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## Article

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Article

# The Long-Term Game: An Analysis of the Life Expectancy of National Football League Players

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**Abstract:** The National Football League (NFL) has recently received significant negative media attention surrounding the safety of its players, revolving largely around the long term health risks of playing the sport. Recent premature deaths and instances of suicide associated with chronic traumatic encephalopathy and other football related injuries have brought the sport under increased scrutiny. By comparing mortality rates of the general population to mortality rates of players using publically available data from the 1970 and 1994 NFL seasons, we test whether participation in football is significantly harmful to the longevity of the players. We conclude that, in total, players in the NFL have lower mortality rates than the general population. However, there is evidence that line players have higher mortality rates than other players and that those who played more games have higher mortality rates than those who played fewer games.

**Keywords:** National Football League; premature deaths; survivability; injuries

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## 1. Introduction

The National Football League (NFL) has recently been scrutinized about the impact of playing the game on mortality and quality of life. High profile cases such as the suicides of Atlanta Falcons safety

Ray Easterling, Chicago Bears defensive back Dave Duerson, and San Diego Chargers linebacker Junior Seau, as well as the tragic premature death of long-time Pittsburgh Steeler Mike Webster, have certainly pushed these issues to the forefront of media attention. Cantu [1] and Samson [2] confirm that both Webster and Seau had chronic traumatic encephalopathy (CTE), and Mecham [3] confirms evidence of CTE in both Duerson and Easterling. CTE is most often caused by severe and repeated head injuries and leads to brain degeneration and dementia [4].

In August 2013, the NFL attempted to settle a lawsuit brought by former players claiming that the league downplayed the risks of concussion-related brain injuries. The NFL agreed to provide \$765 million to compensate victims, pay for medical exams for 4500 plaintiffs and other retired players, and engage in medical research [5]. Due to questions regarding the adequacy of the payout, however, the settlement was not granted initial approval by Judge Anita Brody who noted that, "...it is difficult to see how the Monetary Award Fund would have the funds available over its lifespan to pay all claimants..." [6]. A better understanding of risk factors relating to premature deaths are of interest both to the teams individually, and the NFL collectively.

However, the financial implications go much further than just settling the grievances of past players. The future of the NFL could be at stake through two channels. First of all, the perception already exists that the NFL is a guilty pleasure where spectators enjoy the game at the long-term expense of the health of the participants [7]. Mounting evidence that playing in the NFL causes serious health problems or shortens life could cause a drop in the NFL's popularity similar to what has happened to the sport of boxing [8]. Secondly, due to health concerns there has already been a drop in football participation rates at the youth level. Between 2010 and 2012, a period of heightened awareness of head injuries in the NFL, there was a 6.7% drop in the number of players ages 6 through 14 playing Pop Warner Football, the largest decline in the long history of nation's biggest youth football program [9]. A continued drop in participation would impact the pipeline of players into the NFL as well as future interest in the sport in general.

While anecdotal evidence of players dying prematurely is both alarming and the subject of considerable attention in the popular press, can it be statistically shown that playing in the NFL leads to a lower life expectancy for ex-players? This paper will examine whether NFL players have a higher mortality rate than the general population and will look at which factors affect the mortality of NFL players.

Baron and Rinsky [10] show that former NFL players have a much lower mortality rate than the general population, as well as some other interesting patterns. For example, defensive linemen have higher rates of cardiovascular disease than the general population, and black players were more likely to develop cardiovascular disease than white players. Lehman *et al.* [11] also find that NFL players have lower mortality rates than the general population while having a higher incidence of neurodegenerative mortality. These papers show evidence that high profile deaths can skew the perception of the risk of playing in the NFL.

This paper is related to other papers that examine (excess) mortality in professional sports. Related literature is discussed in Koning and Amelink [12], who show that Dutch professional soccer players have a lower mortality rate than the general Dutch population. Sanchis-Gomez *et al.* [13] and Marijon *et al.* [14] show that mortality among French professional cyclists who participated in the

Tour de France is lower than that of the French population. These studies suggest that professional athletes have better health than the average population, increasing longevity.

