Assessing the Impact: A Survival (Re)Analysis of Hockey Enforcers vs. Non-Enforcers

Abstract

A recent study looked at the relationship between long-term mortality and being an enforcer in the National Hockey League between 1967 and 2022. They performed a matched cohort study that found no significant difference in the mortality rates of enforcers versus non-enforcers (where "enforcer" is defined based on number of career fights or average career penalty minutes). They then perform an additional sub-analysis conditioning on players that were currently deceased and looking at just this subset of players, they find a significant difference in the mean age at death between the enforcers and non-enforcers groups (45.2 vs 55.2; p-value= 0.02) thus reaching the conclusion that enforcers died an average of 10 years earlier than non-enforcers. However, some of the statistical methods used to reach their conclusions were unconvincing, specifically the approach used to reach this last claim. Therefore, we undertook a re-analysis of their study using a survival analysis approach, which we believe is the natural method to use to study this question. In addition, we augmented their data by scraping hockey-reference to find more instances of players who were deceased. Then, using a Cox proportional hazards model, we found no significant difference in survival rate between enforcers and non-enforcers when an enforcer was defined based on the number of career fights. However, when an enforcer was defined by average career penalty minutes, a significant difference was observed, which was notably not found in the original article. Specifically, we find an estimated hazard ratio of enforcers to non-enforcers of 2.35 (p-value: 0.00125). Therefore, we agree with the sentiment of the original paper that there is some difference between survival of these two groups, but we believe our approach to estimating this effect is more appropriate and that the magnitude of the effect in the original article is overstated.

1 Introduction

Fighting in the National Hockey League (NHL) has been an integral part of the sport since the earliest days of the league. More than just a way to express frustration, players often use fighting strategically to the benefit of the team. One of these strategies includes instigating a fight when a player from the opposite team has violated an unwritten rule of the game, which historically has led to hockey teams carrying so-called "enforcers" on their rosters. The enforcer is the teammember tasked with fighting these opposing players. While this is not an officially defined position, the nature of needing to be able to fight any opponent generally designates the biggest and strongest players as those most likely to be enforcers.

Colburn (1986) discusses the intentions behind these public fights. The crowd gets energized and entertained, but more importantly, the fight is a stage used to establish the social customs and expectations of players on the ice. Specifically, they say, "insofar as the fist-fight is the locus of socially available beliefs concerning the moral character and integrity of players, ... the fist-fight represents a mode of informal social control among players".

