

## CTE in Professional Football: Epidemiology, Prevention, and Player Safety

Christophe Chau

### *Abstract*

This research paper aims to provide a comprehensive review of the relationship between football and the development of Chronic Traumatic Encephalopathy (CTE) resulting from repeated traumatic brain injuries (TBIs), including investigating the significance of CTE as a neurodegenerative disease, examining past and present research into its epidemiology and prevention, and emphasizing the need for ongoing studies and urgency in prioritizing player safety. It calls upon coaches, players, and organizations like the NFL to work collectively towards reducing the incidence and impact of CTE. By fostering a safer environment, promoting a collaborative effort, and advancing our understanding of the relationship between football and CTE, a safer future for all athletes may be possible.

### *Introduction*

In 2017, researchers at Boston University examined the prevalence of chronic traumatic encephalopathy (CTE) in 202 former football players across professional, semi-professional, collegiate, and high school levels of play. They found evidence of CTE in 87% of all brains examined, including 91% in NFL players, 88% in CFL (Canadian Football League) players, 64% in semi-professional players, 91% in collegiate football players, and 21% in high-school players<sup>[4]</sup>. In recent years, high-profile cases of former NFL players affected by CTE have prompted further study of the neurological condition while also further raising concerns about player safety in football and other contact sports. As a result, many teams and individuals have called for changes in the way football is played and managed, with a focus on reducing unnecessary contact. Meanwhile, ongoing research continues to explore the long-term effects of repetitive head trauma and the best ways to both diagnose and treat CTE. With the prevalence of football being played at the professional, collegiate, and youth levels, at an estimated 5.23 million players per year, a review of its relationship to the development of CTE is necessary<sup>[17]</sup>.

### *Methods*

When researching the relationship between American football and the development of CTE, evidence points to a link between repetitive head trauma and the onset of neurodegenerative symptoms<sup>[1]</sup>. To reduce the likelihood of this condition for at-risk athletes, it is crucial to implement preventative measures including improved safety equipment and increased education about the dangers of contact sports. To date, there is a continued need to review the current status of such preventative efforts, while also taking into account the existing cultural narrative surrounding football and CTE. This review aims to discuss the aforementioned high-profile cases involving NFL players, the current state of CTE preventative efforts, and how these findings together can be used to improve football player safety.

To conduct this review, a search was conducted on PubMed, major news outlet sites, and official institutes of higher education from January to April 2023, using the search terms "NFL,"

"CTE," and "player safety." Only papers of the document type newspaper or journal article published between 2012 and 2022 were included. The review excluded articles that discussed other forms of traumatic brain injuries and cases of CTE outside of football, such as those of CTE occurring in hockey players. Finally, 17 articles, including 8 from the initial search and 9 additional articles found by cross-referencing, were analyzed for research methodology, study credibility, the scope of investigation, and risk factors evaluated.

### *What is CTE?*

Chronic Traumatic Encephalopathy, known as CTE, is a neurodegenerative disease that results from repeated traumatic brain injuries (TBIs). TBIs are caused by outside forces including blows or jolts to the brain, and they can result in short-term issues in brain function and processing. With enough instances of TBIs, CTE can arise, causing neuron loss and the accumulation of protein/plaque deposits within the brain <sup>[18]</sup>. Symptoms of CTE can often take years or decades to develop and can worsen over time. These symptoms can be categorized into four major fields: cognitive, behavioral, neurologic, and mood. Cognitive symptoms can range from short-term memory deficits to dementia, while behavioral symptoms can include substance abuse, suicidal thoughts, and violent tendencies. Neurologic symptoms consist of Parkinson-like afflictions (uncontrollable movements), dysarthric speech, and mood changes, including depression, irritability, or suicidal thoughts <sup>[16]</sup>. Individuals typically associated with being at risk for CTE include athletes in contact sports, and most notably, American football players, due to the violent nature of the sport and the frequency of head impact <sup>[10]</sup>.

