

Brian Dahdal

Dr. Bowman and Dr. Jareb

HN-300-B

13 December 2022

The Imperative And Financially Feasible Implementations Necessary In The Battle Against
Traumatic Brain Injuries In Professional Football

Every minute that society waits to bring traumatic brain injuries in professional football to the forefront is another minute of disservice to the innocent athletes that dedicate their lives for society's entertainment. It is imperative to deduce if there exists a cost effective budgetary way for the NFL to put new resources, technologies or protocols into place to more effectively prevent and address the traumatic brain injuries that have plagued professional football players for decades, notably concussions and Chronic Traumatic Encephalopathy (CTE). The need to research and understand this topic is as prevalent as ever, especially considering the situation involving Miami Dolphins quarterback Tua Tagovailoa that recently shook the nation.

Tagovailoa, an up and coming quarterback fulfilling his childhood dreams, was failed by the Dolphins, the NFL, and by football itself when he was cleared to play in a Thursday night game four days after experiencing concussion-like symptoms in a game that took place the previous Sunday. As a matter of fact, he was allowed to return to that very game held on Sunday, even after hitting his head on the turf, as it declared he was dealing with a "back" injury. An unfortunate result ensued, as once a defensive linemen of the Cincinnati Bengals collided with Tagovailoa on the game held Thursday, he hit his head once again on the turf, but this time the young quarterback had to be stretchered off after displaying a "fencing response" that is normally a clear indication a traumatic brain injury has occurred. With his hands left in an

unorthodox position on national television, the nation was left stunned with numerous questions as to how an athlete that likely suffered a traumatic brain injury less than a week earlier was cleared to play in this Thursday night game which ultimately led to him experiencing yet another serious traumatic brain injury in a short time frame, a situation that could at times be fatal. Clearly, this innocent athlete and his safety were failed by the resources, technologies, and protocols the NFL had in place at the time, presenting a clear need for change and new implementations. There do exist relatively cost effective resources, technologies and protocols the NFL should invest in to more effectively prevent and address traumatic brain injuries, especially concussions and CTE, that come in the form of better performing helmets, movement from artificial turf to natural grass, and the introduction of a buffer period that would hold players out longer before returning to play which would serve as an extra protection mechanism in the NFL's concussion protocol to ensure the highest level of player safety in relation to traumatic brain injuries.

Establishing The Foundation Of What Traumatic Brain Injuries Are

The establishment of what traumatic brain injuries are, specifically concussions and CTE, is required in order to better grasp the topic at hand. Concussions, the more mild injury of the two, will be discussed first. A dialogue on the more serious of the two, CTE, will then follow.

According to an article by Michael Galgano et al. (2017), concussions can be defined as “mild TBIs without any gross structural damage secondary to a nonpenetrating TBI.” These traumatic brain injuries result from collisions to the head area, such as when professional football players get hit in the head by the helmets of other players or when their heads collide with the turf being played on after falling over. Concussions come with a host of symptoms, which, according to the article by Michael Galgano et al. (2017), can include minor confusion all the

way to the victim going unconscious for a time frame that can reach up to a few whole minutes. The real issue presents itself in the form of “second impact syndrome” which is also vividly described in the article. For it to occur, a person, most likely some sort of athlete, has to experience an initial concussion which is then followed by a second concussion or concussion-like event shortly afterward. It is likely brought on by the athlete being allowed to return to play too early in the recovery process, which puts them at risk to experience this syndrome. The most shocking piece of information provided by the article was when it stated that “the mortality rate ranges from 50% to 100%.” This mirrors the situation Tagovailoa found himself in, meaning him being cleared to play could very well have been fatal, a clear indication of the failure present in the NFL’s concussion protocols to even let this come anywhere close to happening.