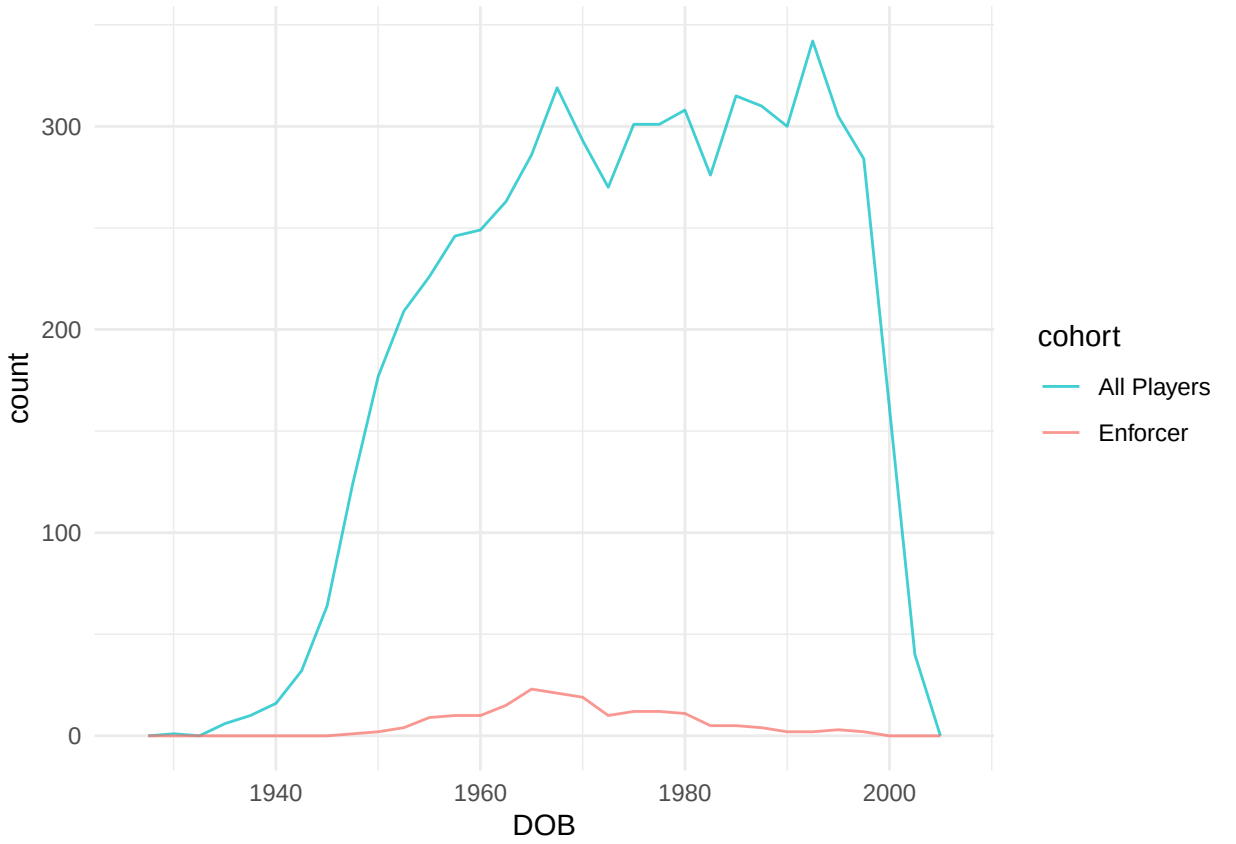

Figure 1: Proportion of Enforcer-Status Players to All Players by Date of Birth

Silverwood (2015), who looked anecdotally at how enforcers fit into a team atmosphere, noticed that teammates put their enforcers on a pedestal. Performing well as an enforcer leads to the player being seen as a protector. When an enforcer fulfills these additional responsibilities to being on the ice as a normal player, players say that it is common for that enforcer to receive perks, such as not paying for their own meals or getting the best seat on the bus. They go as far as to say these players are "deified", emphasizing the social aspects of hockey that surround this history of violence.

The use of violence to enforce social norms in the sport, of course, also has the potential to increase injury and other long-term negative effects for hockey players. While any hockey player may participate in fighting, enforcers are exposed to many more fights than the typical NHL player. As a result of being exposed to more physical contact, they are potentially exposed to additional head trauma when compared to the broader hockey player population, putting them at potentially higher risk for long-term health outcomes. The ingrained nature of fighting into the game of hockey is therefore widely criticized, which has led to declines in the use of hockey violence. For example, figure 1 shows a decline in the proportion of enforcers (as defined by Popkin et al. (2023)) to non-enforcers as players get younger. This brings forth the question of whether hockey will continue to move away from contact-driven strategies in favor of younger, faster, and highly-skilled players.

Popkin et al. (2023) explored the effects of being an enforcer on mortality rates, ages at death, and causes of death to address the long-term impact this repeated contact might have. They defined enforcers in two ways: (1) those who had 50 or more career fights (E-F cohort) and (2) those who had, on average, more than 3 penalty minutes per game (E-P cohort).

Based on their analysis (a matched cohort study) they find that there is no statistically significant difference in the mortality rates between enforcers and controls for either definition of enforcer. However, they do find that enforcers died on average about 10 years earlier than their non-enforcer counterparts. Additionally, while there was no significant difference in all-cause mortality rate, they do suggest that enforcers in their sample died more frequently of drug overdose and suicide.