Our paper adds to the literature by using a flexible probability model developed in Koning and Amelink [12] that can be used to compare NFL mortality rates to those in the general population. In addition, we also use Cox hazard rate models [15], to estimate survival of players at an individual level and to determine the impact of games played, position, and race on player mortality.

Our results show that NFL players have a lower mortality rate than the general population (by race and overall) in both the 1970 and 1994 seasons. In the 1970 season, offensive and defensive line players have higher mortality rates than those in the other positions, and non-white players have higher mortality rates than white players. Most importantly, players who played more than 2 seasons worth of games have higher mortality rates than those that have played less. In the 1994 season, line players have higher mortality rates than those who are in the skilled positions, but other factors are not statistically significant.

Sections 2 and 3 describe the data and models used in the study, while Section 4 displays the results. Section 5 concludes and discusses some more potential research.

## **2. Data**

We examine player cohorts for two seasons, 1970 and 1994, and include all players who appeared in at least one game during either of those seasons. The 1970 cohort consists of 1244 players, and the 1994 cohort has 1600 players. The 1970 season was chosen for two reasons. First, using an older season ensures that survival probabilities in the general population become sufficiently low and observational data with the players have enough natural attrition to be meaningful. Second, 1970 was the first season after the National Football League-American Football League merger effectively doubling sample size of players and also ensuring that players in the sample had relatively standardized equipment and playing conditions. It should be noted, however, that the data set includes all players who played during the 1970 season, not just who started their careers in the 1970 season, so the player statistics may include games played prior to the merger. The 1994 season included to see whether changes in the game, including better equipment as well and stronger and faster players, has had an effect on player mortality. In addition, the 1994 cohort has, anecdotally, experienced an abnormally large number of premature deaths.

Most of the player data for the 1970 and 1994 NFL seasons was collected on “Pro-Football-Reference.com” [16] which has season-by-season statistics for every player to have appeared in an NFL game as well as dates of birth and death for all players. Data on race was revealed through online picture searches of the players. Players were placed into one of three positional categories: skill positions, which include wide receivers, tight ends, quarterbacks, and running backs; line positions, which include players on the offensive and defensive lines, who tend to be much larger and heavier than other players; and other, which includes mostly defensive players who are not linemen plus some punters and kickers.

Table 1 lists summary statistics for the 1970 and 1994 seasons. There were 1244 total players who participated in the 1970 season and 1600 players in the 1994 season with identifiable race data. Approximately two-thirds of the players who played in the 1970 season are white, but by 1994 only

one third of the players are white. Across both whites and non-whites, the percentage of players still alive is very similar. This survival rate equality is not reflective of the survival rates of whites and non-whites in the general population where non-whites have experienced significantly higher mortality rates than whites. For both seasons, the average age was in the mid-twenties at the relevant time. The split between positions was generally even in 1970, with a shift towards line players and away from skill players in 1994. Players in 1994 participated in more games over their career than those in 1970, at least in part due to the regular season being extended by two games. In 1970, whites played about a season's more worth of games over a career than non-whites, but in 1994 non-whites played more than two-and-a-half more seasons than whites. This fact is also reflected in the percentage of whites and non-whites that played at least two season's worth of games in 1970 compared to 1994.

**Table 1.** Summary Statistics.

Season	Variable	All	White	Non-White
1970	Alive in 2012	1091	690	401
	Alive in 2012 (%)	87.7	88.35	86.61
	Dead in 2012	153	91	62
	Dead in 2012 (%)	12.3	11.65%	13.39%
	Age in 1970	25.1	25.45	24.52
	White (%)	64.98	-	-
	Line (%)	33.2	36.24	28.08
	Skill (%)	33.92	32.01	37.15
	Other (%)	32.88	31.75	34.77
	Games Played	95.73	100.12	88.35
Long Career (%) (27+ career games played)		88.1	91.66	82.07
1994	Alive in 2012	1559	523	1036
	Alive in 2012 (%)	97.44	97.03	97.64
	Dead in 2012	41	16	25
	Dead in 2012 (%)	2.56	2.97	2.36
	Age in 1994	25.79	27.13	25.11
	White (%)	33.69	-	-
	Line (%)	38.12	35.99	39.21
	Skill (%)	26.12	27.83	25.26
	Other (%)	35.75	36.18	35.53
	Games Played	108.18	80.68	122.16
Long Career (%) (27+ career games played)		88.62	74.03	96.04

