

CSC1108 BSc Data Science

Formal Project Proposal



Project Title:	Examining the factors influencing injuries in the NFL
Student ID:	21374881, 21356173
Student Name:	Ronan Kelly, Eoin Quinn
Student Email:	ronan.kelly96@mail.dcu.ie eoin.quinn55@mail.dcu.ie
Supervisor:	Mark Roantree

Executive Summary

The aim of our project is to build an injury prediction model for the NFL that can identify the key characteristics that influence the risk of injury. With injuries being a major issue within the NFL we hope our research will help to reduce these impacts to help teams both in performances and financially.

The objective is to leverage machine learning to analyse NFL game data alongside injury data to discover patterns that will allow us to predict future injury risk. The main challenges for us in this project are with data availability and imbalance as well as the complex nature of AI models. Our project will use various techniques and models to create the most accurate predictions while also allowing the results to be approachable for someone without the relevant AI knowledge.

This project should be able to provide valuable insights to NFL management as well as team management to allow them to make informed decisions with regard to player safety and injury prevention. This hopefully will impact player safety standards across all sports, while also allowing teams to remain competitive and to maintain financial stability.

1. Motivation & Background

The area of injury prediction within the NFL is a crucial piece of study that can have significant implications for players, teams and the league as a whole. Annually, there are an estimated 1.2million injuries across all levels of American football[2], this shows the necessity for an all-encompassing approach to injury prediction in the NFL. These injuries not only have effects on the players themselves, resulting in long-term health problems or even possibly retirement, but it can also have significant impacts on team performance and their subsequent profitability. The NFL generates roughly \$16bn annually[11], indicating the sheer amount of money that is in the NFL, and having their best players out through injury can have a significant knock-on effect on these revenues. If the best players are always out injured performances fall, leading to a lack of interest and ultimately a hit to both match day revenue and commercial revenue, if fans both stop showing up at matches or watching on television.

More importantly, injury prevention is a matter of player safety and career longevity. Given the high impact nature of the NFL, big hits and their subsequent injuries are commonplace and so it's important to try and limit these possible career threatening moments. The question of head injuries and concussions has long since been a topic of debate across various sports the world over, none moreso than the NFL and the heavy-hitting that is so prevalent in today's game can be cause for more long-term and significant impacts on players' health. The condition of Chronic traumatic encephalopathy(CTE) and its occurrence amongst NFL players is a somewhat more recent area of study however, despite that around 96% of deceased ex-NFL players have been diagnosed with the disease[7]. This is clearly an urgent issue that needs to be addressed to ensure that former players can continue to live long and happy lives post-retirement.

Unfortunately, the task of predicting injuries is a complex one, with various possible factors it means it is necessary to conduct large scale research to even just discover which variables would have any sort of influence on injuries. The factor selection is also incredibly vast from weather-type to play-style; all of these can have varying importance in any one facet of injury risk. Also, given the highly specialised nature of these machine learning models the results become incredibly difficult to describe to people without the necessary domain knowledge, this calls for the use of more explainable AI that will allow for easier interpretability of how the models work and their results for people without this knowledge. Data or lack thereof is another major issue for creating these sorts of models; the area of injury prediction is relatively novel when considering the use of machine learning to achieve it. Because of this there is not a consensus database that comprehensively catalogues all the necessary information to conduct this sort of research. Data imbalance is also a problem for

developing a machine learning model, the occurrence of injuries are hugely underrepresented in any NFL play-by-play database, meaning that it's essential that sampling techniques take place to make sure the model is able to predict injuries in a meaningful way for analysis.

This all being said, it's incredibly important that research towards large scale injury prediction within the NFL is conducted so as to limit long-term life-altering injuries for its players. This research would allow all stakeholders from coaches to medical staff and even the players themselves to make well-informed decisions about their health and recovery plans. Personalised recovery and training would be able to become a regular part of preseason sessions as well as throughout the season improving player safety and extending careers. With better injury prediction models, the NFL would not only gain a competitive and financial advantage but would also become world leaders in the area of injury prediction and prevention.