However, we believe that some of the statistical methods used in Popkin et al. (2023) to reach these conclusions are not the best choices given the problem that is studied. Here, we attempt not to replicate the results of the analysis in Popkin et al. (2023), but what we believe to be more appropriate statistical methods, specifically survival analysis techniques. This shift in perspective allows us to overcome the weakness of mortality rate, which is that it is a function of when it is calculated (i.e. In all cases, mortality rate will be 100% when all members of the original sample have died). Instead, survival analysis provides a survival curve, which can be used to analyze how the probability of survival changes over time. In addition, we augmented the data used in Popkin et al. (2023) to increase the sample size in the analysis and include more deceased players in the data set.

The outcome of this study is relevant to the debates about regulations and discourse around head trauma in hockey (and other sports). An accurate analysis is imperative to prevent the spread of misinformed conclusions and best inform regulatory safety practices going forward.

There is much work demonstrating that elite athletes on average live longer than the general population. Antero, J., Tanaka, H., and De Larochelambert, Q (2021), as just one example, estimates that "Olympic athletes live 5.1 years longer than the general population" and Garatachea et al. (2014) presents a large meta-analysis of elite-level athletes life spans and concludes that life expectancy for these elite-level athletes is higher when compared to the population at large.

However, several studies that have examined life expectancy for athletes involved in sports with more physical contact / more collisions have found evidence of associations between this contact and reduced life expectancy. Zwiers, R. et al. (2012) examined Olympians across many sports and found that those elite athletes participating in sports with high levels of physical contact exhibited mortality at higher rates later in life than Olympians in less contact heavy sports. They then estimate the hazard ratio associated with high contact sports to be 1.13 (95% CI: 1.06-1.21). Bianco, M. et al. (2007) looked at life expectancy across different sports and did not find any significant results. However, they note that the median life expectancy for boxers was 73 years compared to an overall median of 76 years.

The topic of Popkin et al. (2023)'s study fits in with this line of work with a focus specifically on one type of hockey player (i.e. the enforcer). While these did not identify any significant differences in mortality rates between the enforcers and non-enforcers, they do find shorter lifespans among enforcers who were deceased. We believe that this topic is of great interest, which is why we engaged in a re-analysis with additional data of the original work. By using more appropriate statistical techniques, out hope is to gain a clearer picture of the the conclusions reacdhed in the original work of Popkin et al. (2023).

2 Data

2.1 Data from original paper

We obtained the two data sets used in Popkin et al. (2023): general table (n = 7,432) and death table (n = 45). As in Popkin et al. (2023), we considered only players who's first season was 1967 or later and played any games between the 1967-68 and the 2021-22 NHL seasons. This leaves 6,039 players after filtering (the exact number mentioned in Popkin et al. (2023)). We then removed 4 players with missing height, leaving us with 6035 (6,035) remaining observations, of which 252 are deaths, for our re-analysis.

For direct comparison to Popkin et al. (2023), we defined enforcers using the same two definitions that they used: 1. Enforcers-Fights (E-F): Any player with at least 50 career fights (n = 331) 2. Enforcers-Penalty Minutes (E-P): Any player who averaged at least 3 penalty minutes per game (n = 183)

We note than in Popkin et al. (2023), they find 183 E-P enforcers; we have only 182 in our data set with the discrepancy due the the removal of the 4 players with missing height information, which is used as a control variable in the survival analysis.

2.2 Additional Data

While Popkin et al. (2023) only looks at a total of 45 deceased players (21 enforcers and 24 controls), we identified 252 players who were included in the data used in Popkin et al. (2023) who were deceased as of May 7, 2023 based on data from hockey-reference.com.

2.3 Data summaries

Of the 6035 players included in this analysis, the average age was around 48 years old. The average height and weight for these players was about 73 inches and 197 pounds, respectively. A full summary of the overall data can be seen in table 1.

In this same set of players, on average, enforcers in this data set tended to be older than the non-enforcers (EF: 53.93 vs non-EF: 47.6 and EP: 52.5 vs non-EP: 47.81). Additionally, as seen in Tables 2 and 3 enforcers tended to also be taller and heavier on average than non-enforcers. The means of age, weight, height and played are all significantly different between the enforcers and non-enforcer groups for both definitions of enforcers. We also note differences some substantial differences in the positional distribution of enforcers vs non-enforcers. Specifically, the percentage of defensive players in the enforcer vs non-enforcers is relatively close there are very few enforcers, defined with either E-F or E-P, who are listed as playing center. This also means that the percentage of enforcers who are listed as wings (either right or left) is higher for enforcers than for non-enforcers. The variables listed here are the same as those that were used for matching in Popkin et al. (2023) (i.e. date of birth, total number of games played, height, weight and position).