Further delving into more specific symptoms of concussions, an article by two MDs, Jeffrey Kutcher and Christopher Giza (2014), does a superb job outlining these. Interestingly enough, unconsciousness is not needed for a concussion to be diagnosed, as amnesia is much more common in people that have experienced concussions as it has been seen in approximately 30-50% of cases according to the article. Almost undoubtedly, the most commonly reported symptom of a concussion is a headache, which makes sense given concussions impact a person’s brain. Physical signs also exist and these come in the form of nausea, dizziness, and atypical speaking. One of the more surprising but important points made in this article is that symptoms can also affect the emotional side of a person such as through depression or higher levels of anxiety. The chances of a concussion being present increase as more and more of these symptoms pop up. With concussions being firmly defined, it is now time to transition to a discussion on CTE.

Chronic Traumatic Encephalopathy, or CTE, is also considered in the earlier article by Michael Galgano et al. (2017). It is characterized in the article as a “delayed manifestation” brought about by “repetitive mild TBI.” A saddening consequence of developing CTE is what the article refers to as “psychiatric disturbances” which can ultimately lead to thoughts and behaviors associated with suicide. This seems to especially be true for very well-known professional athletes in famous sports, especially those who have played or spent time in the National Football League, supporting the need for the NFL to more effectively prevent and address traumatic brain injuries in its sport. CTE symptoms are not just limited to behaviors associated with suicide, as other notable signs of CTE could include tremors, having a hard time paying attention or focusing, gaps in the victim’s memory, and having trouble using different parts of one’s body in an efficient manner. This traumatic brain injury is on the much more serious side as compared to concussions discussed earlier. Together, they help establish a real need to review what resources, technologies, or protocols should be invested in to make sure these TBIs are prevented and addressed to the highest degree possible in professional football. Looking at the data of how often TBIs occur in the NFL is now in order.

Examining How Often Concussions and CTE Have Occurred In The NFL

To better get a sense of how prevalent these traumatic brain injuries are in the National Football League, a dive into the empirical data of how often these TBIs have happened in recent years is necessary.

An article written by Ira Casson et al. (2010) delves into twelve years of concussion data in the NFL from 1996-2007 which is important to review as a baseline to see where the NFL was in terms of concussion occurrences a couple decades ago, an important first step. The data was collected based on recordings from NFL athletic trainers and team doctors which were uniform

across all twelve years. A telling statistic from the article was that there were about .38 recorded concussions per game from 2002-2007, only a 7.6% decrease from the earlier time frame also examined. The earlier time frame, 1996-2001, had .42 recorded concussions per game, an indication that the number of concussions per game stayed relatively similar from the first time frame examined to the conclusion of the second time frame. This is concerning because it may point to the NFL historically doing a poor job at the prevention of concussions amongst its athletes since the number of concussions per game did not greatly improve over the twelve year time frame analyzed. The minor silver lining from the article was that it seems the NFL got better at addressing concussions once they occurred over the twelve year time frame. This is because the amount of players who made a return to play in under 7 days went down 8% in the second time frame, from 2002-2007. Additionally, the amount of players who went unconscious and returned to play in under 7 days also decreased by a promising 25% when the second time frame was looked at, a sizable improvement from the first 6 year time frame. This could mean that the NFL thankfully became better at addressing concussions and taking them more seriously from 2002-2007, a positive step in the addressing of concussions. The article still leaves a big desire to see improvement in the prevention of concussions based on its presented findings. Looking at more recent data is now in order to see how things have changed, whether for better or worse.

An article from Christina Mack et al. (2021) provides much more promising information regarding the amount of concussions suffered when looking at data from 2015-2019. According to this article, when looking at the regular season, there were about 177.0 annual in-game concussions per season on average from 2018-2019, which is a decrease of 23% from the previous time frame of 2015-2017. During 2015-2017, there were about 230.0 annual in-game

concussions per season on average when examining the regular season, showing a significant decrease in just a couple years. This is very promising as compared to the data from a decade earlier as the NFL seems to have gotten better at the prevention of concussions in recent years. The first dataset showed a trend of the NFL getting more effective at addressing concussions once they happened as time went on, and this second dataset shows a trend of the NFL getting more effective at the other side of the coin, which is the prevention of concussions. These are very important and promising developments for the players, and it establishes that progress can indeed be made and boosts the desire to find ways to even further build on the progress the NFL has already made.

