The Impact of Helmet Advancements on Concussion Rates in the NFL

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William Moeller

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Travis Elliott, Department of Engineering and Society

Introduction

Concussions have been a growing concern since the early 1900s, and no sports league in the United States has drawn more attention to itself for players' brain health than the NFL (*A brief history*, 2024). With the goal of making football safer, the NFL first made helmets mandatory in 1943 (MacDonald, 2020). Headgear at that time consisted of a hardened leather exterior with ventilation, padding, and earholes (Solomon, 2023). Since then, helmet technology has come a long way thanks to an increase in concerns about the risks of concussions. While the development of the modern NFL helmet was occurring, concussions rates in the NFL were changing. It is hard to say what exactly is the cause of the changing concussion rates in the league because there are three primary factors that may have a significant contribution: (1) the rule changes that the NFL has made, (2) the evolution of the NFL helmet, and (3) the increased awareness of concussions and changing concussion protocol (which may have led to an increase in concussions diagnosed, despite there actually being less concussions). This paper will attempt to determine the effect that the development of football helmets has had on concussion rates in the NFL, independent of these other factors that also influence concussion rates. By isolating the impact of helmet advancements, this analysis aims to clarify whether technological improvements have genuinely reduced concussions or if other factors have played a more significant role.

To do this, the technological momentum theory originally developed by Hughes will be used to frame the topic. Hughes' theory is the synthesis of two different theories on how technology and society affect each other. The first theory is social determinism, which is the theory that both the use and development of technology is determined by society. The second theory is technological determinism, which is the theory that society is changed by the use and

development of technology. This perspective suggests that once a technology is widely adopted, it can shape cultural norms, behaviors, and even regulatory policies. Hughes' technological momentum theory is that when technologies first get developed, society has control over them and their development, but as the technology develops and becomes more engrained in society, the technology itself has a greater effect on society than society does on the technology. Applying this theory to NFL helmet development allows for an analysis of whether improvements in helmet technology were primarily driven by societal concerns or if, over time, the technology itself began shaping the league's approach to player safety.

The invention and entire development of the football helmet is a perfect example of technological momentum. Helmets were first invented when players were concerned for the safety of their heads. Through the years, players, coaches, NFL executives, fans, and scientists have drastically affected the development and style of the helmet's design. For example, NFL players do not always choose to wear the safest helmet, they often choose based on which helmet is the most stylish. Competition amongst helmet companies continues to drive innovations in design. These companies invest heavily in research, testing new materials and impact-dispersing technologies to create helmets that balance safety, comfort, and player preference. Most of all, however, the increasing awareness and emphasis on brain health nationwide has and will continue to be the primary driver in further football helmet innovation. The more dangerous society views football, the more the NFL helmet will have to change to help protect its players. However, as helmet development has progressed and helmets have been viewed as safer and safer, players have developed a sense of fearlessness when wearing their helmets. Players are more likely to lead with their heads (rather than shoulders) when tackling while wearing a modern helmet. This phenomenon aligns with Hughes' concept of technological momentum.

While helmets were originally designed to reduce injuries, their widespread adoption has influenced how players approach the game itself. Because helmets have become more protective, players feel safe taking greater risks, potentially negating some of the intended safety benefits. This demonstrates how technology, once deeply embedded in a system, can start to shape behavior in unintended ways, making it difficult to predict its overall impact. It also adds another layer of complexity when trying to determine whether helmet development has helped decrease concussion rates in the league.

Background on Concussions in the NFL

The NFL did not start formally recognizing concussions until 1994 when they created the Mild Traumatic Brain Injury (MTBI) committee (Strom, 2020). At this time, the league considered knee injuries, as well as drug, steroid, and alcohol use as "far greater" problems than brain injuries (Ezell, 2013). The NFL's commissioners, team owners, and MTBI members have downplayed the significance of brain injuries caused by the sport multiple times since 1994. This reluctance to acknowledge the issue contributed to a delay in implementing meaningful safety measures and concussion protocols. Since this time players have become more open about citing concussions as a reason for retirement, and retired players started mentioning football as the reason for their cognitive problems such as dementia. The overall awareness of concussions as a major issue for the league has drastically risen in recent years, especially after research has shown that repeated head impacts can lead to chronic traumatic encephalopathy (CTE). Players are more likely to be taken out or held out from playing due to concussions than ever before. This shift reflects not only improved medical protocols but also a cultural change in how head injuries are perceived within the league and by the public. The league no longer denies the existence of a problem but rather advertises what they are actively doing to try to solve the issue.