3 Methods

The analysis presented here utilizes all hockey players in the data, both alive and deceased, in a survival analysis to explore differences in survival times between enforcers an non-enforcers, which we believe to be a more appropriate method for analyizing the problem in this setting. Rather than focusing on mortality rates, as in Popkin et al. (2023), we instead focus on survival times and leverage survival analysis techniques, specifically Cox proportional hazards models, to look for differences in survival times of enforcers versus non-enforcers.

Variable	mean (sd)
n	6035
n deceased	252 (4.18%)
Games Played	285.79 (338.93)
Age (Years)	47.95 (15.15)
Height (Inches)	72.65 (2.14)
Weight (Pounds)	197.0271748 (15.9714463)
Fights per game	0.0440494 (0.1472676)
Penalty Minutes per game	0.7492157 (0.8352813)

Table 1: Descriptive Summary of All Hockey Players who Started after 1967 and Played at Least One Game Between the 1967-68 and 2022-2023 NHL seasons

Variable	Enforcers	Non-Enforcers	p-value
n	331	5704	
Games Played	668.13 (308.58)	263.6 (327.19)	<0.0001
Age (years)	53.93 (0.563)	47.6 (0.203)	<0.0001
Weight (lbs)	210.15 (0.889)	196.27 (0.207)	<0.0001
Height (in)	73.58 (0.116)	72.6 (0.028)	<0.0001
percent D	32.9%	33.4%	
percent W	59.5%	40%	
percent C	7.6%	26.6%	

Table 2: Comparison of Enforcers to Non-Enforcers when Enforcer is Defined by Career Fights (E-F)

Variable	Enforcers	Non-Enforcers	p-value
n	182	5853	
Games Played	178.58 (244.27)	289.12 (340.92)	<0.0001
Age (years)	52.5 (0.801)	47.81 (0.199)	<0.0001
Weight (lbs)	208.35 (1.287)	196.68 (0.206)	<0.0001
Height (in)	73.54 (0.164)	72.63 (0.028)	<0.0001
percent D	28.6%	33.5%	
percent W	65.9%	40.3%	
percent C	5.5%	26.2%	

Table 3: Comparison of Enforcers to Non-Enforcers when Enforcer is Defined by Penalty Minutes (E-P)