Transitioning into data on CTE, an article by Jesse Mez et al. (2017) goes through 202 donated brain samples of former football players delivered from a program to deduce the rate of CTE present in the samples. The results were shocking, though unfortunately not that surprising. From these 202 samples, the article states that CTE was “neuropathologically diagnosed” in 177 of the people who used to play football who had their brains donated, representing 87.6% of the total! Looking more specifically at brains who belong to former NFL players, they made up 111 brains of the total 202. Of these brains, 110 were diagnosed with CTE, representing 99% of the total NFL brains looked at. Only one brain from 111 did not come to be diagnosed with CTE, a truly mind-blowing statistic. What this data points to, as the article mentioned, was that “CTE may be related to prior participation in football.” It seems that all levels of playing football are affected, and this is a very serious issue especially when it comes to playing at the professional level in the National Football League. With such high proportions of former players coming down with CTE, it exponentially boosts the need to find as many new implementations as possible to more effectively prevent and address traumatic brain injuries, especially concussions

and CTE, for the sake of all the athletes who dedicate their lives to this sport, a topic that makes up the heart of this essay. With the definitions of both TBIs established and with the empirical data now analyzed, it is time to dig deep into what cost-effective resources, technologies, and protocols can be implemented to help combat this critical issue once and for all.

Potential Implementations Prior To Introducing My Three Main Recommendations

Prior to discussing my three main recommendations that were deduced by putting together all of my research, it is important to go through a rundown on other potential implementations that could prove beneficial but did not make my final recommendations list.

Chapter 6 of a book by Robert Graham (2014) offers one potential improvement the NFL can encourage which starts at the youth level, and that is increasing knowledge and awareness of concussions at the youth football level which is meant to travel with them throughout their playing careers. It mentions that there were gaps and deficiencies in the knowledge young athletes possessed when it came to the various signs and symptoms associated with concussions. An interesting piece of information it turns to is a fairly large study that centered around kids ages 9-18. These kids were given the chance to experience and be a part of a workshop talking about concussions which ended up yielding fairly promising results. They demonstrated great strides in how much they knew about concussions after experiencing the workshop as once given a quiz on symptoms of concussions and how to react to concussions 80% of them passed. This was up from just 34% who passed before participating in the workshop, a remarkable improvement. This study indicates that increasing education at the youth level has potential to really benefit athletes in terms of being able to learn more about concussions. Specifically, from my perspective, The NFL could potentially benefit by encouraging the education of not just concussions but also proper tackling techniques and how to avoid helmet to helmet hits at the

youth football level, which would hopefully travel with the players throughout the entirety of their careers. By implanting this knowledge into the heads of players early on, it increases the likelihood of them mastering proper tackling and how to not lead with the helmet. The NFL, being as influential as it is, would definitely be able to put pressure on youth football to implement this extra education if it so chooses, and based on how beneficial it could be in the prevention of concussions, there is no harm in this being one of the changes made to combat TBIs. The education could potentially come in the form of workshops like in the study or live demonstrations by coaches and experts. Both methods should be instrumental in raising concussion knowledge and awareness at an early age. The next potential implementation comes in the form of an area the NFL may have more control over.

An article written by Dominic Malcolm (2021) provides a unique option that may serve a beneficial role in addressing traumatic brain injuries, especially concussions, for the National Football League. It suggests that granting medical professionals already working with the National Football League more autonomy could be better than what is in place currently. Right now, they mostly serve the role of diagnosing concussions on the sidelines once a game is happening and aiding in the decision of whether a player should return to play or not. While this is a system that is working its way in the right direction, it is not fully maximizing the medical professionals as resources and using them to their fullest advantage. The article states how the medical professionals should play integral roles in the constant management of the traumatic brain injury and throughout the rehabilitation process as the player works their way back to full health. There is no one more well versed in the area of traumatic brain injuries than the medical professionals who dedicate their lives to knowing everything about them, so it is in the best interest of the players to make sure the experts are being fully maximized as resources. If too

