Journal of
Risk and Financial Management

MDPI

Article

Safety versus Compensation for Professional Athletes Who Face the Prospect of Career-Ending Injuries: An Economic Risk Analysis

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Abstract: The National Football League and National Hockey League have instituted several rule changes, equipment improvements and medical protocols in response to the frequency of serious career-ending injuries. These two professional leagues and others have litigated lawsuits by former players who have sought financial compensation. This paper constructs a simple economic model of a risk averse athlete who faces the uncertain prospect of a career-ending injury. Improving the athlete's welfare can be accomplished by reducing the probability of a serious injury or providing increased compensation in the event of such an injury. The net marginal preference for safety is high in sports with moderate to high probabilities of serious injury. Compensation plans are favored in sports with moderate to low probabilities. Significant increases in player salaries have little effect on a players net marginal preference for safety. These results are robust to constant or decreasing absolute risk aversion.

Keywords: concussions; utility; risk; compensation; sports

JEL Classification: D81; I19; Z28

Citation: Rockerbie, Duane. 2023. Safety versus Compensation for Professional Athletes Who Face the Prospect of Career-Ending Injuries: An Economic Risk Analysis. *Journal of Risk and Financial Management* 16: 481. https://doi.org/10.3390/jrfm16110481

Academic Editor: Junyi Chai

Received: 11 October 2023
Revised: 6 November 2023
Accepted: 10 November 2023
Published: 13 November 2023

1. Introduction

Many professional sports contain an element of serious risk of injury. Examples include boxing, mixed martial arts (MMA) fighting, American football, ice hockey and rugby. The most serious injuries can result in long-term physical handicaps, brain injuries, and even in rare cases death. Professional athletes make a choice to engage themselves in these sports and assume the inherent risks with the prospects of large financial rewards.

Players have organized and demanded changes to rules and better equipment to reduce the probability of serious injuries in some sports. Most of these challenges have been successful; however, the probability of serious injury can never be eliminated. Players have also demanded financial compensation in the event of serious injuries, both during and after a playing career. Professional sports leagues are far more hesitant to acknowledge that compensation is warranted and pay it out. Our purpose in this paper is to explore the nature of the trade-off between reducing the probability of serious injury and receiving financial compensation if a serious injury occurs. Of course, professional athletes prefer both options; however, we treat the two as alternatives which athletes must choose between. This allows us to explore the value that is placed on each option, ceteris paribus. The paper is purely theoretical and offers insights using standard expected utility analysis to assist in guiding policies regarding serious, potentially career-ending injuries and their longer-term implications for former players.

Media attention has focused on the incidence of brain injuries in the National Football League (NFL) in the last two decades. The physical trauma of repeated blows to the head and other violent hits manifests in the onset of early dementia, depression, Alzheimer's disease and chronic traumatic encephalopathy (CTE), which cause considerable handicaps for the rest of the player's life. Some cases have resulted in early deaths and suicides.

Medical evidence is mounting that CTE is more common in NFL players than previously thought (Ward et al. 2017) and the NFL has paid over USD 1.2 billion in compensation to former players, or families of players, who have been diagnosed with CTE, even though senior league officials continue to deny the connection between violent play and CTE.

At the furthest end of the spectrum is Formula One racing, where deaths were commonplace in its early decades. Cars featured few safety features and racetracks were built for speed and excitement. A total of 14 drivers died between 1952 and 1959. Changes were made to improve the safety of drivers, largely at the insistence of the drivers, in the early 1970s. Features such as better racing suits, helmets, roll cages and fire-retardant systems came at the expense of higher costs for racing teams. Racetracks were redesigned to make them shorter and eliminate excessively dangerous sections, both for drivers and fans. Driver fatalities declined over the decades: thirteen in the 1960s, twelve in the 1970s, four in the 1980s, two in the 1990s, and two between 2000 and 2010. Driver compensation has significantly increased over the years, but still lags behind given the risks involved, except for the top drivers. To our knowledge, F1 has never paid significant compensation to a driver suffering a serious or career-ending injury.

Professional athletes reveal their acceptance of the risk of serious injury (perhaps life-threatening), given the potentially large financial rewards, when they choose employment in professional sports leagues. This paper is the first attempt in the literature to explore the trade-off between the risk of serious injury and the provision of financial compensation, using a utility maximizing model of a player facing risk. That is, we model the problem from the perspective of the welfare of the player and what the player would prefer. Players who earn salaries at the lower end of the salary distribution will prefer reducing the risk of serious injury to receiving financial compensation for a given known probability of injury, while those at the higher end of the salary distribution will accept compensation much more readily, particularly in sports with low injury probabilities. This has implications for the leagues' policy towards greater safety, since the bulk of players fall into the former category. Financial settlements have addressed former players, but to avoid costly litigation leagues need to move in the direction of greater safety more seriously and quickly.