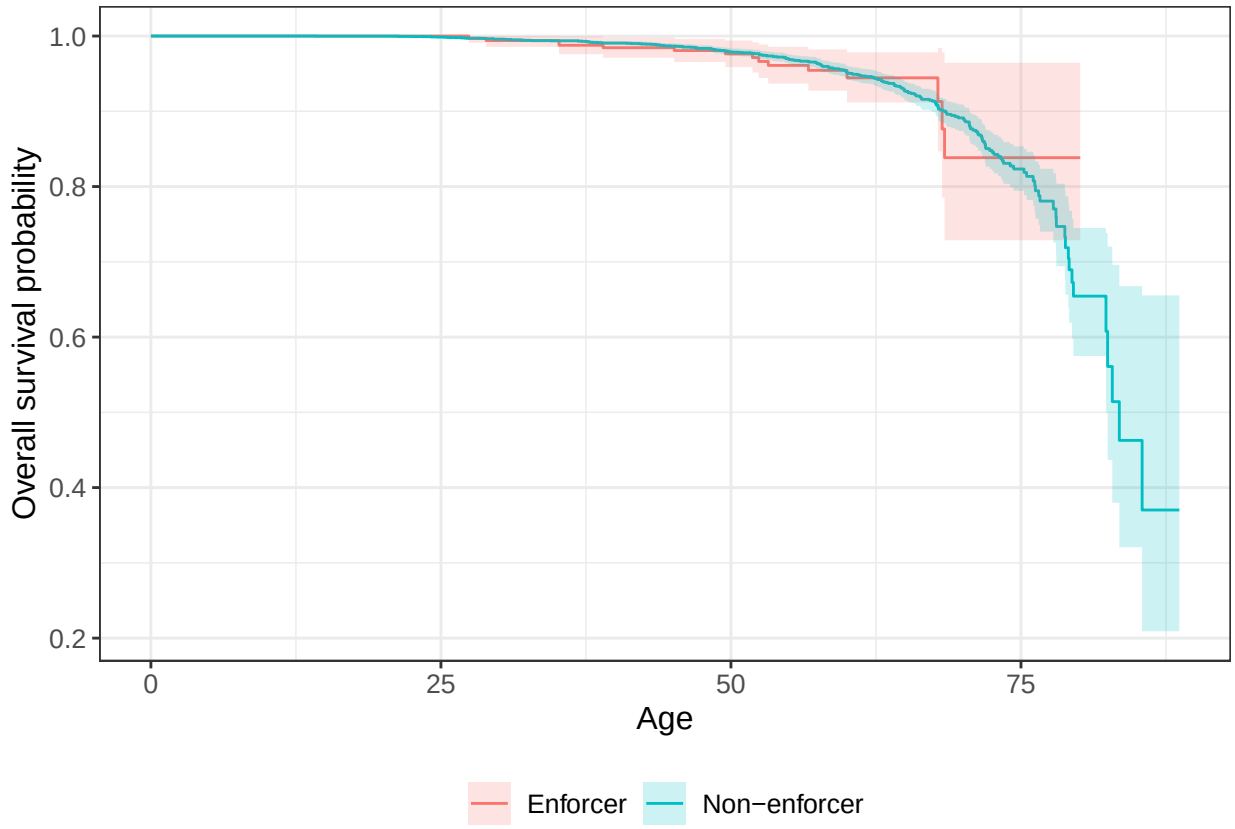

Figure 2: Kaplan Meier Plot Comparing Survival Rates of Enforcers to Non-Enforcers when Enforcer is Defined by Career Fights (E-F)

Figures 2 and 3 show Kaplan-Meier plots for EF and EP. There is substantial overlap in the K-M curves between the enforcer and non-enforcers groups when enforcers is defined using the EF criteria. However, the enforcer group defined by the EP criteria exhibits evidence of lower survival probabilities starting around age 50 relative to the non-enforcer group. Nevertheless, it is important to remember that these two groups differ substantially in age, height, and weight that may lead both to increased probability of becoming an enforcer and an increased probability in early death.

We note here that figure 3 demonstrates clearly why mortality rate is often not an appropriate measure for comparing risk between groups. If one were to look only at mortality rates at age 75, the mortality rates among these two groups are nearly identical (just under 20%). However, the enforcers survival curve is clearly below the non-enforcer survival curve estimate at almost every point below 75 indicating that enforcers are dying at younger ages on average even though the mortality rate eventually becomes nearly indistinguishable near the age of 75. All of this is, by the way, exactly consistent with the findings of Popkin et al. (2023) (i.e. no signficant difference in mortality rates, but enforcers dying at younger ages).

In order to account for these differences between the groups, we estimated full Cox proportional hazard models Cox (1972): one for each definition of enforcer defined in Popkin et al. (2023) (i.e. E-F and E-P) with time until death as the outcome variable. Further, the indicators for each definition of enforcer, games played (GP), height (Ht), weight (Wt), year of birth (DOB), and position indicators (Center (C), Wing (W), or Defender (D)) were added as control variables.