CTE is a progressive disease, typically unfolding over several stages with worsening symptoms. In stage 1 of CTE, the buildup of tau protein remains isolated in the frontal lobe of the brain (responsible for executive function and cognition), and victims of stage 1 CTE can often experience headaches, difficulty concentrating, or possibly even no symptoms at all. In stage 2, symptoms worsen as the tau protein begins impacting more nerve cells, leading to mood swings and depression. In stage 3, greater amounts of tau protein build up and expand to the temporal lobe of the brain, impairing emotion and memory. Common symptoms of stage 3 CTE include confusion, memory loss, and general cognitive impairment. Stage 4 is the final and most severe stage, where the buildup of tau protein overwhelms the brain, causing shrinkage and further damaging nerve cells, leading to severe memory loss and dementia <sup>[13]</sup>. Of note, CTE can only be diagnosed and staged post-mortem from brain samples, limiting its surveillance to clinical manifestations (reference post-mortem).

### *History*

The history of this condition can be dated back to Dr. Harrison Martland, who in 1928, coined the term: "punch drunk syndrome" Punch drunk syndrome symptoms included slurred speech and faltering gait and were often diagnosed in professional boxers who fought with aggressiveness over skill or those who were frequently knocked out in training. In the years following Martland's initial findings, J.A. Millspaugh and C.B. Courville would expand on his research and reclassify punch drunk syndrome as dementia pugilistica. Later on, Courville referred to it as the psychopathic deterioration of pugilists, or those inclined to fight. In 1949, the British neurologist Macdonald Critchley built upon their investigations in his study presented in

the Lancet. While examining a case study of a retired boxer exhibiting symptoms of neurological decay, Critchley used the term Chronic Traumatic Encephalopathy for the first time <sup>[6]</sup>. In more recent decades, the research of Dr. Bennet Omalu has proved critical. While his groundbreaking discovery of CTE in former Pittsburgh Steeler Mike Webster sparked significant controversy, it also led to further research and progress in understanding the condition <sup>[9]</sup>. Understanding the history of CTE and its evolution in sports sheds light on the gravity of the condition and the need for further research into its diagnosis and treatment.

### *Developments*

The Diagnose CTE Research Project at Boston University has provided new insight into possible early pre-mortem CTE detection methods. Using positron emission tomography (PET) scans, researchers have been able to detect the buildup of tau proteins, an early marker of CTE. The PET scans use radioactive tracers to produce gamma rays which are then detected by the scanner. Researchers hope that these tracers bind to proteins present in patients with CTE, which would allow them to monitor the condition within the brain. Although the process is years away from providing definitive diagnoses, it serves as a benchmark for future advances in early detection <sup>[2]</sup>. Additionally, scientists from the University of Southern Australia have developed a new drug that they hope could mitigate, and even prevent the symptoms of CTE. When the brain experiences a head injury, it releases substance P, a neurotransmitter; this process causes the buildup of tau protein, prevalent in cases of CTE. However, scientists believe that if substance P were to be inhibited by a drug, the symptoms of CTE could be prevented. Currently, the drug has passed animal testing but is still awaiting human clinical trials <sup>[12]</sup>.

### *Prevention*

Recent advances in medicine have given way to further developments in education and prevention efforts. While there is no definitive way to prevent CTE, it is possible to minimize the severity and volume of head injuries that could lead to CTE. This can be achieved through dedicated education of coaches and athletes, proper “return to play” protocols from injury, and protective equipment. With regard to the latter element, new studies have provided insight into the protective potential of certain helmets. A study in the Journal of Neurosurgery compiled data recorded from 8 college football teams to determine whether different helmet designs affected the incidence of concussions. The study compared the Riddell VSR4 against the Riddell Revolution helmet and concluded that the Revolution model provided more effective protection against concussions <sup>[15]</sup>. Despite this proof of concept, helmets today still have room for improvement. At the University of Cincinnati, engineers have tested several helmet models and their ability to mitigate impacts. Although the majority of models tested similarly, they shared a glaring weakness at the back of the helmet, where players were most vulnerable. The researchers suggested that the shell and padding of the helmets could be adjusted in order to provide better protection for the wearer. However, they also conceded that more research both on and off the field was needed in order to fully determine the scope of the issue <sup>[11]</sup>. While developments in the helmet industry show promise, equipment is only one part of a multifaceted approach to preventing traumatic brain injuries.