2. Problem Statement

The primary problem we aim to address is understanding and predicting injury occurrences in NFL American football games. Injuries are unfortunately a massive part of sports and cause professional and amateur sports teams and players a lot of issues. Whether it's physical health, mental health, individual performance or team performance, any type or injury or number of injuries can affect a teams' ability to win. Our objective in this project is to identify the most influential factors that lead to injuries occurring in NFL games and to build models that can assess injury risk on a per-player basis. By utilising statistical methods and machine learning algorithms we hope to build a model capable of predicting injury occurrence based on game-related and player specific factors, such as workload, weather conditions and more.

The scope of our work involves applying machine learning techniques to publicly available NFL data, such as injury reports, game statistics, and other contextual information. Our intention is to analyse the factors that contribute heavily to injuries within the NFL, having gained an idea what these factors are likely to be through reading literature of other similar studies. From our current understanding, injuries can happen for all sorts of reasons, be it freak accidents, lack of recovery from a recent training session or game, returning too soon after an earlier injury. In a lot of these cases what causes an injury can be unpredictable, which is why we hope to collect as many data points as possible to potentially use as model features to have a chance to predict injury occurrence. We also understand that certain players are more prone to getting injured than others which can skew any models we apply. While injuries may sometimes appear as random, our aim is to uncover patterns and factors that increase the likelihood of injury occurrence, which we believe we can do based on utilising techniques we've seen in other studies and considering the data we have available to us as mentioned in the Methodology section.

3. Literature Review

3.1 - Introduction to Injury Prediction in Sports

An extensive amount of research has been conducted in the world of sports injury prediction and prevention particularly in the NFL. The sheer amount of data and money involved makes the need for an effective injury prediction system vital for team success. The NFL generated somewhere in the region of \$16bn in 2019[11] showing that there is the money available to conduct studies on injury prevention. The effect of even one player's injury can not only reduce on field performance but it can also hurt the team financially through lost revenues from negative results[1]. According to a study conducted in 1991 an estimated 1.2 million athletes are injured across all age groups in one entire football season[2]. This number is staggering and shows the need for a comprehensive prediction model that could hopefully be implemented and benefit all throughout the football system. We have seen in recent years in both the NFL and Rugby Union the push for the mitigation of head injuries as a result of poor tackle technique; however it remains a massive problem in both sports. Recent studies have found that the NFL concussion rate was on a steady increase in the mid 2010's reaching as high as 16% in 2017/18,[7] and these effects can cause massive issues in the lives of NFL players as it opens them up to a risk of developing Chronic Traumatic Encephalopathy (CTE) in their later lives as we have seen around 96% of deceased ex-NFL players have been diagnosed with CTE[7]. The lower body is also at major risk when playing NFL as the 1991 study found that injuries to the lower extremities (knees and ankles) accounted for 50% of all injuries in their study[2]. These are often caused due to poor field and weather conditions but also through poor tackling technique. A similar study in 2001 which focused on injuries to Quarterbacks showed that 82.3% of injuries were caused by direct contact while overuse injuries only accounted for 15% of total quarterback injuries, demonstrating that tackling technique and style is clearly a problem within the NFL and action must be taken to limit the amount of injuries we see today[5].

3.2 - Influence of External Factors on Injury Rates

There are a number of external factors that can influence the likelihood of someone getting injured in the NFL from pitch conditions to team performance which I will examine in this section. Pitch conditions have been a point of contention in recent years as it seems more players are developing serious injuries in their lower extremities such as ankles and knees. A study conducted in 2009 found that artificial surfaces produce greater torque and rotational stiffness[12] which can likely lead to more injuries. Weather is another crucial variable that can influence injury risk. Studies have shown that sports that have a winter calendar tend to experience greater injury rates than those of summer calendars or with indoor arenas[13]. Research has also shown us that playing on a wet surface can lead to more ligament injuries[1]. Cold exposure can also lower muscle efficiency leading to more injuries[1]. The amount of travel and rest provided to NFL players between matches is another important variable given the nature of the sport, it requires lots of travel and lots of heavy contact, rest between games is important. However,

according to a study conducted in 2023, the cumulative travel distance of each NFL team had little statistical significance on the amount of injuries they suffered[6]. The timing of the bye week also had very little statistical significance on injuries[6] implying that rest is maybe not as important as previously thought. One finding of that 2023 study was that teams who made it to the playoffs tended to have less injuries than teams who fell short[6]; this is maybe because lower performing teams are forced to play their best players even when hurt in an attempt to make the playoffs, while better teams have the luxury to rest theirs. Rule changes are probably the main external variable that the governing body has control over. The league could develop rules to make tackling safer to reduce injuries. This has been shown in the past to have a big impact on injuries as seen between 1975-1984 when the rate of cervical spine injury fell dramatically due to new regulations being brought in around tackle technique and safety[2].