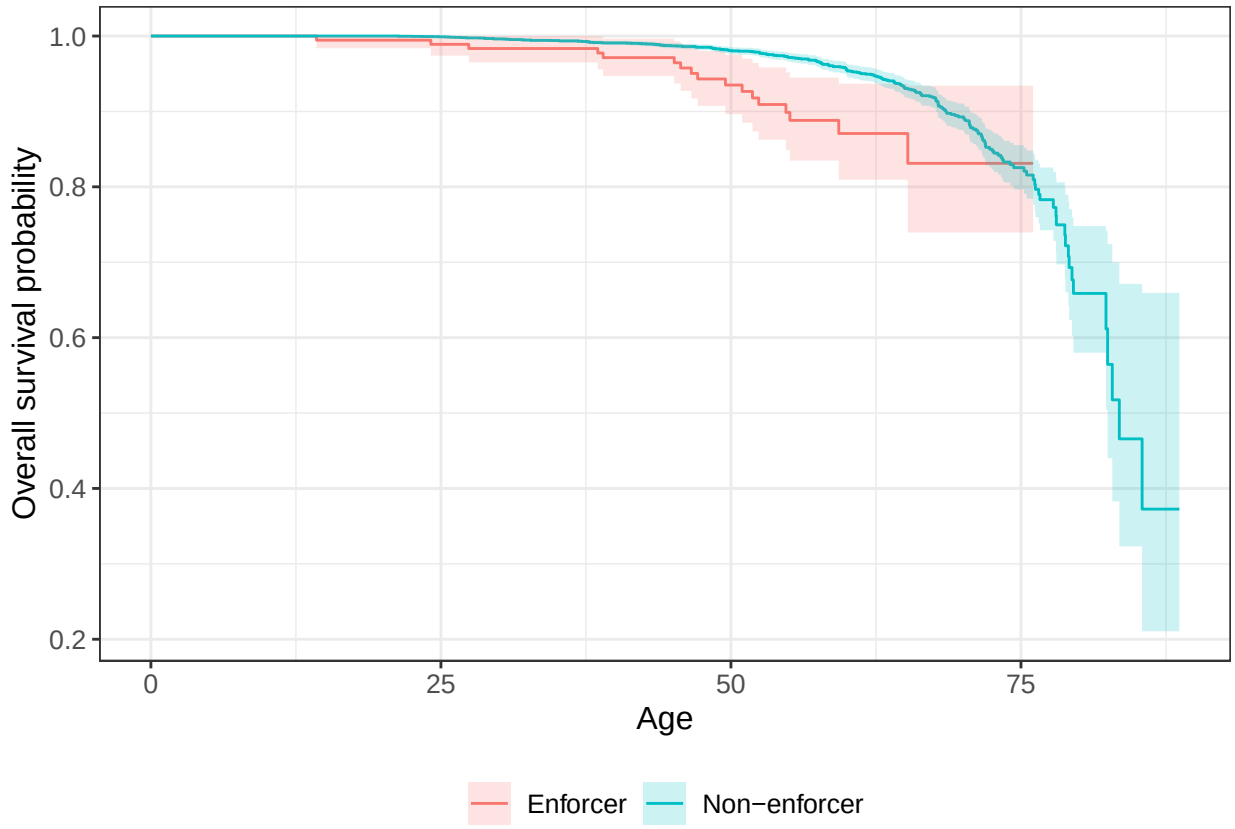

Figure 3: Kaplan Meier Plot Comparing Survival Rates of Enforcers to Non-Enforcers when Enforcer is Defined by Penalty Minutes (E-P)

All analysis was performed in R version 4.4.0 R Core Team (2024) using the survival library Terry M. Therneau and Patricia M. Grambsch (2000).

4 Results

Table 4 shows the results for the Cox proportional hazards model when enforcers were defined based on their number of career fights. No statistically significant difference was observed in the hazard functions of enforcers versus non-enforcers (p-value = 0.490). However, a significant difference is observed between enforcers and non-enforcers when the enforcer is defined based on their number of penalty minutes per game (p-value = 0.00125). The estimated hazard ratio for E-P is 2.35, indicating a 135% increase in the hazard for enforcers vs non-enforcers when all other variables are held constant.

Figure 4 shows the estimated survival curves for enforcers (E-P) versus non-enforcers for defenders with all continuous variables held constant at mean levels. Using this, the estimated survival rate at the age of 50 for enforcers vs non-enforcers is 96.45% (95% CI: 94.44%, 98.51%) vs 98.47% (95% CI: 97.96%, 98.99%). For the same conditions at the age of 75, the estimated survival rate for enforcers is about 74.01% (95% CI: 60.78%, 90.23%) compared to non-enforcers estimate survival rate of 88.00% (95% CI: 83.11%, 93.18%). The estimated survival rate for enforcers drops an additional 11.97% between the ages of 50 and 75 versus non-enforcers.