### 3. Models

The following survival model is an adaptation of the one developed in Koning and Amelink [12] for Dutch soccer players. The idea is to compare the expected survival of individuals based on the general population at the appropriate time to the observed survival of NFL players. Let  $x$  be the age of an individual,  $t$  be the base (or starting) year, and let  $s$  be the number of years after  $t$ . Also, let  $N(x, t)$  be the number of individuals of age  $x$  alive at time  $t$ . Therefore,  $N(t)$ , which is the number of individuals (regardless of age) that are alive at time  $t$  is as follows.

$$N(t) = \sum_x N(x, t) \tag{1}$$

Let  $(x, t, t + s)$  be the probability that an individual of age  $x$  at time  $t$  survives to time  $t + s$  (or in other words, survives  $s$  years from time  $t$ ). So, for example, an individual survives one year from time  $t$  with a probability  $P(x, t, t + 1)$ . As such, the probability that an individual of age  $x$  at time  $t$  survives to time  $t + s$  can be represented by the product of successive one-year probabilities.

$$P(x, t, t + s) = \prod_{n=1}^s P(x, t + n - 1, t + n) \tag{2}$$

The expected number of individuals of age  $x$  alive at time  $t$  that are still alive at  $t + s$  can be represented as follows.

$$N(x + s, t + s) = N(x, t) * P(x, t, t + s) \tag{3}$$

Using equation (1) above, the total number of individuals alive at time  $t$  that are expected to be alive at time  $t + s$  is the following.

$$N(t + s) = \sum_x N(x + s, t + s) \tag{4}$$

$N(t + s)$ , the expected number of individuals that survive to time  $t + s$  can then be compared to the actual number of players that survive to time  $t + s$  to see if these players experience different longevity than the general population of a similar age composition.

This approach compares mortality between the population of NFL players, and the US population in general. Besides that, we also examine whether observable risk factors influence the individual risk of mortality within the population of NFL players. To do so, we estimate a Cox proportional hazard model was also constructed to determine factors that impact mortality with the following equation.

$$\lambda(t) = \lambda_0(t)e^{(\beta'x)} \tag{5}$$

The covariates used are games played, position played, and race. In this case, the baseline hazard ( $\lambda_0(t)$ ) captures mortality among NFL players in general. In this specification, we do not allow for time-varying covariates. That is, we only allow for individual specific covariates. The relevant time scale is the age of the player, and we allow for censored observation using the usual start/stop approach as in Therneau and Grambsch [15] and Fox [17].

**4. Results**

The expected number of survivors, classified by age, based on population probabilities of survival and the model above can be calculated in order to make a comparison with the actual numbers of players (also classified by age) surviving. Tables 2 and 3 list the comparisons overall and by race for 1970 and 1994.

**Table 2.** Actual Survival and Expected Survival (1970 Season).

Age	All				White				Non-White			
	Number	Alive	Expected Alive	P-value	Number	Alive	Expected Alive	P-value	Number	Alive	Expected Alive	P-value
21	116	107	94.97	0	64	60	53.41	0.03	38	34	25.46	0
22	186	176	150.28	0	110	107	90.65	0	71	64	46.42	0
23	168	156	133.71	0	94	87	76.36	0	67	62	42.67	0
24	150	126	117.35	0.09	90	81	71.92	0.02	53	39	32.82	0.09
25	154	137	118.18	0	97	85	76.09	0.03	52	48	31.23	0
26	100	89	75.11	0	64	58	49.18	0.01	35	30	20.35	0
27	104	87	76.29	0.02	64	54	48.07	0.11	37	30	20.79	0
28	75	63	53.61	0.01	56	46	41.02	0.17	19	17	10.29	0
29	60	50	41.68	0.02	43	35	30.63	0.18	16	14	8.34	0
30	47	34	31.62	0.54	28	22	19.33	0.31	19	12	9.48	0.26
31	32	29	20.76	0	24	22	16	0.01	7	6	3.33	0.06
32	18	12	11.21	0.81	15	10	9.61	1	3	2	1.35	0.59
33	14	10	8.33	0.43	13	9	7.96	0.78	1	1	0.43	0.43
34	10	9	5.66	0.05	9	8	5.24	0.09	1	1	0.4	0.4
35	4	4	2.14	0.13	4	4	2.2	0.13	-	-	-	-
36	4	1	2.01	0.37	4	1	2.07	0.36	-	-	-	-
38	1	1	0.44	0.44	1	1	0.45	0.45	-	-	-	-
42	1	0	0.3	1	1	0	0.31	1	-	-	-	-

