by Dr. Bennet Omalu. The NFL failed to make a true effort to reduce head injuries until very recently, as the organization was more concerned with income and the public eye than the safety of their players. The NFL therefore has an even greater duty to increase public knowledge of the associated risks and continue carrying out all necessary efforts to increase player safety.

Presently, the NFL acknowledges the correlation between participation in football and development of CTE and is working to further increase the safety of players. Since 2002, the NFL has incorporated 50 new rule changes with the intention of reducing injuries.⁶ Helmets were created to protect the skull, and engineering of equipment has led to more effective helmets. However, because of this, players feel increasingly comfortable using their heads as weapons to initiate contact, without understanding the risk this poses to their brain.⁵ Many rule changes aid in reducing these mechanisms that compromise the health of the brain. Some of the changes include all defenseless players being given protection from contact to the head by the opponent's helmet, shoulder, or forearm (2010), runners and tacklers being prohibited from initiating contact utilizing the top of their helmet (2013), and prohibition of players from lowering the head to

initiate contact with the helmet (2018).⁶ The latest rule change is the elimination of the blindside block, in which a player initiates contact with his head, shoulder, or forearm, while directed towards his own end line (2019).⁷ Recent changes were also made to football's most iconic, yet greatest TBI generating, play. From 2015-2017, kickoff accounted for just 6% of plays, but caused 12% of the concussions suffered during those seasons.⁸ Some of these changes include the kicking team being required to line up no more than one yard away from the restraining line and the requirement of the kick return team to have eight players lined up within the 15 yard set up area (2018).⁸ All of these changes to the game have the intention of preventing high velocity collisions, and the NFL's readiness to make these significant adjustments demonstrate its growing comprehension of the importance of player health and safety.

Responsibilities of NFL medical staff, one of the more obvious issues, have been adjusted in accordance with the increasingly radical stance in concussion prevention. During the preseason, each player is required to take a baseline concussion assessment.⁹ When diagnosing concussions, to improve accuracy of assessment, the NFL requires the use of tablets containing an application with a provided checklist and a comparison to the individual's prerecorded baseline.⁶ Concussion policies have also become increasingly strict. If a player exhibits symptoms of a concussion, including loss of consciousness, gross motor instability, confusion, or amnesia, they are forced to cease participation and are taken immediately to the locker room for further evaluation.⁹ They are then unable to return to the game during the same day.⁹ This approach will eliminate concussed players, whose brains are in a compromised state, from reentering the game. Additionally, a progressive and comprehensive return to play protocol has been implemented. Once a concussion has been confirmed, the injured player must then progress through four stages before being able to return to play: rest and recovery until baseline level

symptoms are reached, participation in light aerobic exercise, continued aerobic exercise with the introduction of strength training, noncontact football specific activities, and full football activity.⁹ If symptoms arise once again, the athlete returns to the previous stage until symptoms reside.⁹ This progressive approach of return to play ensures that the athlete does not come back to full participation too quickly and further the severity of their injury. The NFL's stance on the correlation of CTE and football participation has shifted from one of denial to one of strict, preventative measures. The implementation of these adjustments, regardless of the risks to the future of the business, demonstrates the urgency to protect athletes from permanent cognitive damage.

The NFL has collaborated with a plethora of outside organizations in order to increase awareness and further prevent incidences of TBIs. The NFLPA has worked with the NFL through collective bargaining agreements to further prevention. This has been achieved through rule changes, additions to medical staff, and increasing player knowledge regarding health and safety. Through the 2011 Collective Bargaining Agreement, the number of full contact practices allowed during the regular season has been reduced to 14, and two-a-day practices were eliminated.⁶ This has significantly reduced the incidences of high velocity impacts to the head. The NFL and NFLPA have collaborated with the incorporation of new medical personnel and technology to enhance the ability to recognize injuries such as concussions. Personnel additions include Unaffiliated Neurotrauma Consultants (aid in the identifying and diagnosing of concussions by monitoring broadcast feeds), Visiting Team Medical Liaisons (board certified and locally licensed physicians that are required when travelling across state lines), and Booth ATC Spotters (certified athletic trainers that remain in a booth during games, and observe broadcast feed to help identify injury).⁶ Prior to the beginning of training camp, a health and

safety presentation developed by the NFL and NFLPA is given to all players, containing information about the diagnosis and management of concussions alongside other potential risks.⁶

The NFL also collaborates with biomechanical engineers and material scientists to identify preventable mechanisms that put players at an increased risk for concussion.⁶ The NFL requires helmets worn by its players to be up to The National Operating Committee on Standards for Athletic Equipment (NOCSAE) standards. NOCSAE conducts scientific research regarding the performance of various helmets and their ability to limit maximal rotational forces, which are often the cause of concussions.¹⁰ Helmet safety is evaluated through pass-fail assessments, in which a single helmet receives 29 impacts, at seven different locations, at various velocities and temperatures.⁹ The collaboration of outside organizations in the prevention of head injuries demonstrates a mutual understanding of importance between varying professional specializations.