Covariate	β	e^{β}	s.e.	p-value
$I_{\text{E-F}}$	0.200	1.221	0.289	0.490
GP	-0.00061	0.999	0.00023	0.00675
Ht	-0.0341	0.966	0.045	0.445
Wt	0.0213	1.0216	0.00658	0.00118
DOB	-0.0169	0.983	0.00825	0.0405
I_{Defense}	-0.384	0.681	0.175	0.028
I_{Wing}	-0.284	0.753	0.160	0.075

Table 4: Cox Proportional Hazards Model Output Comparing Enforcer to Non-Enforcer when Enforcer is Defined by Career Fights (E-F) and Controlling for Games Played (GP), Height (Ht), Weight (Wt), Year of Birth (DOB), and Position Indicators

Covariate	β	e^{β}	s.e.	p-value
$I_{\text{E-P}}$	0.854	2.350	0.265	0.00125
GP	-0.00052	0.999	0.00022	0.0159
Ht	-0.0278	0.973	0.0444	0.531
Wt	0.0186	1.0188	0.00659	0.00480
DOB	-0.0170	0.983	0.00831	0.0410
I_{Defense}	-0.388	0.678	0.175	0.0269
I_{Wing}	-0.313	0.731	0.160	0.0509

Table 5: Cox Proportional Hazards Model Output Comparing Enforcer to Non-Enforcer when Enforcer is Defined by Penalty Minutes (E-P) and Controlling for Games Played (GP), Height (Ht), Weight (Wt), Year of Birth (DOB), and Position Indicators

5 Conclusion

Popkin et al. (2023) presented work looking for differences in mortality rates between NHL enforcers and non-enforcers who played between 1967 and 2022 where they defined enforcers in two ways: one based on the number of career fights and the other based on the average career penalty minutes per game. They performed a matched-cohort study matching on date of birth, total number of games played, height, weight, and position. They conclude there there is no statistically significant difference in the mortality rates for either definition of enforcer. They then go on to perform an additional analysis where they condition on death and show that of players in their matched data set who are deceased, enforcers died an average of about 10 years earlier than their non-enforcer counterparts.

While we found this work to be of interest, we believe that a more appropriate statistical framework for this analysis is survival analysis. Therefore, we performed our own extended analysis with additional data using methods from survival analysis to estimate difference survival times between enforcers and non-enforcers. For enforcers, defined based on number of career fights we find no significant difference in survival times. Conversely, we do find a significant difference in survival times for enforcers defined based on average penalty minutes per game. Specifically, we find that enforcers defined in this way have a hazard ratio of 2.35 (p-value: 0.00125) relative to non-enforcers indicated that there are significant risks associated with the position of enforcer.

While we find this clear association between enforcers and increased hazard by controlling for the variables that were matched on in Popkin et al. (2023), there are several obvious uncontrolled