**Table 3.** Actual Survival and Expected Survival (1994 Season).

Age	All				White				Non-White			
	Number	Alive	Expected Alive	P-value	Number	Alive	Expected Alive	P-value	Number	Alive	Expected Alive	P-value
19	1	1	0.97	1	1	1	0.97	1	-	-	-	-
20	7	7	6.79	1	-	-	-	-	7	7	6.62	1
21	66	66	63.97	0.27	14	14	13.61	1	52	52	49.09	0.12
22	163	163	157.78	0.01	37	37	35.93	0.63	126	126	118.68	0
23	255	249	246.46	0.49	62	61	60.12	1	193	188	181.28	0.05
24	202	195	194.85	1	43	42	41.62	1	159	153	148.88	0.25
25	175	170	168.41	0.69	49	48	47.32	1	126	122	117.54	0.15
26	154	149	147.79	0.84	48	44	46.23	0.1	106	105	98.45	0.01
27	135	130	129.16	1	44	43	42.26	1	91	87	84.1	0.32
28	116	113	110.62	0.38	50	47	47.88	0.47	66	66	60.66	0.01
29	87	87	82.68	0.02	48	48	45.82	0.17	39	39	35.62	0.05
30	58	57	54.92	0.37	32	31	30.44	1	26	26	23.59	0.17
31	70	68	66.02	0.44	45	44	42.66	0.73	25	24	22.5	0.51
32	44	41	41.31	0.75	20	19	18.88	1	24	22	21.41	1
33	30	28	28.03	1	18	17	16.92	1	12	11	10.6	1
34	14	12	13.01	0.26	9	8	8.42	0.45	5	4	4.37	0.49
35	7	7	6.47	1	6	6	5.59	1	1	1	0.86	1
36	4	4	3.67	1	4	4	3.7	1	-	-	-	-
37	9	9	8.22	1	7	7	6.44	1	2	2	1.68	1
38	1	1	0.91	1	1	1	0.92	1	-	-	-	-
39	2	2	1.8	1	1	1	0.91	1	1	1	0.82	1

For the 1970 cohort for almost all ages, the actual number of NFL players still alive in 2013 is statistically significantly higher (at the 5% level) than what is predicted by the population survival model. In 1994, the actual numbers of players surviving by age is also generally higher than expected, but the observed number of survivors is typically not statistically significantly larger than the expected number of survivors. There are two possible explanations for this result. First, most of the players from the 1994 cohort are still alive and therefore the statistical power of this test to uncover differences in survival rates is lower than statistical tests for the 1970 cohort. Second, it is possible that the increasing size, speed and strength of players in the modern game subjects more recent players to higher long-term risks. Thus, the much higher survival rates of older NFL veterans may not be replicated in more recent age groups. That being said, it is still notable that the number of deaths in this cohort is below the number of deaths that would be expected in the general population, which goes against the popular notion that this cohort had a particularly high mortality rate.