In 2015, for the first time, the NFL acknowledged the serious long-term health effects of concussions by releasing a poster to the players. The poster disclosed more information on the effects of repeated head trauma than prior information that had been released to players. (*Head to head,* 2019). Society's increased focus on brain health has led to more rapid development and innovation for football helmets.

Since 1996 concussion rates in the NFL have slowly declined, but not by much (Casson, 2010). In recent years concussions rates have started to stagnate, however. For example, the 2022 season saw an 18% increase in concussions suffered during regular season games compared to 2021. It is hard to say whether this is because the concussion problem is getting worse, or because the definition of a concussion has become more definitive. Either way, the league has become more cautious and conservative in its evaluation and diagnoses of concussions (Seifert, 2023). Being a business corporation, the NFL ultimately wants to make money. Public perception plays a crucial role in the league's decision-making, as negative press regarding player safety could impact viewership and revenue. As conversations among fans concerning head injuries has increased, so has the strictness of the NFL's concussion protocol. However, the league still has strides to make. For example, NFL doctors still say that the league is not a direct contributor to CTE (*Dangers of concussions,* 2023). As scientific evidence linking football to long-term brain damage grows, the NFL may eventually have to take a more definitive stance on its connection to CTE.

Do helmet advancements help?

Yes, helmet development does help reduce the risk of head injuries for NFL players. The NFL began annual helmet testing in 2015. This annual testing involves running a series of tests under 36 different impact conditions on each helmet model and scoring every helmet based on a

few different safety metrics. The results are then published for players, typically a poster graphic, to show which helmets are the safest. Each helmet falls into one of three categories: (1) Newly prohibited, (2) Not recommended, and (3) Better laboratory performance.

Since this testing began, the rate of helmet model improvement has become nine times faster. To illustrate this drastic current rate of helmet improvement, seven of the 'top performing' helmets in 2020 were prohibited from being worn in 2023. From 2018 to 2023, better performing helmets have contributed to an estimated 25% reduction in concussion rates, independent of other concussion reducing factors (*Helmet innovation*, 2022). The drastic rate of change of helmet models in it of itself is evidence that helmet advancements do help improve concussion rates. This rapid acceleration of helmet development reflects the principle of technological momentum. As helmets become more sophisticated, the demand for even better models grows—not just from players and teams, but also from equipment manufacturers competing to create the most protective designs. What began as a response to societal pressure for safety has now become a self-sustaining cycle of continuous improvement, where helmet technology drives further advancements and policy changes within the NFL.

The NFL has spent over $100 million on concussion research and helmet improvements (Eichelkraut, n.d.). This investment includes funding for biomechanical studies, impact simulations, and the development of position-specific helmet models tailored to different styles of play. And again, this is evidence that improving the helmet does reduce concussion rates because the NFL would not spend such a large amount of money for no reason.

Researchers independent of the NFL also believe that helmet advancements do and will continue to help improve players' brain health. For example, researchers at Standford University have been working with the company Savior Brain to develop a new helmet design that they

believe will help reduce concussions. Their design involves 21 liquid shock absorbers in the helmet. Stanford's laboratory has run the same experiments that the NFL runs annually and has compared their newly designed helmet to those that the NFL uses and have seen promising results. This new helmet performed better than all existing helmets in 33 out of 36 of the different impact conditions tested. It had an average reduction in impact metrics of 33% throughout these tests. All the tests run on this helmet so far have been finite element models, but Stanford's laboratory plans to develop a physical model that could be tested in real-world conditions (Cecchi, 2023). The reason this is important is not only that it shows another example of a lot of time and money being spent on researching helmet designs, but it shows numerical evidence that a more advanced helmet design may reduce head impacts by about 33%. These both support the fact that helmet advancements do in fact matter when trying to reduce head injuries in football.