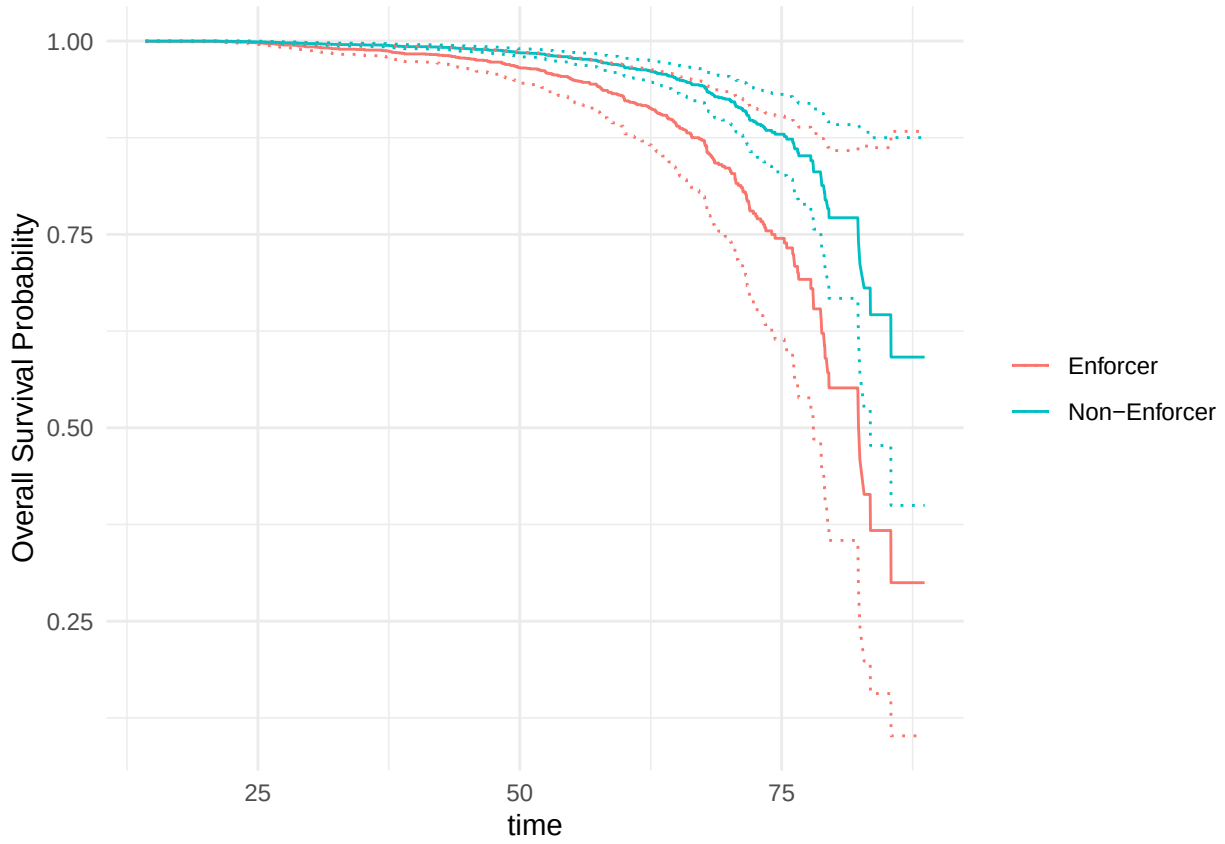

Figure 4: Estimated Survival curve for E-P for defenders. All other variables are fixed at their mean level (GP = 285.8, Ht = 72.7in, Wt = 197.03, and Year of birth 1974.5)

variables that have substantially different distributions in the enforcer and non-enforcer populations. One simple example are the differences in average number of goals scores between the two groups significantly different for both definitions of enforcers. The average number of goals scores for E-F enforcers vs non-enforcers was 89.99 vs 47.05 (p-value: <0.0001). For E-P enforcers, the average number of goals for enforcers was 15.14 vs 50.47 (p-value: <0.0001).

Perhaps more interestingly, we find highly significant differences in geographic region of enforcers vs non-enforcers for both definitions. In the enforcer group 96.07% and 96.7% of those groups are from North America (i.e. United States or Canada) for E-F and E-P, respectively. For non-enforcers, North American players make up only 76.93% for E-F and 77.4% for E-P. For both definitions of enforcer, these differences are significant with p-values for both definitions less than 0.0001. While we do not address this imbalance here, as we focus on closely following the work of Popkin et al. (2023), it is worth noting this imbalance in geographic origin (i.e. North American vs outside of North America) of enforcers versus non-enforcer, and we leave the exploration of this issue for future work.

Finally, while our finding that there is an association between increased hazard and enforcers defined by penalty minutes, we note that this is a rather arbitrary definition of enforcer. We hypothesize that the effect is not actually driven by the "enforcer" category, but simple by an increase in penalty minutes. We posit that a higher average number of penalty minutes is associated with more general contact, including but not limited to fighting. Further, these contacts in hockey are often at high

speeds due the the nature of the game (i.e. the players are on skates). We leave this proposal as future work, but even without exploring this avenue, we believe this work adds to the body of literature relating contact in sports and a reduction in life spans.

Acknowledgements

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