much power is given to the head coach, as an example, over the medical professional to make judgements and decisions about an injury then bias could easily trickle in. The coach may be blinded by wanting to win at all costs possible as that defines if they get to keep their job or not. If that happens, player safety may not be put at the forefront and players may be cleared to return prematurely, seriously putting them at risk. That is why the point made by the article seems to be a good one, in that medical professionals will make sure player safety is the highest priority, so them obtaining greater autonomy in decision making could be key in more effectively addressing traumatic brain injuries, especially concussions. It also mentions using the public, and all members of society, to create sustained pressure for change to occur and to make it the norm that concussions are not to be tolerated, but this seems very difficult to put into practice as society rarely fully agrees on anything, so uniting enough people around this single cause may end up being time consuming and unfeasible. Concussions are not going to wait around for the public to agree to unite against them, so other measures that can be implemented faster may prove to ultimately be more effective. Now that these other potential implementations have been thoroughly given the light of day, it is time to step into my three final recommendations and the rationale behind each one.

Three Final Recommendations Formulated Through The Totality Of My Research

It is now imperative that I conclude with my three final recommendations formulated by compiling and analyzing all of the sources that make up my research on this topic. While not all are cheaper as compared to what the NFL has in use today, the benefits these implementations will offer far outweigh the minimal additional costs associated with putting some of them into place.

The first firm recommendation I have for the NFL is to encourage, and potentially mandate, the use of better performing helmets for all players, regardless of position. The NFL and NFLPA, which is the players association, recently released the results of their helmet testing which is conducted annually, and these results indicate which helmet types have the best performance and are the most effective. Considering these have the backing of the NFLPA, which always puts player safety and their interests first, they are more than trustworthy. The top four best performing helmets are those made by VICIS, with their Zero2-R models ranking at the top. Riddell, which has been the main maker of helmets for the NFL in years past, also is near the top with its SpeedFlex and Axiom models being the most notable. The first part of this recommendation comes in that it has to be mandated that players can only choose from these helmet types to be able to participate in games, as everything else beneath the helmets mentioned above perform worse. While they may still be good helmets, they are not nearly as effective as the Riddell and VICIS models discussed above, as supported by the results, so to truly be the most effective in preventing TBIs, the NFL has to mandate using these best performing models. These give players the best chances to avoid traumatic brain injuries in a naturally violent sport, so this is an integral piece of the recommendation. Looking at the second part of this recommendation, I would more specifically recommend mandating the Riddell Axiom and VICIS Zero2-R helmets for players. Right now, the most common helmet in usage is the Riddell SpeedFlex helmet, with notable players, like New England Patriots Quarterback Mac Jones, using this model. As has already been established, there is definitely room for improvement for the NFL in preventing TBIs, so continuing to allow the SpeedFlex, the most common helmet already in use, may not be the most optimal and effective decision. The Axiom and Zero2-R have the potential to boost the effectiveness of preventing TBIs more so than SpeedFlex. This is

because the Zero2-R is higher than it on the performance results released and Axiom is a much newer model that is characterized as having enhanced technology that can track the number of collisions to the person wearing the helmet. Axiom also has better fitting capabilities and is said to be more flexible and have higher “responsiveness to impact” according to Riddell’s VP of research and product development. Looking at the cost aspect, the Axiom goes for around \$750 per helmet, while VICIS goes for about \$900 per helmet. For context, the SpeedFlex goes for around \$500 per helmet, which is not too far off from these other models that have potential to be more effective at preventing TBIs. There are 2208 players in the NFL, 16 on each practice squad and 53 on each roster. There are also 32 total teams in the NFL. If the Axiom model is purchased for all players, it would cost \$1,656,000 (32×750). The VICIS would cost \$1,987,200 if purchased for every player. The SpeedFlex would cost \$1,104,000 if purchased for every player. This means that for less than one million dollars, the NFL could offer players much better performing helmets with potential to more effectively prevent TBIs than SpeedFlex. That is nothing when compared to the billions the league makes annually. Therefore, a move to Riddell Axiom helmets and VICIS Zero2-R would both be cost-effective and increase the prevention of TBIs in the NFL, making this my first firm recommendation. While they are not cheaper, the additional costs of these helmets is miniscule compared to the benefits they offer. The NFL can easily afford the extra but miniscule cost to put these helmets into place, meaning it would be nowhere near a burden to implement them. This all points to this being a cost-effective and medically effective move that the NFL should make.