Section 2 reviews the previous literature and provides some insights into the economic costs of serious sports injuries, the efforts that have been made to prevent them, and injury compensation paid to athletes. Section 3 provides an overview of how the prospect of a serious injury can be treated as a gamble, provides example calculations of what players will pay, in the sense of reduced salary, to avoid serious injury, and the compensation necessary for the leagues to pay for players to accept the risk of serious injury. Section 4 provides simulation results of the safety–compensation trade-off that a representative player will face. Section 5 considers the case of decreasing risk aversion with higher wealth and Section 6 provides concluding remarks.

2. Previous Literature

Professional athletes in the major sports leagues around the world earn significantly higher incomes than the general population. Economics suggests that this is due to the large revenues that players can generate for their profit-maximizing clubs—the salary = marginal revenue product rule. However, these salaries seem to bear no association with the risk of serious injury between sports. The average salary in the NFL for the 2023 season was USD 3.3 million with the highest paid players earning more than USD 40 million. Players in the relatively lower risk Major League Baseball (MLB) earned an average salary of USD 4.9 million with the highest paid also earning more than USD 40 million.[1] The bulk of the higher ranked fighters in professional boxing earn less than USD 10,000 per fight; however, the top-rated fighters can earn USD 10–50 million per fight.[2] The economic cost of a serious or career-ending injury is high for elite professional athletes. This includes the foregone wages, the cost of treatment, and the potentially shorter lifespan after leaving the sport. Professional sports have used a combination of equipment and rule changes

to make their sports safer and provide financial compensation in the event of a serious career-ending injury.

Equipment and rule changes can be a contributing factor to reducing serious injuries. Hanson et al. (2017) found that a 1996 rule prohibiting hitting with the crown of the helmet reduced head and neck injuries by 34% in the NFL. A subsequent 2018 rule prohibited NFL players from lowering their heads to contact another player. Improved helmet designs are claimed to have reduced the number of concussion injuries by 20 to 25 per season (Reed 2023). The National Hockey League (NHL) prohibited targeted hits to the head in 2011. Players in the NHL and the NFL must submit to a concussion protocol testing period if there is suspicion of a head injury during a match and can be required to miss matches for a period determined by medical personnel. The implementation of concussion protocols has resulted in more concussions being detected and treated in the NFL (Nathanson et al. 2016) and NHL (Andrews et al. 2022). Rugby has lagged behind in implementing rules and equipment changes to reduce concussions. Concussion rates increased consistently each season from 2010 to 2017 despite greater penalties for high tackles. Requiring the use of helmets has not been considered by any national rugby association. However, concussion protocols have recently been adopted (2019). The culture of professional sport demands that the player returns to play quickly after an injury, possibly increasing the probability of a more serious injury to follow (Nixon 1993). Improving the safety of equipment and enacting new rules to change this culture is only helpful if players consider the risks while they are still playing, not after their playing careers are over, in which case pursuing financial compensation is the only course of action available to them.

Recently, some empirical research has estimated the economic costs of serious injury in response to the media, litigation and medical attention given to brain injuries. Donaldson et al. (2014) estimated that concussions and serious head and neck injuries cost NHL players a total of USD 58.3 million over the 2009–2010 to 2011–2012 seasons (USD 81.6 million in 2023 dollars), an average salary cost of USD 353,000 (USD 494,000 in 2023 dollars) and accounted for 25.7% of the total lost salaries due to all injuries. These are not significant costs for NHL teams since insurance pays for 80% of any player's salary who misses 30 or more games in each season. The NFL agreed to a settlement of USD 765 million in 2013 to retired players for treatment and lost income from brain injuries. The total amount paid has now reached over USD 1 billion; however, it is widely believed that the compensation is well below the costs to players.[3] The NHL reached a settlement of USD 18.9 million brought by more than 300 former players in 2018.[4] In 2023, over 300 former rugby players brought litigation against World Rugby and the Rugby Football Union for compensation for brain injuries, arguing that rule changes, equipment changes and medical care were not sufficient to prevent these injuries.

A related research field, beginning with Thaler and Rosen (1976), to the safety–compensation trade-off considered here considers compensating differentials paid to workers to incentivize them to take on higher workplace risks. Workers who accept these wage top-ups for risk reveal their preference for compensation over safety. Dickens (1984) found a significantly larger risk premium for unionized workers compared to nonunionized workers. Biddle and Zarkin (1988) estimated a worker utility function using U.S. labor market data for 1977 to construct an optimal wage differential risk frontier. The income elasticity of income earned outside of the workplace on the compensating differentials was estimated to be approximately two. Workers with higher incomes may prefer less risky jobs if their health is normal and good. Hence jobs with higher wages may demand higher risk premiums for injuries and death. Garen (1988) found this to be the case, resulting in higher risk premiums than previously estimated. The literature relating to compensating differentials for risk in professional sports is sparse, even though player salaries and characteristics are easily measured and controlled for with widely available performance metrics. Anderson (2022) estimated a significant risk premium in prize money paid to professional boxers if a fighter had suffered a previous concussion, using a sample of 1211 professional fighters.