NFL Concussion Data

One of the primary reasons it is difficult to determine whether concussions are being reduced in the NFL is the fact that the NFL did not start electronically tracking concussions until 2015. Before this, concussion reporting relied heavily on team medical staff and self-reporting by players, leading to potential underreporting of head injuries. All of the official data (from 2015 and onward) is shown in the table below (National Football League, 2025).

Year	Preseason			Regular Season			Preseason + Regular Season		
	Game	Practice	Total	Game	Practice	Total	Game	Practice	Total
2015-2020*: 4 Preseason Games and 16 Regular Season Games per Team									
2015	54	29	**83**	183	9	**192**	237	38	**275**
2016	45	26	**71**	166	6	**172**	211	32	**243**
2017	46	45	**91**	179	11	**190**	225	56	**281**
2018	34	45	**79**	127	8	**135**	161	53	**214**
2019	49	30	**79**	136	9	**145**	185	39	**224**
2020*	N/A	30	**30**	129	13	**142**	129	43	**172**
2021-2024: 3 Preseason Games and 17 Regular Season Games per Team									
2021	22	30	**52**	126	9	**135**	148	39	**187**
2022	27	25	**52**	149	12	**161**	176	37	**213**
2023	32	26	**58**	152	9	**161**	184	35	**219**
2024	26	18	**44**	129	9	**138**	155	27	**182**

This table shows the number of concussions diagnosed during practice and games from 2015 to 2024. The 2020 season is marked with an asterisk because no preseason games were played. Aside from 2020, you can see that 20 games were played per season (combining regular and preseason games). Looking at the total column (far right), you can see a general downward trend in concussions over the years. However, the argument could be made that this downward trend is for reasons other than improvements to the helmet model. Determining the exact role of helmet advancements in this trend requires isolating their impact from these other influential variables.

Concussion Protocol Changes

The definition of a concussion has changed evolved as scientists have learned more about the complex injury, and while this definition has changed, the protocol for assessing and diagnosing concussions in the NFL has also changed. President Theodore Roosevelt drew attention to the deaths and severe brain injuries amongst football players in 1905. From then until 1980, however, the primary focus of assessing concussions in football was to prevent potentially fatal internal bleeding of the brain. Throughout the 1980s, the NFL only worried about head impacts that caused players to lose consciousness (Maroon, 2014). This limited approach meant

that players who experienced symptoms like dizziness, headaches, or confusion, now recognized as clear concussion indicators—were often allowed to continue playing. It wasn't until 1994 (upon the creation of the MTBI), that the NFL really started evaluating for what we consider today to be concussions. Due to the changing definition of concussions and the lack of tracked concussion data prior to 2015, it is difficult to track historical concussion rates.

It is noteworthy to mention the recent change in concussion protocol prompted by star quarterback Tua Tagovailoa's return to playing in the same game that he featured one of the NFL's "no-go" signs of a concussion (McKessy, 2024). Prior to the protocol change, the four "no-go" symptoms of a concussion according to the NFL were loss of consciousness, gross motor instability, confusion, and amnesia. Tagovailoa showed signs of gross motor instability, which would typically rule him out from returning to playing in the game at all. Due to a loophole, however, Tagovailoa was able to return. The loophole allowed players to return if the gross motor instability was caused by an orthopedic injury. In Tagovailoa's case, the Dolphins team doctor determined that his gross motor instability was caused by an injury to his back rather than his head. Tagovailoa's case was well followed by the fans and the media because of his status as a player. Many former players and analysts publicly criticized the league for failing to protect its athletes, leading to immediate discussions about changes in concussion assessments. By the start of the next season, the NFL removed the loophole of blaming gross motor instability on an orthopedic injury and changed the "no-go" sign from gross motor instability to ataxia. Ataxia is defined as "abnormality of balance/stability, motor coordination or dysfunctional speech caused by a neurological issue" and is more well-documented in the medical field (Tretter, 2022).