Companies that engineer football equipment are now getting involved with concussion prevention, furthering biomechanical research. Riddell, a company that specializes in football equipment, has made significant strides in TBI reduction through new helmet technology. Although the primary function of helmets in football is to prevent skull fractures and head lesions, a new device for the helmet, the Riddell SRS, is able to monitor and record every incident of significant impact to the head throughout a football session.¹² This involves the use of an accelerometer located within the helmet that detects linear and rotational acceleration, location, direction, and the time of each impact.¹¹ If a significant impact takes place, medical staff are alerted immediately.¹¹ This technology is important not only for the immediate identification of concussions, but it can be used for scientific research regarding the mechanisms and incidences of concussions. Maximizing research opportunities and identifying incidences

where players may be at an increased risk is of great significance and will allow for a better understanding of the issue.

In addition to changes and collaborations initiated by the NFL or outside organizations, certain coaches are independently working to implement safer, yet effective mechanisms when initiating collisions with other players. A prime example of this is the effort of the Seattle Seahawks' head coach, Pete Carroll. Carroll teaches his players to initiate contact when blocking and tackling in a manner that reduces injury risk and maintains the physical intensity of the game.¹¹ The Seahawks are instructed to utilize the rugby-style tackle, emphasizing shoulder contact below the opponent's neck and above the knees.¹² When performed correctly, Carrolls method maximizes leverage and minimizes the risk of injury for both players involved in the collision. When initiating contact with the head, the brain and cervical spine are at an increased risk for injury due to the change in velocity experienced by the brain within the skull and the axial loading of the spine. Utilizing the rugby-style tackle removes the tackler's head and neck from the play. The unstable knee joint of the offensive player, which is increasingly susceptible to injury, is also removed. Torque, which is equal to force multiplied by the perpendicular distance from the axis of rotation, is maximized through this technique. The tackler is generating force perpendicular to the offensive player's body, and parallel to the force being applied to them by the offensive player. Instructional videos have been released by the Seahawks with the intention of educating players and coaches outside of the organization.¹² An understanding of the issue is becoming increasingly prevalent across the league, and coaches and players are making adjustments to the style of play as a result.

Taking a quick glance at concussion data from 2013 to 2018, although efforts to decrease concussion incidence are being made, the effectiveness of these methods appear to be questionable. From the 2013 to the 2018 NFL season, concussion incidences among players have been 229, 206, 275, 243, 281, and 214.¹³ The statistics do not seem to follow a pattern, significantly increasing from 2014 to 2015, followed by a steep decline from 2017 to 2018. However, applying knowledge of the NFL's increasingly radical approach towards concussion prevention, it is likely that the initial increase is due to an increase in the reporting of concussions, and not due to an actual increase in incidence. During this time period, there was a rapid increase in awareness of the permanent damages associated with playing while concussed, and the NFL's approach shifted as a result. Additionally, regarding the changes to kickoff, concussion incidences during these plays have decreased 35% from 2017 to 2018 (when new kickoff rules were first implemented).⁷ Regardless of the scattered incidences reported, changes to the game have reduced the opportunities for players to experience concussion causing mechanisms, and education has allowed for the involvement of outside organizations and the implementation of safer techniques by coaches and players.

Although decreasing the risk for irreversible cognitive deficits through changes to the game may appear to favor the players, rule changes have brought about mixed feelings among current and retired NFL players. Players such as Eric Dickerson, Roddie White, and Pernell McPhee are against changes such as the 2018 rule limiting the use of helmet when initiating contact.¹⁴ At a charity event hosted by NFL player Anquan Boldin, hall of fame running back Eric Dickerson expressed his frustration: "What's next, take the stiff-arm away? Why don't they take the helmets off? They're just thinking of any and everything because of all the things that are coming their way with the lawsuits."¹⁴ Along with many other players, Dickerson is worried

that the changes being made to the game are taking away from the sport's intended physical nature. He states that lowering of the helmet prior to contact is a natural reaction for running backs; it is an unavoidable protective mechanism.¹⁴ On the opposite side of the spectrum, other players are grateful that these conservative rules are being implemented, as they reduce concussion causing mechanisms and career ending injuries. Among these players are Antonio Brown and Ramon Foster. Brown states "I just want to protect myself. Getting hit is part of the game, but obviously that rule will help protect players for that crazy play when (players) want to take you out."¹⁵ Although football's physicality should remain, the safety of the players should be of utmost importance. Brown is especially aware of this, as he was left unconscious in a 2016 wildcard game, after a player led with his helmet to initiate contact with him. Although not all players recognize the importance of rules preventing significant head injuries, it is clear that other methods are not sufficient alone.