The economic costs of a career-ending injury are harder to quantify after the player has left the sport and we could not find any studies. Murphy and Topel (2006) estimated that the value of a year of healthy life is approximately USD 260,000 at age 30 (USD 400,000 in 2023 dollars), reaching a peak of approximately USD 360,000 at age 50 (USD 554,000 in 2023 dollars), then declining to USD 170,000 at age 80 (USD 262,000 in 2023 dollars). The value of the remaining years of life at age 30 is just over USD 7 million for a normal healthy male (USD 10.8 million in 2023 dollars). The compensation paid to former NFL and NHL players pales in comparison.

3. Safety and Compensation Treated as a Gamble

Our approach to the problem of the player's safety–compensation choice draws on an expected utility framework as a starting point. We consider a player who assumes the risk of a serious injury that ends his playing career. Professional sports in North America compensate players quite handsomely, not necessarily for the inherent risk of injury but for their talent and the revenue generating potential they bring to their teams. However, professional athletes willingly incur the risk of personal injury when entering into contracts to play particularly violent professional sports. We assume the probability of a career-ending injury is known based on the past incidence of such injuries. The factors that affect the probability of serious injury change only slowly over time (playing rules, safer equipment, better medical care, etc.) making the use of past information useful.

The player's preferences over income are represented by a concave utility function that displays diminishing marginal utility of income (Figure 1). Our professional football player faces the risky prospect of receiving an annual salary of Y_G = USD 5 million for five years if healthy (the good state) or the alternative annual income of Y_B = USD 100,000 each year when incurring a career-ending injury (the bad state). The utility analysis of a gamble is typically couched in uncertain values of an individual's wealth.[5] Assume that the player has an initial level of wealth of USD 100,000. The present value of the player contract is equal to USD 21.65 million assuming a discount rate of 5%, resulting in wealth equal to USD 21.75 million if the player does not suffer any serious injury. Also assume that a career-ending injury results in a return to the initial level of wealth. Both levels of wealth are known with certainty. The gamble is represented by the straight line connecting the utilities from the good and bad states. The expected value of the contract (the gamble) is given by p\$21.65 million + $(1-p)$\$0.1 million, where p is the probability of *not* incurring a serious or even career-ending injury. The known probability of career-ending injury is equal to $1-p$ = 0.05 giving an expected value of wealth equal to USD 20.57 million (not drawn to scale in Figure 1). If given the choice between the gamble (the playing contract) with known expected value, or a certainty equivalent amount of income equal to USD 20.57 million (agreed to by contract), the risk averse football player will choose the certain income as it yields higher utility measured on the vertical axis. A risk averse player will always choose the certainty income contract when the gamble is equal to the certain income.

The player is willing to forego the difference between the certainty equivalent amount of wealth (W_{CE}) and the expected value of the gamble (EV) to eliminate risk. This takes the form of accepting a lower salary offer. We assume a simple risk averse utility function $U = lnW$ that features diminishing marginal utility of wealth and an Arrow–Pratt risk aversion coefficient equal to one over all levels of wealth. The certainty equivalent amount of wealth for our football player is determined where the player is indifferent between the expected utility of the gamble and the utility of the certain income, which determines W_{CE}.

$$0.95ln(21.65) + 0.05ln(0.1) = lnW_{CE} \quad (1)$$

The solution for Y_{CE} is USD 16.55 million. The football player will accept a lower salary to eliminate income risk and secure a USD 20.57 million contract. The reduction in salary is USD 20.57 − USD 16.55 = USD 4.02 million (the horizontal distance in Figure 1). A decrease in $1-p$ to 0.01 increases the expected value of the salary to USD 21.435 million, increases W_{CE} to USD 20.57 million, and reduces the foregone salary (risk premium) to USD

0.865 million. The football player would be willing to take an annual salary reduction equal to USD 4.02 − USD 0.865 = USD 3.155 million to reduce the probability of a career-ending injury from 0.05 to 0.01 when negotiating the contract.