The second of my firm recommendations is to make a move from artificial turfs to natural grass. One of my previous sources by Robert Graham (2014) mentions the difference between playing on turf vs grass. While it says results vary on if one is worse than the other, it

alludes to the fact that artificial turf is generally harder and creates a faster speed to the game than natural grass. It also mentions one study that did find concussions, and head or neck injuries in general, were much greater on turf than on grass, with 4.31 happening on turf for every 1000 player hours as compared to 2.37 happening on grass for every 1000 player hours. Another source by Tiffany O'Callaghan (2022) that measured deceleration in g-forces found that deceleration on turf was 23 g higher than on natural surfaces, another indication of the risks turf may pose. The cost element also doesn't hinder this recommendation. The cost for equipment, supplies and labor for turf can range from \$23250-\$127000, while grass ranges from \$42800-\$205500. This again is not a major difference in cost for a league that pulls in billions of dollars annually. If it was a difference of \$500,000 or more, then that would no longer be cost effective, but as it stands, these ranges are not far enough apart not to warrant a switch to natural grass. With artificial turf seemingly posing a higher risk to players than natural grass, and with the costs between the two not being very far off, this ultimately leads me to call for the NFL to move from artificial turf to natural grass. The NFL should not hold onto anything that jeopardizes player safety even a little bit, and that is what turf seems to be doing according to the sources above, leading to this recommendation.

The final recommendation I have is to introduce a buffer period that would hold players out longer before returning to play which would serve as an extra protection mechanism in the NFL's concussion protocol. According to medical doctor Mike Harris (2022), the normal time for a concussion to heal is about 10-14 days, while in the NFL players can be seen returning in just 6-7 days, about half of the normal time to heal. This is a bit concerning, as it may mean concussions are not allowed to fully heal as things currently stand. That is where this buffer period comes into play. It could be an extra couple days and start after a player is initially cleared

to return to play. Just in case the concussion was not fully allowed to heal, this buffer would step in and make sure the player is held out longer than they normally would be to air on the side of caution. Even though a player may be ready after initially being cleared, less than a week is likely not enough time to truly allow a TBI to heal, so adding this buffer period of a couple extra days is another mechanism that helps to leave no doubt a TBI is completely healed before someone starts playing again. If someone is normally cleared in 7 days, the buffer would allow them to return in no less than 9 days at the minimum, which is more in line with how long a concussion takes to heal. It would have ensured Tua playing Thursday night would have never have happened, which is the rationale behind this recommendation. Cost wise, it would cost the NFL nothing to update its concussion protocol to include this, and its benefits could be monumental in making sure TBIs are fully healed. Therefore, by being both cost effective and having the potential to greatly aid in addressing and treating traumatic brain injuries, this is my third and final recommendation.

Conclusion

Through the use of better performing helmets, a switch to natural grass from artificial turf, and the introduction of a buffer period into the concussion protocol, there do exist cost effective resources, technologies, and protocols that the NFL should implement to be more effective in preventing and addressing traumatic brain injuries, especially concussions and CTE. The better performing helmets could greatly aid in preventing TBIs for a very little additional cost, making them great options for every player to wear. Artificial turf seems to pose a higher risk to players than natural grass, so a shift to grass should take place, especially since the cost between them is not that much different. Finally, the buffer period would make sure concussions are given enough time to fully heal, and this update to the protocol would cost the NFL

essentially nothing, making it the clear cut third firm recommendation. What kind of society would this be if player health and safety, and human safety in general, was not put at the forefront?

Works Cited

Casson IR, Viano DC, Powell JW, Pellman EJ. Twelve Years of National Football League Concussion Data. *Sports Health*. 2010;2(6):471-483. doi:10.1177/1941738110383963

This article outlines data on concussions in the NFL over a twelve year time frame using information retrieved from trainers and physicians working in the NFL. It showcases some major symptoms that were recorded such as dizziness. It also talks about percentages of players who were held out and those who returned to the game which give good insight into how concussions were handled over the course of the twelve year time frame. Such data is an important starting point to finding out the history of concussions in the NFL before being able to give recommendations later on in my essay.