This Tagovailoa case is important because it is an example of concussion protocol (and concussion definition) changing since concussion data began being tracked in 2015. Changes like this affect the validity of the data, as concussion rates may fluctuate not only due to the actual number of injuries but also because of evolving diagnostic criteria and stricter enforcement. For example, what may not have been classified as a concussion under older protocols could now be counted, leading to an apparent increase in reported cases even if the true rate of head injuries remains unchanged. Additionally, as concussion protocol continues to be refined, comparisons between different time periods become more difficult, making it challenging to determine long-term trends in concussion frequency and the effectiveness of helmet advancements.

NFL's Strategy

As expected, the NFL would like to see concussion numbers go down. Some even say that the potential for long- term brain damage, including CTE, is the biggest risk that the NFL faces as a league. Every week that games are played players are getting concussions, and the league has been under scrutiny for not protecting its players' brain health for the past 20 years. One third of former NFL players who were surveyed by a medical journal believe that they have CTE (Grashow, 2024). Parents are more likely than ever to prevent their kids from playing tackle football due to the risks it comes with. The 2021-2022 school year was the first since 2000 where fewer than one million players played high school football (Most, 2024). Declining participation at the youth and high school levels threatens the long-term talent pipeline of the league, raising concerns about the future of the sport. There are even long time fans who have decided to stop watching football due to the violence and harm that it can cause its players (Sailofsky, 2022). The increasing number of high-profile concussion cases, including those of retired players

struggling with neurological disorders, has only intensified the ethical debate surrounding football's risks.

At the end of the day, the NFL is a business. This means they need to try to prevent concussions and negative media attention about the league. In response, the league has attempted to demonstrate progress through rule changes, investment in helmet technology, and promoting player safety initiatives. However, there have been reports in the past about the NFL skewing concussion data to make themselves look better outwardly (Salvi, 2014). Critics argue that while the NFL presents itself as committed to player safety, its financial interests often conflict with full transparency regarding the dangers of the sport (Sullivan, 2024).

Despite the NFL's claims of progress, scientists remain deeply skeptical about whether helmet innovations and rule changes meaningfully reduce concussions. James M. Smoliga, a professor at Tufts University, has pointed out flaws in the NFL's reporting on concussion prevention, particularly its promotion of Guardian Caps, the padded outer shells worn in preseason practices. According to the league's own data, these caps have supposedly reduced preseason concussion rates by 52%, yet scientists challenge the legitimacy of these numbers, arguing that they fail to account for differences in practice intensity and other variables. Smoliga and other researchers compare the idea of improving helmets to the concept of "safer cigarettes"—a solution that might reduce harm slightly but does not eliminate the fundamental risk of injury. Furthermore, even if helmet advancements were to provide better protection, their adoption is hindered by the NFL's cultural and financial priorities. As researchers have pointed out, helmet design is not just about safety—it is deeply tied to the branding and identity of football itself. The helmet is the most recognizable symbol of the sport, with team logos carrying deep cultural and economic significance. While more radical helmet designs, such as the

Guardian Caps, might offer increased protection, they have never been seriously considered for full-time use. The NFL's reluctance to adopt visibly different helmets suggests that aesthetics and branding take precedence over player safety, reinforcing the idea that maintaining the game's traditional image and marketability is just as important to the league as addressing the risks of head injuries (Cohan, 2023).

Conclusion

Helmet advancements in the NFL have undeniably contributed to making the game safer by reducing the risk of head injuries. Innovations in helmet design, materials, and testing have led to measurable decreases in impact severity, and both league-funded research and independent studies suggest that modern helmets offer better protection than their predecessors. However, the effectiveness of these advancements is difficult to isolate due to several confounding factors. The NFL has only been electronically tracking concussions since 2015, making historical comparisons unreliable, and changes in concussion protocols over time have altered the way injuries are diagnosed and reported. Additionally, while the league promotes its commitment to player safety, concerns remain that its financial interests and public image play a significant role in how concussion data is presented.