3.3 – Genetic and Physiological factors in injury likelihood

A player's likelihood of injury is influenced by a variety of factors, including their genetics as well as psychological factors. A player's mental state can also significantly influence their risk as it can cause them to make bad decisions leading to injury. Studies suggest that players who are injured tend to have a higher susceptibility to stress compared to players who aren't injured[14]. Research also suggests that the ratio of internal workload such as psychological factors and external workload from GPS data to be an important predictor for injuries[8]. The Functional Movement Screen(FMS) is a test of an athlete's movement techniques to see if the athlete's movements could put them at risk of injury. A study conducted on 46 football players on the FMS found that players who scored lower than 14 on the test were 11 times more likely to get injured in the first 3 weeks of the season[9]; this shows the importance of proper movement technique in preventing injuries. Genetics can also play an important role in predicting a player's possibility of injury. Studies have shown that a family history of ligament injuries is prominent in athlete injury[15]. These studies show us that in some cases athletes are just genetically predisposed to getting injured.

3.4 – Injury Distribution

The most common injuries that occur to NFL players are lower body injuries in the hamstrings, calves, ankles and knees as these account for almost 50% of American football injuries[2], with strains and sprains accounting 40% of injuries and fractures dislocations accounting for 10% and 15% respectively[2]. The current incidence rate per 1000 players for injuries within the NFL is between 23.1 and 64.7[11] which does seem quite high, however, in comparison with professional rugby which has an incidence rate of between 83.9 and 90.1[16], although their method for calculation may be different. A study conducted on NFL quarterbacks between 1980 and 2001

found 1534 injuries in this period[5], these quarterbacks missed on average 18.8 days with a median of 6 days[5]. This really shows the importance of being able to predict when a player will get injured as this can prevent players from missing future games. This same study found that 70% of shoulder studies occurred while the quarterback is being tackled[5], showing that finding methods to limit contact to the quarterback while also understanding when to pull the player to prevent injury is vital to maintaining team performance throughout the season. A team's playstyle can also play an important role in predicting how likely a player is to get injured, a team who runs a lot with their quarterback would be more likely to face injuries as it puts them at risk of contact injuries. The study on quarterback injuries found that 12.6% of all quarterback shoulder injuries happen when the quarterback is acting as a ball carrier[5]. This may seem low however, quarterback runs account for roughly 1% of plays within an NFL game[17]. The most common type of shoulder injury that happens to quarterbacks is an AC joint sprain while being tackled, on average quarterbacks missed 22.1 days with a median of 12.5 days[5]. Now we are going to look at how we might be able to predict these injuries and the challenges involved with that task.

3.5 – Challenges with injury Prediction Modelling

The idea of injury prediction using machine learning is certainly not a new phenomenon as people have attempted to do this across various sports. A major problem that people have discovered when trying to create these models is the 'black box' nature of these machine learning models, this makes it very difficult for implementation as the results can be difficult to interpret and lack any real reporting transparency[1]. Another major problem for these previous studies is data availability, given the specified domain of the problem set it's very difficult to create a comprehensive model for all sports, meaning all current studies have relied on limited data based on a specific team or specific leagues[1][3]. Data imbalance is a massive challenge for all previous studies; the nature of how infrequent injuries occur means that the ratio of instances where injuries do take place to instances where injuries do not take place is massively skewed in favour of the latter category[3][7][8]. This makes modelling incredibly difficult and emphasises the importance of sampling methods and generating synthetic data to ease modelling. The Injury prediction space remains relatively new and so therefore the consensus on which features are most appropriate and beneficial for the model is not a well investigated question, new studies should focus on encompassing a wider range of features, this will help to discover the most important features and will help to build a comprehensive model that may be more beneficial across multiple sports[1][8].