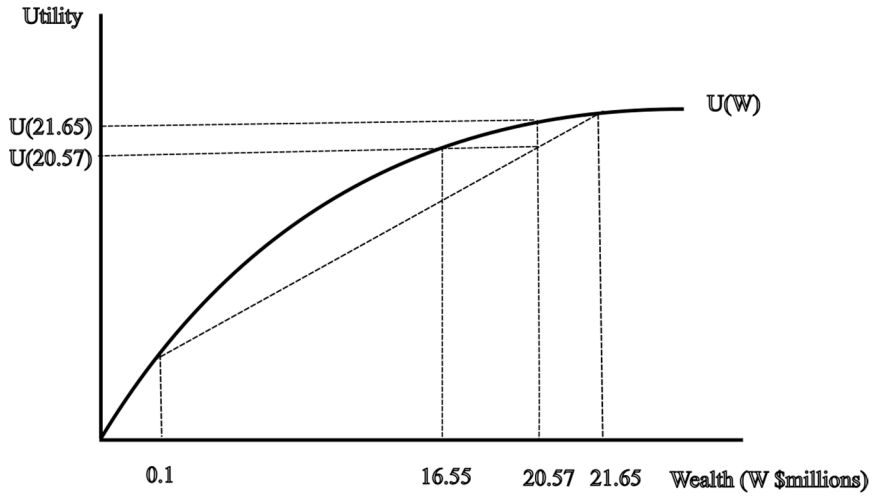

Figure 1. Risk aversion, the certainty equivalent and the risk premium for gambling choices.

A decrease in the probability of the bad state moves the expected value of the gamble up the gamble line and increases utility, increasing the risk premium up to a maximum and then decreasing as the probability approaches zero. An injury compensation plan or higher guaranteed minimum salary pivots the gamble line to make it flatter, increasing the expected value of the gamble and utility. Suppose the football league will pay the player a lump sum of USD 1 million if a career-ending injury is incurred at any point during the five-year contract. This roughly corresponds with the settlements reached with NFL players on average.[6] If the probability of receiving the payment is equal in each of the five years of the contract, the present value in each year weighted is USD 0.866 million plus the initial wealth of USD 0.1 million. The certainty equivalent amount of wealth for the player will increase.

$$0.95ln(21.65) + 0.05ln(0.966) = lnW_{CE} \tag{2}$$

The solution for W_{CE} is USD 18.53 million and the risk premium is USD 20.62 − USD 18.53 = USD 2.09 million. The saving in the risk premium is USD 4.02 − USD 2.09 = USD 1.93 million in comparison to no compensation. Ideally the player will be willing to give up this amount of salary to reduce the level of risk.

4. The Trade-off between Safety and Compensation

Although players would prefer to reduce the probability of serious injury *and* benefit from a compensation plan if seriously injured, we model a player who can only choose more of one of these options. The NFL has incorporated equipment and rule changes to reduce the risk of serious injury but has been stubborn about providing compensation. We wish to investigate the conditions under which players prefer this policy or oppose it. We define the risk premium (RP) as $RP = EV - W_{CE}$.

$$RP = EV - W_{CE} = (pW_G + (1-p)W_B) - e^{(pln(W_G)+(1-p)ln(W_B))} \tag{3}$$

The last term in (3) converts the certainty equivalent amount of utility into units of wealth. Reducing the probability of serious injury increases the expected wealth, moving

up the gamble line in Figure 1. Clearly this makes the player better off in terms of expected utility. Taking the derivative of (3) with respect to p gives

$$\frac{\partial RP}{\partial p} = W_G - W_B - e^{(pln(W_G)+(1-p)ln(W_B))}[ln(W_G) - ln(W_B)] \quad (4)$$

Increasing the level of wealth in the bad state (serious injury) draws a new gamble line with a flatter slope. This also makes the player better off in terms of expected utility. The derivative of (3) with respect to W_B gives

$$\frac{\partial RP}{\partial W_B} = 1 - p - e^{(pln(W_G)+(1-p)ln(W_B))}\left[\frac{1-p}{W_B}\right] \quad (5)$$

When the difference between (4) and (5) is positive, the player is willing to pay a risk premium in the form of reduced salary to reduce the probability of the bad state greater than what he is willing to pay to increase the compensation in the bad state. The difference, defined here as the net marginal preference for safety, is given by

$$\begin{aligned} \frac{\partial RP}{\partial p} - \frac{\partial RP}{\partial W_B} &= W_G - W_B - 1 + p - e^{(pln(W_G)+(1-p)ln(W_B))}\left[ln(W_G) - ln(W_B) + \frac{1-p}{W_B}\right] \\ &= W_G - W_B - 1 + p - W_G^p W_B^{1-p}\left[ln(W_G) - ln(W_B) + \frac{1-p}{W_B}\right] \end{aligned} \quad (6)$$

Using the initial parameter values for the example of the football player, W_G = USD 21.65 million, W_B = USD 0.1 million, $1 - p = 0.05$, and the net marginal preference for safety is negative, suggesting the football player prefers increasing wealth in the bad state to reducing the probability of a serious injury. The compensation plan increases wealth in the bad state to USD 0.966 million, reducing the net preference for safety to a negative amount that is almost half of the net preference with no compensation, yet still a net preference for the compensation plan. The net marginal preference for more safety in dollars is simulated in Figure 2 for all values of $1 - p$. The player prefers a decrease in the probability of career-ending injury (p) over higher injury compensation for values of p above 0.31 (or values of $1 - p$ below 0.69) without the compensation plan and for p values above 0.38 with the compensation plan. In this case, a nearly ten-fold increase in compensation results in the player accepting only a modest increase in the probability of a career-ending injury, although this relationship is nonlinear.