The satisfaction of viewers and maintenance of sponsors are also of great importance to the NFL, as this is where their income stems from. Many fans have been critical of the league, as rules implemented to prevent head injuries over time have caused the game to stray from its intended nature. The 2018 rule change, penalizing players for lowering the head to initiate contact, has brought about significant backlash from fans. However, regardless of criticism, the NFL as a business is still thriving.¹⁶ To list contracts possessed by the NFL: NBC, CBS, and Fox total 27.9 billion dollars of income, all of which that expire after the 2022 season.¹⁶ Additionally, ESPN, for Monday Night Football, and Direct TV, for its NFL Sunday Ticket package, are both on eight year contracts with the NFL, bringing in 15.2 billion and 12 billion dollars.¹⁶ As demonstrated by this enormous influx of money, the NFL is in no way struggling economically. Arguments are often made against the changes, discussing the 8% drop in the NFL's ratings from

2015 to 2016 and the 9% drop from 2016 to 2017.¹⁶ Although these statistics alone do not look promising for the NFL, it must also be taken into consideration that broadcast television networks experienced a 16% loss of viewers and cable networks experienced a loss of 11% during this time period.¹⁶ It is likely that this decrease in viewership is due to the transition of cable television viewers to streaming services. It may therefore be in the NFL's best interest to make their product available on such services or to develop a streaming service of their own. It is often argued that live sports are one of the few things keeping cable television alive. This is supported by the fact that NBC's Sunday Night Football has been statistically the highest rated show on television for 7 consecutive years.¹⁶ Sponsorship and satisfaction of viewers therefore seem to be less of a problem for the NFL than enhancing the safety of the players, and it is likely that the population will continue to watch football as long as the product is available.

As more information regarding the dangers of football is released, an additional concern for the continuation of the sport's popularity is youth participation. Youth participation has begun to bottleneck, due to the increase in knowledge linking football to neurodegenerative disease. From 2010 to 2012, there has been a 9.5% decrease in participation of youth Pop Warner football players.¹⁷ A study conducted by Murphy et al. utilized surveys given to 497 parents who have a child that is of 18 years of age or less in order to determine factors influencing parental intentions to allow their children to play football.¹⁷ Attitudes towards youth football participation, social norms, behavioral control, and perceived risk of concussions in football were found to be significant in the prediction of parental intentions.¹⁴ Additionally, USA Football, the national governing body of football, has been working to increase concussion education and the implementation of proper tackling techniques through the Heads Up Football initiative.¹⁴ This will have a positive effect in decreasing the number of concussion occurrences

in youth football. However, it will also increase parental awareness regarding the risks involved with the participation in football. Although there are physiological, psychological, and social benefits related to youth football participation, the risks associated with concussions have led to the deterring of parents from allowing their children to participate in the sport.¹⁴ Therefore, the conservation of the game is essentially in the hands of youth participation, and less so in maintaining the violent nature upon which the sport was created. Consequentially, further safety measures within play are essential for the preservation of football.

Because youth participation is so important to the preservation of football, it is important that the NFL continues to maximize the identification of concussions, further public education, and limit the concussion causing mechanics within the game. The NFL has done a good job of ensuring that their players utilize the safest helmet's available. However, in the future, implementation of accelerometer-based devices in every player's helmet, such as the Riddell SRS, will aid in the identification of players who have received a TBI. This will allow for them to be removed from the game before damage is furthered. Additionally, presentations regarding the diagnoses, management, and risks of concussions should be delivered to youth players, their legal guardians, and coaches in order to increase awareness on these levels. To reduce occurrences, safer mechanisms when initiating contact should be implemented and coached at every level, and further rule changes can be applied over time. If found necessary, the intentional initiation of contact with the head, and the initiation of contact above the opponent's neck, should be gradually removed from play. Finding a balance between the game's physicality and player safety is essential for the preservation of football.

Although certain athletes and viewers criticize the changes to the game implemented by the NFL, maintaining the highest level of safety possible for the players is of greater importance than maintaining the intended physical nature of the game. This is due to the high prevalence of TBIs in the NFL, and the neurodegenerative consequences significantly affecting quality of life as a result of these injuries. The NFL has acted to enhance the safety of players through the addition of numerous health and safety rule changes, collaboration with biomechanists and medical staff, and efforts to increase awareness among coaches and players. The NFL's shift in stance on the topic, from one of burying evidence and denial to that of radical head injury prevention, regardless of the possibility of negative backlash, demonstrates the importance of preventing TBIs. Additionally, regardless of player and viewer criticisms, the NFL has continued to thrive as a business, maintaining high ratings and securing billions in contracts. Increasing the safety of players is important not only to maximize the quality of life of the players as they age, but it is essential in the preservation of football as we learn more about the neurodegenerative consequences resulting from the high concussion rates in the sport.

ACKNOWLEDGEMENTS

I would like to thank Dr. Thomson and Dr. Trudeau for guiding me in the development and writing of my paper. Additionally, I would like to express gratitude to all of my peers who have aided me in my research. All of you have all played a substantial role in the enhancement of my paper.

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