3.6 – Preventative Measures and Risk Management

As mentioned above an intelligent system for injury prevention will be incredibly beneficial for coaches, as it can provide them actionable insights

that will help to decrease the likelihood of injury for their players[1]. Preseason and off-season sessions should focus on conditioning and limit physical contact drills so as to prevent injuries while also putting players in a position to be able to take contact without experiencing injuries[2]. It's also important that an injured player is not rushed back and his return-to-play is managed focusing on conditioning as a preventative measure to ensure there isn't a risk of reaggravation[2]. Studies have emphasised the importance of a rigorous preseason regime to prepare players for the NFL season[4], the effects of a limited preseason were seen during the covid struck 20/21 season where an increase in injury rate throughout the season[4]. When considering the predictive models, a comprehensive list of internal and external factors should be considered when creating such models, also by leveraging various models and classifiers the system can better adjust to a players specific needs and be able to provide personalised injury prevention strategies.[1]

3.7 – Conclusion and Future Directions

As discussed, any future work in this topic should focus on expanding the data collection methods currently in place, this will allow more accurate and versatile models to be built[1]. Also by consolidating all this information into one comprehensive source, it will allow for greater research to take place across multiple sports, which will have a knock on effect of improving the overall usefulness of these models for coaches. A key challenge for this research is the 'black box' nature of the models and so placing a greater emphasis on any future research on creating more explainable AI and having better transparency, this will create more trust in the models and lead to greater levels of implementation. This review examined the various factors be that internal or external that affect the likelihood of injury and so focusing on analysing and optimising the factors so as to build the most efficient and accurate models is vital. This review discussed the problems current research has on data imbalance, measures must be implemented to limit the effects this imbalance will have on the models being created. Ultimately, the implementation of predictive analysis for injuries will have a massive effect on how the sport of NFL is coached by providing greater insights for management while also helping to minimise the influence injuries will have on the revenue for teams and the league.

4. Methodology

Solving the problems involved in this project requires continuously working through numerous steps and challenges from data collection, data cleaning and processing to feature selection and model development. We plan to examine the most influential factors that cause injuries in the NFL utilising each of these skills having reviewed and considered previous studies into injuries in the NFL and in other sports.

Our first essential problem to solve regards collecting useful data that can help us with anything injury-related such as injury prediction, feature importance when predicting injuries. Official NFL injury data is considered public information,

meaning there are no issues with collecting this data via web-scraping etc. or any GDPR problems. This means that we can freely scrape the NFL Injury Report, and the NFL Injured Reserve, each of which have been updated on a weekly basis by the NFL over the last few years. This data provides us with weekly injury updates for each player and team, allowing us to track when a player gets injured, how long they are injured for, the severity of the injury, the type of injury etc. The NFL games schedule is also public information, this means we can collect information about each game such as venue, weather conditions, game statistics, injuries occurred in a game along with anything relevant to potentially causing an injury in a specific game. We also have the ability to collect in-depth information about the events that occurred in games that could correlate with the occurrence of injuries.

This data collection allows us to conduct necessary data cleaning and processing to develop clean dataset(s) we can use to develop models for the primary tasks of the project like predicting injury occurrence and examining feature importance. We hope to be able to build and tweak numerous models so that we can collect multiple sets of results to give us the best chance of achieving success. Once we obtain an accurate model, we plan to extract the most effective features that contribute to the models' predictions.

It's clear to us from our literature review that our goals are definitely achievable and that our research questions can be answered. There have been numerous studies on injuries in field sports including soccer and American football. We have seen from reviewing these studies the numerous factors' that tend to lead to or cause injury. These factors are anything from training load, weather conditions, the type of pitch a match takes place on to things like sleep, stress, genetics, the list is nearly endless. Of course, we do not have access to an infinite amount of information about each player to be able to take all of these potential factors into account. However, we can collect enough publicly available information to tune a hopefully accurate model.