Galgano, Michael et al. "Traumatic Brain Injury: Current Treatment Strategies and Future Endeavors." *Cell transplantation* vol. 26,7 (2017): 1118-1130. doi:10.1177/0963689717714102

This article gives a great overview of various kinds of traumatic brain injuries that an individual can suffer, such as for the professional athlete through repeated impact to the head. There is also a rundown on the available traumatic brain injury treatments that people, like professional athletes, can be given. It concludes with a discussion on where traumatic brain injury treatment may be headed with a possibility that experimental methods could further enhance it. The explanations for concussions and CTE that it provides could prove very beneficial to helping me describe these traumatic brain injuries towards the beginning of my essay.

Such descriptions of these traumatic brain injuries will set the foundation for writing the rest of my essay, and this article could be a great resource for formulating those descriptions.

Graham, Robert, et al. *Sports-Related Concussions In Youth: Improving the Science, Changing the Culture*. National Academies Press, 2014.

Chapter 6 of this book goes over various methods that could be used to curb concussions with a particular focus on youth sports, but elements still translate to football in general. One way to possibly reduce concussion risk is to bring down rotational acceleration, and helmets have some evidence backing them that they have the capability to mitigate just that presented in the chapter. There is not as conclusive as evidence when it comes for the fields being played on, but there is some data that could show playing on artificial turf is worse in terms of producing concussions as compared to natural grass which may be considered. Education is also examined to see if athletes at a young level could use more of it in order to potentially mitigate concussion risk which can be carried throughout their entire playing careers. This chapter could definitely be used to learn more about various methods that could contain the potential to help prevent concussions even at the NFL level.

Kutcher, Jeffrey S, and Christopher C Giza. "Sports concussion diagnosis and management."

Continuum (Minneapolis, Minn.) vol. 20,6 Sports Neurology (2014): 1552-69.

doi:10.1212/01.CON.0000458974.78766.58

This article goes into detail about various aspects of concussions specifically, with a breakdown on three degrees of certainty that what is being examined is a

concussion and not another issue. It provides typical symptoms that can be looked for when examining if someone has a concussion, as well as the proper steps that are followed whenever examination is taking place during a live game on the sidelines. It also walks through potential reasons for athletes to completely retire from contact-oriented sports, which is far from an easy decision for those who dedicate their lives to professional sports. This article gives great insight that I can use to see what measures society uses today to diagnose concussions and what is looked for to allow players to return to games. In order to see the ways the NFL can improve when it comes to concussions, I first need this kind of background information to understand where things currently stand, and this article does a good job of providing such information.

Mack, Christina D et al. "Epidemiology of Concussion in the National Football League, 2015-2019." *Sports health* vol. 13,5 (2021): 423-430. doi:10.1177/19417381211011446

This article dives into data over a five year period for the concussion rate in the NFL from 2015-2019. The trend that came out of looking over the data was a reduction in the concussion rate over previous years, and it became important to see why such a trend occurred. The article provides all the key implementations the NFL has put into place in recent years that may have played key roles in creating this trend, and these included player and coach education, getting rid of any blindside blocks, and requiring players to change poorly-functioning helmets to ones that perform more effectively. There is even a graphic showing the number of concussions from year to year alongside what changes the NFL made from year to year, allowing one to see what worked and what did not. Seeing what

the NFL invested in in years past is crucial to my research, as I need to get a good sense of what changes they have experimented with in the past. From there, I can determine if certain areas could use more investments than others to reduce the number of concussions even further. The efforts they have already made provided in this article are good benchmarks to build off of as I continue looking into what new resources or protocols could make sense to also invest in to aid in either the prevention or treatment of traumatic brain injuries, namely concussions and CTE.

Malcolm D (2021) The Impact of the Concussion Crisis on Safeguarding in Sport. *Front. Sports Act. Living* 3:589341. doi: 10.3389/fspor.2021.589341.