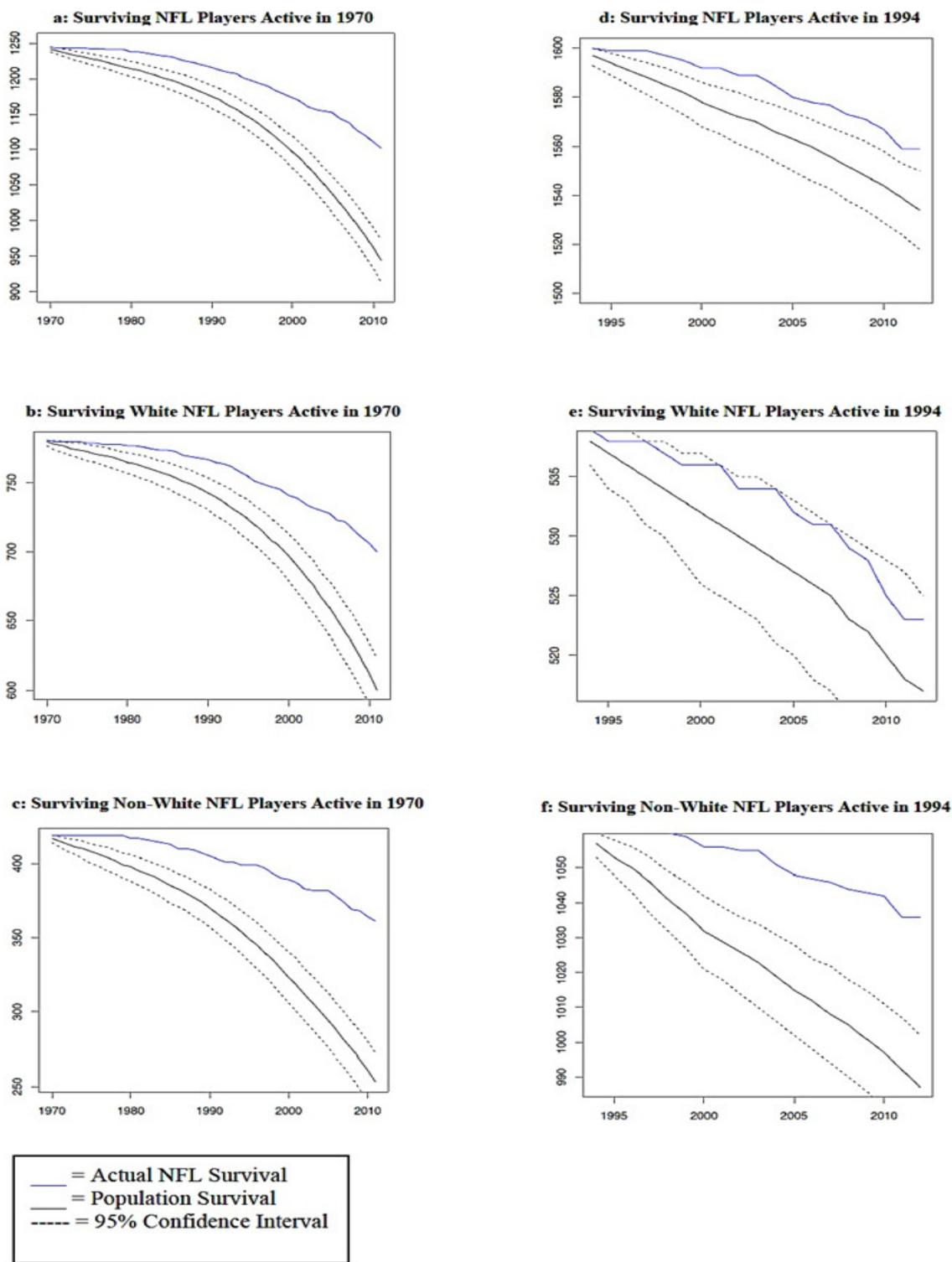
Figure 1a–f charts overall survival by year *versus* the number expected to survive by year. For both the cohorts, the actual survival plot is above the expected survival plot. In fact, the only time when the actual survival plot is even within the 95% confidence interval of survival is for white players who played in the 1994 season. Perhaps this reflects the unusual mortality of that particular season, but the confidence interval is very wide due to the fact that one would not expect there to be many deaths for such a young cohort.