Although we have developed skillsets across various programming languages environments, we expect that the majority of our software and programming to be through python notebooks. From our personal programming development so far, we both believe that Python is our strongest language and we are confident that we can complete each of our required tasks using Python Notebook environments. We plan to leverage multiple python libraries such Pandas, Matplotlib, Seaborn, Scikit-Learn, Beautiful Soup, Requests, Googlesearch Python, among others if necessary. We may also utilise other tools like Excel and Power BI for storing and visualising data. We believe we have the necessary skills to adjust and use other programming environments should we be required to for specific tasks.

As mentioned, our coding tasks start with data collection. We will use the Requests library to scrape data from URLs providing NFL Injury Report, Injured Reserve, games schedule, game reports. We can also use the BeautifulSoup library in python to parse through HTML code for webpages if necessary. Other libraries useful for our data collection include Selenium and GoogleSearch Python which we may use if we are unsuccessful scraping with Requests in some cases. Following this we will primarily use Pandas for any data processing necessary with the raw data we collect.

After this we can build models with our processed data using Scikit-Learn libraries. From our literature review we have been able to see numerous similar studies and have gauged an understanding of what models tend to be used and what models seem to work best for predicting injury occurrence in the NFL. From previous studies we have overall seen Support Vector Machines used 7 times, Logistic Regression models three times, XGBoost models used twice, just to name a few. The most successful and modern techniques seem to be Tree-based models. Based off of this information we plan to firstly try to predict injury occurrence for each player playing in an NFL game. Ideally, we would like to achieve an adequately accurate model this way. However, we can additionally tweak and adjust these models or try other classifiers to achieve our best possible results.