Thus, prevention efforts must also be implemented, including education and proper management of head injuries. Athletes should be counseled on the risk factors that can contribute to the development of CTE, including history and severity of concussions, illicit substance use, alcoholism, pre-existing medical conditions, and genetic predisposition. Additionally, athletes should be encouraged to be transparent with their team about seeking treatment and reporting possible symptoms of a head injury/TBI. Likewise, coaches should receive training on identifying symptoms of TBI and CTE, and also be informed that the full scope of the latter condition has not yet been realized with premortem diagnosis technology still in its infancy. For players that have suffered previous head injuries, properly managing their ailments is vital to preventing further complications. In this area, coaches must be prepared to gradually re-introduce their athletes through the implementation of proper return-to-play protocols.

According to Mass General Brigham's rehabilitation protocol, the returning player must undergo several phases in order to be medically cleared to return. Phase one is initiated immediately after the injury and consists of rest and precautionary action in the case of any symptoms. Phase two suggests light activity to recondition the athlete and no contact in sports. Phase three is a continuation of the prescribed activity, still with no contact. Phase four transitions the athlete back into sports-specific activity with the ability to participate in drills, continuing with the theme of no contact. Finally, phase five is a full return to play and additional intervention, if necessary. This process is not linear and may require further patience as coaches monitor any signs or symptoms of concussion <sup>[14]</sup>. By taking preventative measures against head injuries, such as using the appropriate protective gear and implementing proper return-to-play protocols, the incidence of concussions and associated risks may be reduced. However, education remains a critical component in the fight against CTE. In addition to informing athletes and coaches about the risks of CTE, it is essential to teach them how to recognize and respond to symptoms of TBI.

### *Notable Cases*

Despite improvements in medicine, the devastating effects of CTE continue to be observed, which has been highlighted by several recent cases in notable NFL players. The most infamous of which involves former Florida Gators and New England Patriots tight end, Aaron Hernandez. Hernandez was a star player at the University of Florida, helping lead the Gators to a national championship in 2008. In his final college season, he was a consensus All-American and awarded the John Mackey Award for being the premier tight end in college football. In 2010, Hernandez was drafted by the New England Patriots and immediately made an impact on the field with a standout rookie season. Two years later, he would be instrumental in the Patriots' playoff run and subsequent Super Bowl appearance. Unfortunately, his career was cut short in part due to the damage he suffered on the field, and his decisions off the field. Hernandez, aged 27, died April 19th, 2017 by suicide. Prior to his death, Hernandez had reportedly deteriorated physically and mentally. On June 26, 2013, Hernandez was taken into police custody for the alleged murder of Odin Lloyd, a semi-professional football player who was dating the sister of his fiancée. During trial, new evidence emerged that linked Hernandez to a previous double homicide in 2012, leading to his conviction of first-degree murder among other charges. Throughout his trials, Hernandez reportedly exhibited symptoms of TBI/CTE such as depression, mood swings, and outbursts of violence. Hernandez would later plead not guilty but

was sentenced to life in prison without parole. Upon autopsy examination, his brain showed signs of advanced stage 3 CTE with large amounts of tau protein buildup in addition to dilated ventricles, an atrophied fornix, and a shrunken brain <sup>[8]</sup>.