Table 4 reports the results of the Cox hazard rate model. In both seasons, the baseline hazard is that of non-white line players with a career length in the bottom 10% of their respective cohort. For both 1970 and 1994 this means career lengths of approximately two NFL seasons or less. A negative coefficient implies a lower hazard rate of death (compared to the baseline hazard) and a positive coefficient implies increased risk. The results are quite striking in for the 1970 cohort. White players have a 33% lower hazard rate (which is the odds ratio reported in Table 4 subtracted from one) than a non-white players. Skill position players and other players have a 38% and 46% lower hazard rate, respectively, than the baseline. Both of these results are in line with the findings of Baron and Rinsky [10] who found that defensive linemen and black players both experienced high rates of cardiovascular disease. It is acknowledged, however, that individuals with body types similar to line players are more susceptible to ailments such as cardiovascular disease solely due to their body mass alone. Of most interest, however, is that the players with more than 2 seasons of experience have a striking 347% higher hazard rate than those players who played in the NFL in 1970 but had only a short NFL career. Other specifications of games played are also robust to this analysis.

**Table 4.** Cox Hazard Rate Model Results.

Attribute	1970 Season			1994 Season		
	Coeff.	Odds Ratio	P-Value	Coeff.	Odds Ratio	P-Value
White	-0.4	0.67	0.02	0.03	1.03	0.93
Skill	-0.48	0.62	0	-1.65	0.19	0.01
Other	-0.63	0.54	0.01	-0.34	0.71	0.3
Long career	1.5	4.47	0.01	-0.3	0.74	0.6

Figure 1. Surviving NFL Players by Year and Date.



The 1994 cohort produces substantially different results. White players no longer exhibit lower mortality than non-white players. In addition, only skill position players have a significantly different hazard rate than linemen. Here, skill position players have an 81% lower hazard than the baseline, but other players are not statistically significantly different. Players with short NFL careers no longer exhibit lower mortality than players with longer careers. However, as discussed previously, not enough time has elapsed since that season to estimate effects with a high degree of precision.

## 5. Conclusions

It has been popular recently, based on anecdotal evidence and a few very high profile cases, to conclude that players in the NFL may have higher mortality rates than the general population. Using data on the actual survivability of NFL players and comparing it to the expected population survival of individuals in a similar time period, it seems that NFL players have higher survivability (lower mortality) rates than the general population. However, there is evidence that mortality rates are higher for line players, who may take more abuse or have different physical characteristics than other players. There is also evidence that those players who play more than two seasons worth of games also face higher mortality rates than other players. So, compared to the overall population, NFL players survive longer, but when compared with their peers who do not play many games, those that play more do not survive as long.

There are some limitations to this study. For example, a claim may be made that the difference in expected *versus* actual survivability may be overestimated due to the fact that players in the NFL may be healthier (they are elite athletes, after all) or have better access to quality health care in general [18,19]. Income differences could also lead to differential health effects, and Weir *et al.* [20] show that NFL player earnings are substantially higher than that of the general population. If it can be assumed, however, that players with longer careers have similar general background characteristics (such as innate health, body mass index, life circumstances, *etc.*) as those without career longevity, then this study provides clear evidence that the rigors of the NFL may actually shorten life expectancy, but not to an extent that NFL players have a higher mortality rate than the general population.

We have also not touched on any specific ailments or any injury history (such as concussions), which could cause quality of life issues that differ from the general population. This issue is often conflated with mortality, but may be even more important and need elucidating. In terms of purely examining life expectancy, however, our results suggest that this is another example of confirmation bias in the NFL, where a presupposition is backed by strong anecdotal evidence but no statistical backing [21].

The NFL, however, has cause to be alarmed by the variation in the mortality rates between players at different positions. This study provides some evidence that certain types of players (*i.e.*, linemen) die faster than others, potentially cutting into the future pipeline of these types of players. Even more concerning is the evidence that players with the shortest careers have the longest life expectancy. A general public distaste of knowing that a source of entertainment may actually shorten the lives of those who participate in it the most, may hurt interest in the NFL in the long term, which will subsequently negatively impact the NFL's bottom line.

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## Author Contributions

All listed authors contributed equally in all aspects of the paper including writing, editing, literature review, data collection and analysis.

## Conflicts of Interest

The authors declare no conflict of interest.

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