Beyond helmets, other factors such as rule changes, player behavior, and increased awareness of brain injuries also influence concussion rates, making it difficult to determine the true impact of helmet improvements alone. Furthermore, skepticism from the scientific community suggests that no helmet, regardless of technological advancements, can fully prevent concussions in a high-impact sport like football. While helmet innovation will continue, it is clear that addressing concussions requires a more comprehensive approach—one that goes beyond equipment design and considers broader changes to the game itself.

References

A brief history of concussion as a public health issue. (2024). Concussion Alliance. https://www.concussionalliance.org/history-of-concussion

Agarwal, N., Thakkar, R., & Than, K. (2024, April 11). *Sports-related head injury*. American Association of Neurological Surgeons. https://www.aans.org/patients/conditions-treatments/sports-related-head-injury/

Casson, I. R., Viano, D. C., Powell, J. W., & Pellman, E. J. (2010). Twelve years of National Football League concussion data. *Sports Health, 2*(6), 471–483. https://doi.org/10.1177/1941738110383963

Cecchi, N., Liu, Y., & Camarillo, D. (2023, June 9). New high-tech helmets may protect American football players from debilitating concussions. *EurekAlert!* https://www.eurekalert.org/news-releases/991921

Cohan, N. (2023, November 26). *Why a hot idea for making football safer is such a hard sell for the NFL*. Slate. https://slate.com/culture/2023/11/football-helmet-safety-innovation design.html

Crow, K. (2021, August 27). *The history of football helmets*. Xenith. https://xenith.com/blog/the-history-of-football-helmets?srsltid=AfmBOor4BpJo20H8vo3TXhN4WXCpOD1ovR0-b4u2YLuI7KHNkegbi8pO

Dangers of concussions in the NFL. (2023). Pro Athlete Law Group. https://proathletelawgroup .com/dangers-of-concussions-in-the-nfl/#:~:text=Chronic%20Traumatic%20 Encephalopathy%20(CTE)%20is,eventually%20kill%20the%20nerve%20cells

Eichelkraut, C. (n.d.). *The NFL earns a first down in concussion prevention*. Brain Injury Association of Arizona. https://biaaz.org/brain-waves/the-nfl-earns-a-first-down-in concussion-prevention/

Ezell, L. (2013, October 8). *Timeline: The NFL's concussion crisis*. FRONTLINE.https://www .pbs.org/wgbh/pages/frontline/sports/league-of-denial/timeline-the-nfls-concussion-crisis/

Grashow, R., Terry, D. P., Iverson, G. L., et al. (2024). Perceived chronic traumatic encephalopathy and suicidality in former professional football players. JAMA Neurology, 81(11), 1130–1139. https://doi.org/10.1001/jamaneurol.2024.3083

Head to head: The National Football League & brain injury. (2019). NYU Langone Health, Division of Medical Ethics. https://med.nyu.edu/departments-institutes/population-health/divisions-sections-centers/medical-ethics/education/high-school-bioethics-project/learning-scenarios/the-nfl-brain-injury#:~:text=In%202015%2C%20the%20 NFL%20released,term%20harm%20that%20concussions%20cause

Helmet innovation: More and better choices, fewer concussions. (2022, September 16). NFL Player Health and Safety. https://www.nfl.com/playerhealthandsafety/equipment-and-

innovation/engineering-technology/helmet-innovation-more-and-better-choices-fewer-concussions#:~:text=The%20rate%20of%20improvement%20of,from%20which%20players%20can%20choose

Helmet test protocol. (2019, September 11). Biomechanics Consulting & Research, LLC (Biocore). chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://static.www.nfl.com/image/upload/v1597314821/league/x1555pmeldebfym2qwky.pdf

Hughes, Thomas P. (1987). The Evolution of Large Technological Systems. In W. Bijker, T. P. Hughes, and T. Pinch (Eds.), *The Social Construction of Technological Systems* (pp. 45 76). MIT Press.