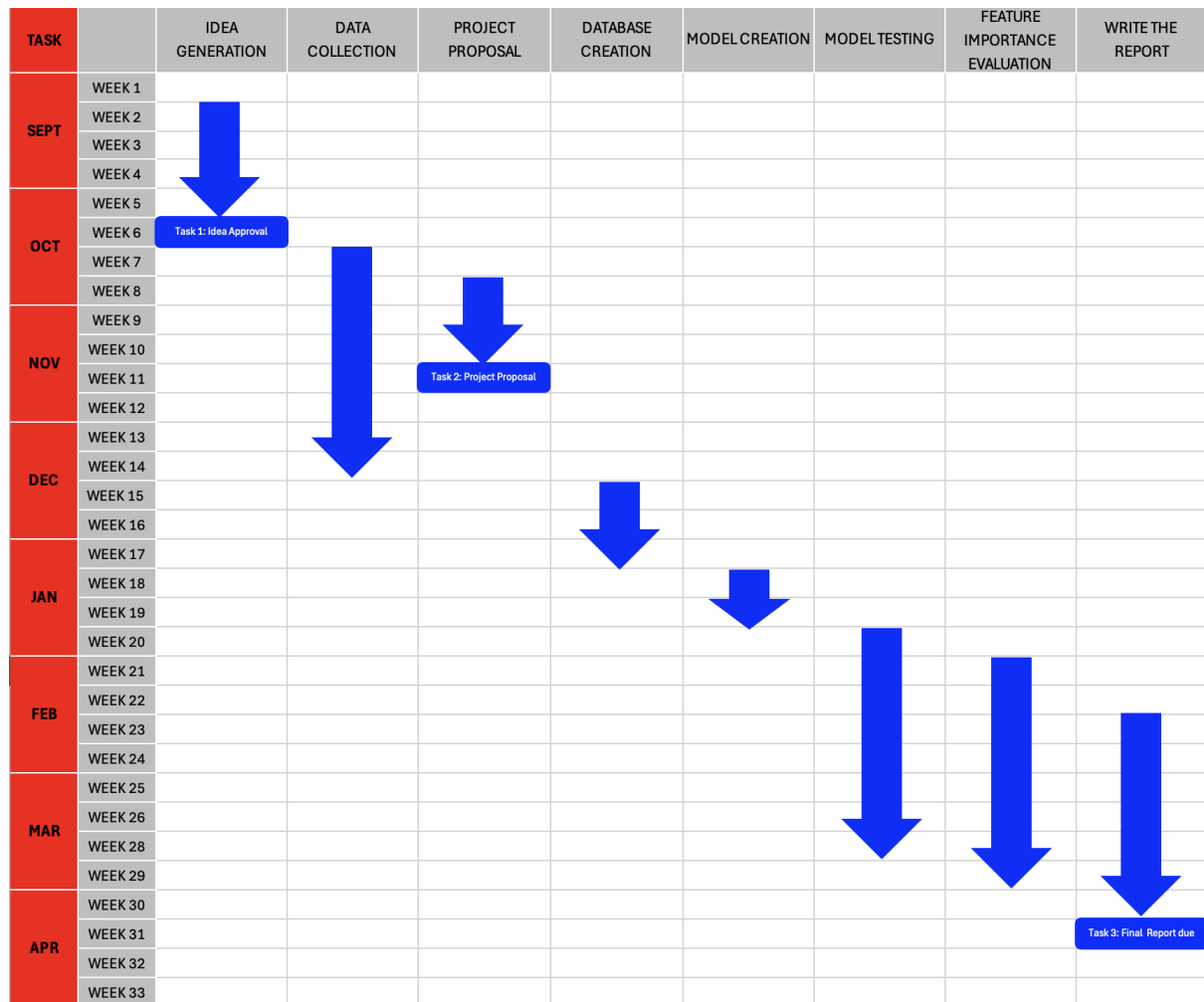
We have numerous data sources for our investigation, having mentioned earlier the NFL injury report is publicly available online, which each NFL team updates on a weekly basis, showing the list of players with minor injuries in a given week, also providing additional information such as the type of injury they have and the players' participation in training status that week (whether they took part fully, partially or not at all). We also intend to use the NFL Injured Reserve which consists of a list of injured players on each NFL team with more serious injuries that take longer to recover from. If a player is put on the injured reserve, he is ineligible to play for the team for 4 weeks, and the team can sign a replacement for the period of the injury. ESPN has publicly available game reports on each game since 2019, these game reports show a list of injuries that occurred in each game. These data sources can be useful to us as they provide basic information we can use for multiple purposes. Whether it's tracking the number of injuries that occur per game, the number of players that get injured in a given season, or utilising this data to create features for our models, for example we could track "time since last appearance on Injury Report" and feed that to our model as a feature since this could represent how recent a players' last injury was. However, our most crucial information surrounding what is causing these injuries comes from advanced game statistics. This concerns the numerous avenues different NFL games can take like the number of times a team passes the ball or runs the ball in a game, how many times a player has to tackle another, the different tasks assigned to each player based on their position, just to name a few. Each of these types of nuanced factors we expect to correlate with injury occurrence. We are able to obtain this advanced information via Pro Football Focus (PFF), who have been for "over 15 years as the world leader in advanced football data, tools, & analysis"[18]. There are also other sources that provide similar data points to what PFF provides, each of these sources including PFF require a subscription to access their data, and once paid for can be used for any purpose.

We expect to experiment with numerous models using different algorithms and features. Initially trialling multiple combinations of features that contribute to the occurrence of injuries. We intend to create features using the data collected from our data sources, whether checking if a player has had a serious injury that has caused them to miss a full season in recent years and using that as a feature, or using how much rest a player was given in a game based on their snap count. Thanks to having numerous informative data sources, we have multiple avenues and different potential

features to use and evaluate. As mentioned earlier we intend to start with tree-based algorithms such as decision trees or random forests, testing out numerous features extracted from our data sources to achieve optimal results. The output of our experiments will likely show a predicted injury status class for each player that has played in a game. Using our ESPN NFL game reports we can identify what players were injured or not injured in a given game. We can then predict this outcome using model features as described earlier. We can then evaluate our results using standard metrics for Machine Learning models including accuracy, precision, recall, F1 scores, looking at the resulting confusion matrix.

5. Project Plan

For the first few weeks we began researching topics, until we got to the idea approval stage of the project or the 'go or no go' phase where we got our idea accepted. From this point we will begin creating the database, we will scrape data from the various websites mentioned above and consolidate the information into one database from which we will create our models, while this is taking place we will also begin writing up our project proposal. From the start of semester two we plan to begin creating testing various models and techniques to get the most accurate results. Alongside this we will also start evaluating the most important features to see which ones have the biggest influence on injury prediction. We hope to spend most of the last 7/8 weeks writing up the final report.



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