This article summarizes the NFL's battle with Congress in regards to them ignoring player safety in 2009 which created much needed awareness regarding concussions and their importance. It also provides some interesting points on how concussions can be fought which are unique to other typical methods of prevention. One point was to delegate greater power to medical professionals to truly maximize the prevention of concussions as just using them in diagnosing concussions is limiting and not maximizing them as a resource. Another point was to use culture and society as a tool to maximize concussion prevention. Society should stand for vehemently opposing concussion risk and every member has a job in helping to call for concussions to be taken seriously as a vital issue to obtain wanted changes. These methods are unique to other methods I have looked into and could be useful as further resources to consider when making recommendations in my essay.

Mez J, Daneshvar DH, Kiernan PT, et al. Clinicopathological Evaluation of Chronic Traumatic Encephalopathy in Players of American Football. *JAMA*. 2017;318(4):360–370.

doi:10.1001/jama.2017.8334

This article goes through a study based on 202 donated brain samples to try to identify the presence of CTE in former football players who played at any point in life, from high school to the NFL. The most striking piece of evidence obtained that could prove very useful in my essay was about how 110 of 111 brains from former NFL athletes in the study were found to show CTE, which equates to an astonishing 99% of the NFL athlete brains utilized exhibiting CTE. The deduced conclusion based on the study was there they may be a relationship between CTE and someone previously having played football. The unfortunate but telling aspect of the study was how most brains from former NFL athletes were not just diagnosed with CTE, but most were also found to have a severe case of CTE as well. The data behind this study could be utilized in my essay to support that playing football, especially at the professional level, could put players at risk of getting CTE at some point in their lives. This boosts the need to identify ways to improve resources, technologies, or protocols to especially target prevention of traumatic brain injuries to the greatest extent possible in my essay.

Journal of Orthopaedic & Sports Physical Therapy,

<https://www.jospt.org/doi/full/10.2519/jospt.2014.5298>.

This article goes through a study on how concussions may be lower in higher altitude games as opposed to ones played in lower altitudes. Statistics are provided to showcase this based on the information collected and it is an

interesting point to further research to see why this may be the case. It is another element to use in my research to study the factors that could impact concussions in the NFL.

“The NFL and Players Union Agreed to an Updated Concussion Protocol.” *NPR*, NPR, 9 Oct. 2022, <https://www.npr.org/2022/10/08/1127713600/nfl-concussion-protocol-tua-tagovailoa>.

Lea, Chris. “NFL Should Update Concussion Protocol According to Triangle Doctor.” *WRALSportsFan.com*, WRAL, 6 Oct. 2022, <https://www.wralsportsfan.com/nfl-should-update-concussion-protocol-according-to-triangle-doctor/20509320/>.

“Costs: Grass vs. Synthetic Turf.” *Safe Healthy Playing Fields Inc.*, <https://www.safehealthyplayingfields.org/cost-grass-vs-synthetic-turf>.

“ZERO2.” *Vicis*, <https://www.vicis.com/zero2>.

O'Callaghan, Tiffany. “Athletes May Have Higher Risk of Concussion on Artificial Grass.” *New Scientist*, New Scientist, 7 Oct. 2022, <https://www.newscientist.com/article/2341481-athletes-may-have-higher-risk-of-concussion-on-artificial-grass/>.

“NFL and NFLPA Release 2022 Helmet Testing Performance Results: NFL Football Operations.” *NFL and NFLPA Release 2022 Helmet Testing Performance Results | NFL Football Operations*, <https://operations.nfl.com/updates/the-game/nfl-and-nflpa-release-2022-helmet-testing-performance-results/>.

“Riddell Launches Axiom, the Latest Helmet to Combat Concussions.” *Yahoo! News*, Yahoo!, <https://news.yahoo.com/riddell-axiom-helmet-concussions-140040227.html>.

“The Average Cost for an Artificial Turf Football Field.” *Turf Factory*, 24 June 2022,

<https://turffactorydirect.com/2021/02/08/the-average-cost-for-an-artificial-turf-football-field/#:~:text=Artificial%20turf%20costs%20around%20%242.00,around%20%244.00%20per%20square%20foot.>