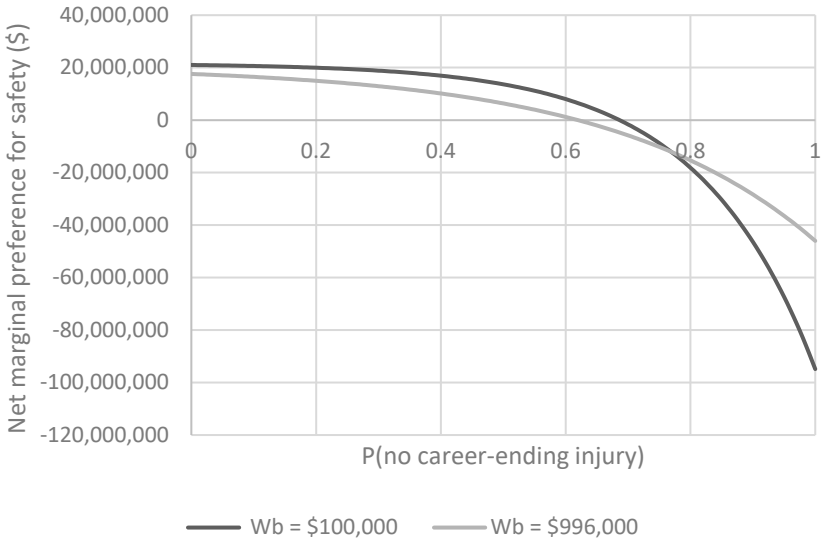

Figure 2. Net marginal preference for more safety using values of W_G = USD 21.65 million, W_B = USD 100,000 and W_B = USD 996,000 and $U = lnW$.

Perhaps offering a much higher salary in the good state could act as compensation for injury in the bad state, since the probability of serious injury is perceived to be low at $p = 0.05$. When the annual salary is doubled to USD 10 million, W_G increases to USD 43.3 million and the net marginal preference for safety is positive for values of p above 0.29 with no compensation and 0.35 with compensation (not shown in Figure 2). Paying a much higher salary in the good state does very little to reduce the player's preference for safety over the same amount of compensation in the bad state. Overall, increasing compensation or increasing salary has only a modest effect on reducing the player's preference for safety.[7]

If a career-ending injury is very serious, or even life-threatening, such as is the case with CTE brain injuries, wealth falls to zero in the bad state.[8] Without compensation the net marginal preference for safety is plotted in Figure 3 for W_B = USD 0.01 and W_G = USD 21.65 million for values of p. The net marginal preference for safety is positive for values of p above 0.16, a significant drop from 0.31 in the case of W_B = USD 0.1 million. This is to be expected, but the player will still accept a small probability of career-ending injury. Perhaps if wealth in the bad state is sufficiently negative, such as in the case of death, the net marginal preference for safety will be positive at the level of p. The log utility function prevents this experiment.

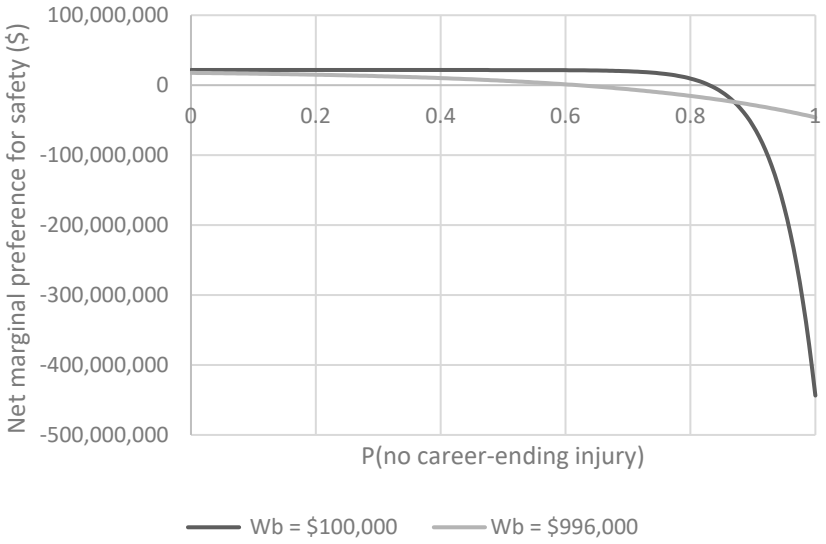

Figure 3. Net marginal preference for more safety using values of W_G = USD 21.65 million, W_B = USD 0.01, W_B = USD 996,000 and $U = lnW$.