Hernandez's case was instrumental in raising public awareness of the dangers of head trauma in football and bringing attention to the lack of concern over player safety by the NFL. However, this wasn't the first and, unfortunately, it wasn't the last instance of a former NFL player being diagnosed with CTE. In 2022, it was revealed that former Denver Broncos wide receiver Demaryius Thomas had also suffered from the disease. Thomas was drafted by the Denver Broncos in the 1st round of the 2010 NFL draft, and was an elite wide receiver in the NFL, making 4 Pro Bowls. Thomas played a pivotal role in the Broncos' 2013 season, which would see the team make the Super Bowl; in the championship game, Thomas would surpass a then Super Bowl record for most receptions with 13 along with 118 receiving yards and a touchdown. When the Broncos broke through and won Super Bowl 50, Demaryius Thomas continued to make an impact. On June 28, 2021, Thomas would announce his retirement, bringing his 10-year professional career to a close. However, in December of that year, Thomas, aged 33, would unexpectedly die from complications caused by a seizure <sup>[3]</sup>. After an autopsy, researchers at Boston University found lesions in his frontal and temporal lobes, diagnosing his brain with stage 2 CTE. Although his death was caused in part by prior off-field injuries, including a car crash and fall, those close to Thomas noted that his behavior and tendencies were symptomatic of CTE. Thomas had tried to seek help for his dementia, panic attacks, and mood swings, but was unable to be treated <sup>[7]</sup>. Demaryius Thomas's tragic death has since prompted the NFL to renew its commitment to player safety and develop new protocols to address the prevalence of head injuries. The league has pledged to invest hundreds of millions of dollars into helmet and concussion research <sup>[5]</sup>. While it is a step in the right direction, many argue that the NFL needs to do more to protect its players and prevent cases like those of Aaron Hernandez and Demaryius Thomas from happening in the future.

### *Discussion*

The incidence of CTE in NFL players points to a link between repetitive head trauma and the onset of neurodegenerative symptoms. Although the primary risk factor for CTE is exposure to repeated TBI, it is not a perfect causation-to-correlation relationship. To reduce the likelihood of CTE, the implementation of preventative measures such as increased education and improved safety equipment is critical. The high-profile cases of NFL players diagnosed with CTE have raised awareness of the severity of the condition. Despite the current efforts being made to prevent CTE in football players, there is still much work to be done; there must be a concerted effort to educate coaches, players, and parents about the risks associated with contact sports. Additionally, there should be continued efforts to develop improved safety equipment that can better protect players from head trauma and minimize the risk of CTE. These efforts must be supported by the NFL to ensure that the cases of Aaron Hernandez, Demaryius Thomas, and others are not repeated.

### *Conclusion*

The prevalence of CTE in football players, specifically at the professional level, is an



ongoing issue that requires further research into its epidemiology and prevention. Although much progress has been made in recent years, player safety remains a priority. It is essential for all involved in the sport, including coaches, players, and organizations like the NFL, to work towards reducing the incidence and impact of CTE. By continuing to study the relationship between football and CTE, a safer future for all athletes may be possible.

## References

- [1] Asplund, Chad A., and Thomas M. Best. 2015. "Brain Damage in American Football Inevitable Consequence or Avoidable Risk?" *British Journal of Sports Medicine* 49 (15): 1015–16. <https://doi.org/10.1136/bjsports-2014-h1381rep>.
- [2] Belson, Ken. "A Test for C.T.E. in the Living May Be Closer Than Ever." *The New York Times*, 17 Nov. 2022, [www.nytimes.com/2022/11/17/sports/football/cte-test-concussions-alzheimers.html](http://www.nytimes.com/2022/11/17/sports/football/cte-test-concussions-alzheimers.html).
- [3] Belson, Ken. "Demaryius Thomas Diagnosed With C.T.E., Family Reckons With His Death." *The New York Times*, 5 July 2022, [www.nytimes.com/2022/07/05/sports/football/demaryius-thomas-cte-nfl.html](http://www.nytimes.com/2022/07/05/sports/football/demaryius-thomas-cte-nfl.html).
- [4] "BU Researchers Find CTE in 99% of Former NFL Players Studied | the Brink | Boston University." Boston University, 25 June 2019, [www.bu.edu/articles/2017/cte-former-nfl-players](http://www.bu.edu/articles/2017/cte-former-nfl-players).
- [5] Chappell, Bill. "NFL Pledges Another \$100 Million for Study of Head Injuries, Safety in Football." NPR, 14 Sept. 2016, [www.npr.org/sections/thetwo-way/2016/09/14/493971205/nfl-pledges-another-100-million-for-study-of-head-injuries-safety-in-football](http://www.npr.org/sections/thetwo-way/2016/09/14/493971205/nfl-pledges-another-100-million-for-study-of-head-injuries-safety-in-football).
- [6] Concannon, Leah G., Marla S. Kaufman, and Stanley A. Herring. 2014. "Counseling Athletes on the Risk of Chronic Traumatic Encephalopathy." *Sports Health* 6 (5): 396–401, 17 April 2014, <https://doi.org/10.1177/1941738114530958>.
- [7] Conway, Katie, et al. "Demaryius Thomas: Parents of Late Super Bowl Champion Reveal He Suffered from Stage 2 CTE - ABC7 Los Angeles." 5 July 2022, <https://abc7.com/demaryius-thomas-stage-2-cte-nfl-champion-what-is/12020343/>.
- [8] Kilgore, Adam. "Aaron Hernandez Suffered from Most Severe CTE Ever Found in a Person His Age." *Washington Post*, November 9, 2017, sec. Sports. [https://www.washingtonpost.com/sports/aaron-hernandez-suffered-from-most-severe-cte-ever-found-in-a-person-his-age/2017/11/09/fa7cd204-c57b-11e7-afe9-4f60b5a6c4a0\\_story.html](https://www.washingtonpost.com/sports/aaron-hernandez-suffered-from-most-severe-cte-ever-found-in-a-person-his-age/2017/11/09/fa7cd204-c57b-11e7-afe9-4f60b5a6c4a0_story.html).