Joodaki, H., Bailey, A., Lessley, D., Funk, J., Sherwood, C., Crandall, J. (May 6, 2019). Relative Motion Between the Helmet and the Head in Football Impact Test. *ASME. J Biomech Eng.* 141(8): 081006. https://doi.org/10.1115/1.4043038

Kent, R., Forman, J., Bailey, A. M., Funk, J., Sherwood, C., Crandall, J., Arbogast, K. B., Myers, B. (2020). The biomechanics of concussive helmet-to-ground impacts in the National Football league. *Journal of Biomechanics, 99*, 0021-9290. https://www.sciencedirect.com/science/article/pii/S0021929019308085?casa_token=NK1

Kraus, H. (2023, April 28). *The evolution of NFL helmets*. Prezi. https://prezi.com/p/boaa3arxmqsd/the-evolution-of-nfl-helmets/

Lessley, D. J., Kent, R. W., Funk, J. R., Sherwood, C. P., Cormier, J. M., Crandall, J. R., Arbogast, K. B., & Myers, B. S. (2018). Video analysis of reported concussion events in the National Football League during the 2015-2016 and 2016-2017 seasons. *The American Journal of Sports Medicine, 46*(14), 3502–3510.https://pubmed.ncbi.nlm.nih.gov/30398897/

MacDonald, F. (2020, April 10). *History of the football helmet*. Atavus. https://atavus.com/history-of-the-football-helmet/

Maroon, J. C., Mathyssek, C., & Bost, J. B. (2014). Cerebral concussion: A historical perspective. *Progress in Neurological Surgery*, 28, 1–13. https://doi.org/10.1159/000358746

McKessy, J. (2024, November 28). *Tua Tagovailoa concussion history: How many has Dolphins QB suffered?* Palm Beach Post.https://www.palmbeachpost.com/story/sports/nfl/dolphins/2024/11/28/tua-tagovailoa-injury-history-miami-dolphins-qb-concussions/76586759007/

Most, D. (2024, October 11). *Research on CTE and concussions changed the NFL. Experts say that's not enough*. Boston University. https://www.bu.edu/articles/2024/research-on-cte changed-thenfl/#:~:text=As%20public%20awareness%20of%20CTE,participated%20in%20high%20school%20football.

National Football League. (2025, January 30). *Injury data*. NFL. https://www.nfl.com/player healthandsafety/health-and-wellness/injury-data/injury-data

Reed, T. (2024, February 2). *NFL reports lower-body injuries down, concussions up in 2023 season*. The Athletic. https://www.nytimes.com/athletic/5245956/2024/02/02/nfl-concussions-lower-body-injuries/

Newall, M., & Sawyer, J. (2024, February 8). *Majority of parents would let their children play tackle football if they wanted to*. Ipsos. https://www.ipsos.com/en-us/majority-parents-would-let-their-children-play-tackle-football-if-they-wanted#:~:text=Just%20one%20in%20five%20Americans,to%20participate%20in%20tackle%20football

Sailofsky, D. (2022, September 10). *The NFL has gone to great lengths over time to obfuscate the clear link between football, chronic traumatic encephalopathy (CTE), and violence*. The Guardian. https://www.theguardian.com/sport/2022/sep/10/nfl-fan-no-longer-watch-football-cte

Salvi, P. A. (2014, October 10). *The NFL's head-scratching concussion statistics*. Salvi, Schostok & Pritchard P.C. https://www.salvilaw.com/blog/nfls-head-scratching concussion-statistics/

Seifert, K. (2023, February 3). *NFL says regular-season concussions increased 18% in 2022*. ESPN. https://www.espn.com/nfl/story/_/id/35582897/nfl-says-regular-season-concussions-increased-18-2022

Solomon, R. (2023, August 28). *How football helmets are made*. ProQuip Inc. https://proquipinc.com/how-football-helmets-are-made/

Strom, P. (2020, January 25). *Concussion history: The NFL's MTBI committee 1994*. Strom Law Firm. https://stromlaw.com/concussion-history-the-nfls-mtbi-committee-1994/

Sullivan, B. (2024, September 23). *A third of former NFL players surveyed believe they have CTE, researchers find*. NPR. https://www.npr.org/2024/09/23/nx-s1-5121019/nfl-players-cte-survey

Tretter, J. C. (2022, October 26). *Concussion protocols: Where we stand now*. NFL Players Association. https://nflpa.com/posts/concussion-protocols-where-we-stand-now