5. Decreasing Absolute Risk Aversion

Theoretical and empirical support for decreasing risk aversion with higher wealth was initially suggested by Graves (1979). Bosch-Domenech and Silvestre (1999) used experimental data that suggested that individuals facing gambles involving large increases in wealth in the good state are more willing to buy insurance when their initial wealth is low, suggesting that higher-wealth individuals (in the good state) are less risk averse. For individuals with modest differences in wealth, the analysis of the preference for safety in the last section is appropriate. Professional athletes who face this choice typically have dramatic differences in wealth based on performance and longevity. The distribution of salaries for 2023–24 NHL players (N = 854) and its Lorenz curve is shown in Figure 4. At the lower end of the distribution, 41.7% of players earn salaries of USD 1.75 million or less while only 10% earn salaries of more than USD 7.5 million. The Gini coefficient is 0.435, suggesting that salaries are far from equally distributed. The distribution of salaries for 2023–24 NFL players (N = 1923) and its Lorenz curve is shown in Figure 5. Its Gini coefficient is 0.594 suggesting that salaries are far more unequally distributed than in the NHL. The top salary stands at USD 52.5 million with the lowest salary at just USD 672,000.

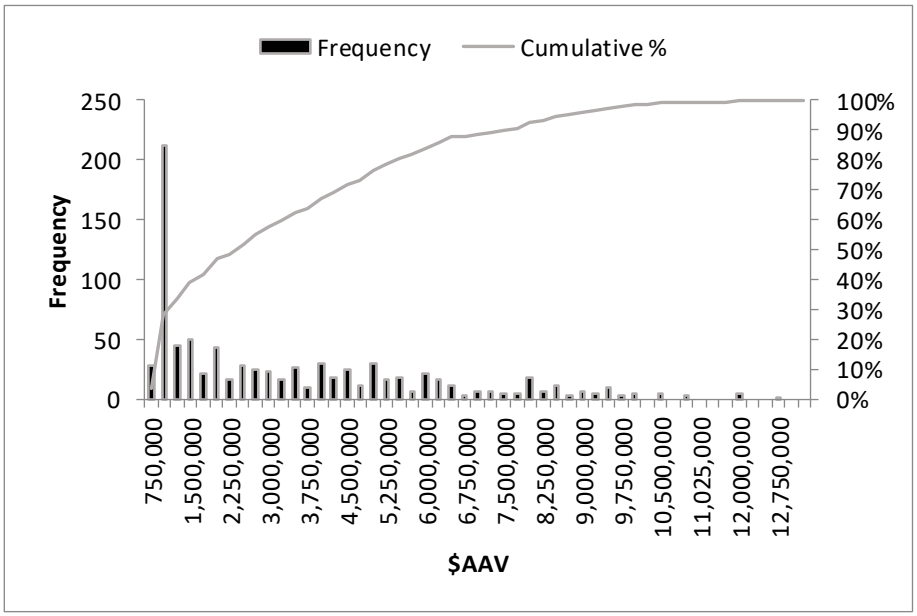

Figure 4. Distribution of 2023–2024 NHL salaries and Lorenz curve. Source: https://www.spotrac.com/nhl/contracts (taken on 17 August 2023).

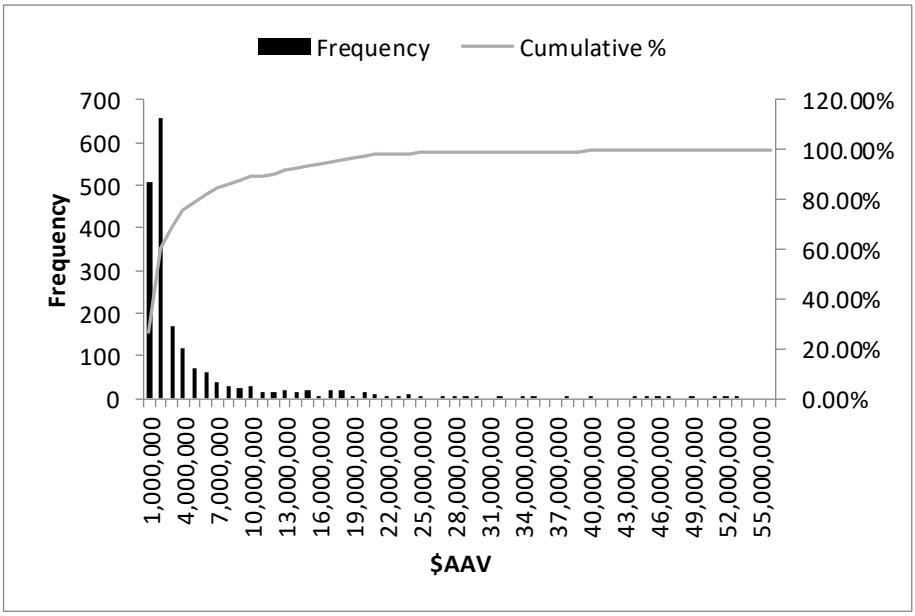

Figure 5. Distribution of 2023–24 NFL salaries and Lorenz curve. Source: https://www.spotrac.com/nfl/contracts (taken on 5 September 2023).