- [9] Laskas, Jeanne Marie. 2015. "The Brain That Sparked the NFL's Concussion Crisis." *The Atlantic*. December 2, 2015.  
<https://www.theatlantic.com/health/archive/2015/12/the-nfl-players-brain-that-changed-the-history-of-the-concussion/417597/>.
- [10] Lindsley, Craig W. "Chronic Traumatic Encephalopathy (CTE): A Brief Historical Overview and Recent Focus on NFL Players." 2017. *ACS Chemical Neuroscience* 8 (8): 1629–31.  
<https://doi.org/10.1021/acschemneuro.7b00291>.
- [11] Miller, Michael. 2023. "How to Prevent Concussions in Football? Better Helmets." *UC News*. March 6, 2023.  
<https://www.uc.edu/news/articles/2023/03/uc-engineer-wants-helmets-that-prevent-concussions.html>.
- [12] "New Drug to Halt Dementia after Multiple Head Injuries." n.d. Home. Accessed March 21, 2023.  
<https://unisa.edu.au/media-centre/Releases/2021/new-drug-to-halt-dementia-after-multiple-head-injuries/>.
- [13] Ortiz, Aimee. "Learn the Symptoms in the Four Stages of CTE." *BostonGlobe.com*, 21 Sept. 2017,  
[www.bostonglobe.com/metro/2017/09/21/symptoms-watch-for-four-stages-cte/Q1wniQOnQXH1bU8OibU3WJ/story.html](http://www.bostonglobe.com/metro/2017/09/21/symptoms-watch-for-four-stages-cte/Q1wniQOnQXH1bU8OibU3WJ/story.html).
- [14] "Rehabilitation Protocol for Concussion Return-to-Sport." n.d.  
<https://www.massgeneral.org/assets/mgh/pdf/orthopaedics/sports-medicine/physical-therapy/return-to-sport-concussion-protocol.pdf>.
- [15] Rowson, Steve, and Jonathan G. Beckwith. n.d. "Can Helmet Design Reduce the Risk of Concussion in Football? In: *Journal of Neurosurgery* Volume 120 Issue 4 (2014) Journals." <https://thejns.org/view/journals/j-neurosurg/120/4/article-p919.xml>.
- [16] Saulle, Michael, and Brian D. Greenwald. 2012. "Chronic Traumatic Encephalopathy: A Review." *Rehabilitation Research and Practice* 2012: 816069.





<https://doi.org/10.1155/2012/816069>.

[17] “Tackle Football Participation in the U.S. 2010-2021.” Statista, 8 Dec. 2022,  
[www.statista.com/statistics/191658/participants-in-tackle-football-in-the-us-since-2006](http://www.statista.com/statistics/191658/participants-in-tackle-football-in-the-us-since-2006).

[18] “Traumatic Brain Injury (TBI).” National Institute of Neurological Disorders and Stroke,  
[www.ninds.nih.gov/health-information/disorders/traumatic-brain-injury-tbi](http://www.ninds.nih.gov/health-information/disorders/traumatic-brain-injury-tbi).