The decision by the NHL and NFL brass to enforce more rules to reduce injuries or pay higher compensation in the event of injuries is negotiated with the players in a collective bargaining agreement (CBA). Since most NHL and NFL players fall into the lower end of the salary distribution, they will rule the vote, so it is insightful to use the gambling model to predict their preference for safety versus those players in the upper portion of the salary distribution who are few.

There are many utility functions which have decreasing risk aversion in higher wealth.[9] We choose a simple utility function so that the derivatives in (4) and (5) are easily found,

$U = \sqrt{W}$. The Arrow–Pratt measure of absolute risk aversion is $\frac{1}{2W}$. The risk premium is given in (7) below.

$$RP = EV - W_{CE} = (pW_G + (1-p)W_B) - \left(p\sqrt{W_G} + (1-p)\sqrt{W_B}\right)^2 \quad (7)$$

Taking the derivatives of (7) with respect to p and W_B gives

$$\frac{\partial RP}{\partial p} = W_G - W_B - 2\left(p\sqrt{W_G} + (1-p)\sqrt{W_B}\right)\left(\sqrt{W_G} - \sqrt{W_B}\right) \quad (8)$$

$$\frac{\partial RP}{\partial W_B} = 1 - p - \frac{1-p}{\sqrt{W_B}}\left(p\sqrt{W_G} + (1-p)\sqrt{W_B}\right) \quad (9)$$

The net marginal preference for safety is given in (10) below.

$$\frac{\partial RP}{\partial p} - \frac{\partial RP}{\partial W_B} = W_G - W_B - 1 + p - \left((1-p)\sqrt{W_G} + p\sqrt{W_B}\right)\left[2\left(\sqrt{W_G} - \sqrt{W_B}\right) + \frac{1-p}{\sqrt{W_B}}\right] \quad (10)$$

If at a given level of wealth, with a decrease in p and an increase in W_B, the value of (10) is positive, the player will prefer an increase in safety over higher compensation. The net marginal preference for more safety in dollars is simulated for all values of $1 - p$ in Figure 6. The player prefers a decrease in the probability of a career-ending injury (p) over higher injury compensation for values of p above 0.50 (or values of $1 - p$ below 0.50) without the compensation plan and for p values above 0.46 with the compensation plan. As in the previous case, a nearly ten-fold increase in compensation results in the player accepting only a modest increase in the probability of a career-ending injury. The curious feature is that the trade-off is virtually linear, as demonstrated by the near constant slope of the net marginal preference for safety. There is only a very small increasing net marginal preference for safety, which is not evident in Figure 6 due to the scale of the vertical axis.[10]

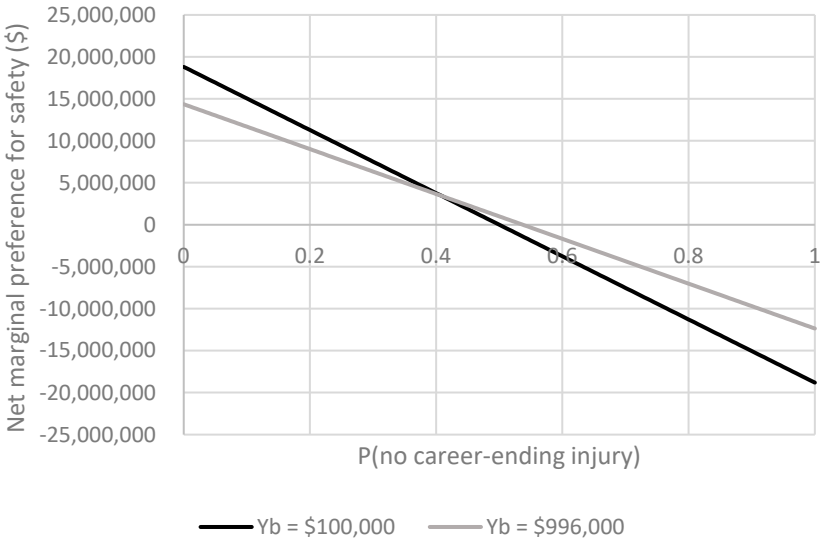

Figure 6. Net marginal preference for more safety using values of W_G = USD 21.65 million, W_B = USD 100,000 and W_B = USD 996,000 and $U = \sqrt{W}$.

Increasing the annual salary to USD 43.3 million in the good state has virtually no effect on the player's preference for safety, regardless of whether compensation is offered in the bad state or not, as was the case with log utility. The results also demonstrate virtually no change from the log-utility case if wealth falls to zero in the bad state. One cannot say if these results are robust to any utility function (which obeys the axioms of a proper utility function), but the results here are quite suggestive of such.

6. Conclusions

With the newer awareness of the consequences of career-ending injuries, such as CTE and dementia, professional sports leagues have made efforts to incorporate rule and equipment changes to make their sports safer. This is most evident in the NFL and NHL, sports which are particularly physical, but other sports in which concussion injuries are also prevalent include basketball, rugby, boxing and soccer (Ianof et al. 2014). Both leagues have also litigated recent lawsuits launched by former players who have sought financial compensation for these types of injuries. League decision makers face the choice of making their sports safer, perhaps at the cost of attractiveness to fans and some financial cost or offering financial compensation to their players who suffer career-ending injuries (perhaps covered by insurance with costly premiums). Players would prefer both options, and in an ideal world team owners could develop a safer game with greater compensation. This paper considers a world where team owners could determine the optimal mix of safety and compensation from the perspective of the player's welfare, not their own financial profitability. The approach here is purely theoretical. The practitioner may see little value without surveying player and owner opinions; however, economics can offer insights if players are assumed to demonstrate behaviors which are consistent with economic axioms.

The simple model here assumes that a professional player faces the uncertain prospect of a career-ending injury with a known probability. The financial value to player in guaranteeing a fixed level of wealth (salary) regardless of what state of the world is revealed is calculated as a risk premium in a standard method. The player's net marginal preference for safety is defined as the difference in the marginal effects of a lower career-ending injury probability and higher compensation in the event of such an injury. The calculation is dependent upon the specification of the utility function. We choose simple natural log and square root utility functions as examples of more complex functions and simulate the net marginal preference for safety when facing different levels of wealth in the good and bad states.

Regardless of whether absolute risk aversion is constant (log utility) or decreasing (square root utility) in wealth, it is much more effective to reduce the probability of career-ending injury in a sport with a moderate to high probability of a career-ending injury to increase the welfare of the player. Players prefer a greater compensation package in the event of a career-ending injury when the probability of such an injury is moderate to low. Some sports are particularly violent and the probability of serious injury is high. Professional boxers suffer many serious blows to the head and vital organs; however, it is difficult to make the sport safer without diminishing its fan appeal. The boxer's welfare is best served by reducing the probability of career-ending injuries (and complications after leaving the sport) but only promoters may be able to offer generous compensation packages. Head gear was made mandatory for the 1984 Olympic Games but subsequently removed in 2013 due to an *increase* in stoppages for head injuries caused by the larger diameter of the head when wearing head gear and the reduced visibility for the wearer (Loosemore 2016). A standing eight count has been introduced which allows the referee to pause the contest if a boxer is perceived to have a reduced ability to defend themselves due to injury. Formula One racing has instituted many rule changes and safety improvements over the last two decades, such that the occurrence of serious injuries is very low.

Deaths were fairly commonplace in Formula One racing until the 1980s when rule changes to driver equipment, car safety features, and track changes reduced the incidence of serious injury or death significantly. In its first few decades, drivers were not well-compensated to assume the risks, typically receiving a single fixed payment for the season and a share of their prize money. Tournament theory predicts that drivers will not invest heavily in costly training if the rewards are small (Lazear and Rosen 1981). Compensating drivers financially with higher salaries could reduce the incidence of serious accidents and deaths as they will invest more intensively in training and safety. However, compensation plans for drivers who are seriously injured or die are not offered, rather, the sport has relied upon improving driver safety at the request of the drivers. This is as predicted by the

economic risk model when salaries are quite high, as is the probability of serious injury, as they can be in F1.[11]

The NFL and NHL have implemented significant rule changes and concussion protocols to make their sports safer, as well as requiring players to use safer equipment to reduce the chances of serious injuries. However, financial compensation has only been awarded after legal decisions in courts. This is as predicted by the simple model developed in this paper. Further efforts should be made to reduce the probability of serious injuries. Compensation packages have been slow to develop, but some ground has been made.[12] The model here suggests that more generous compensation packages encourage players to accept only a slightly higher probability of career-ending injury, further emphasizing that efforts should continue to be focused on increased safety.

Ideally a league would establish a compensation scheme that could generate a separating equilibrium (Rothschild and Stiglitz 1976) in which some players play their sport at a lower probability of serious injury while others play the same sport at a higher probability but receive financial compensation. Unfortunately, this scheme is not practical, even if each type of player could be identified, when football and hockey players play on the same field or sheet of ice. A pooling equilibrium, in which the same rules and compensation schemes apply to all players, achieves lower overall welfare but is easily practical.

Player salaries have increased dramatically since the abolition of the reserve clause which governed the major North American professional sports leagues in the late 1970s. Even if the probability of career-ending injury has not changed over the same decades, the model here predicts that higher player salaries (wealth) will do little to reduce players' net marginal preference for safety. The notion of fast cars and extravagant living does not compensate for brain injuries when considering the welfare of the players.

Funding: The author received no external funding.

Data Availability Statement: Data for Figures 4 and 5 and the simulation programs in MSExcel can be found at https://www.researchgate.net/ (accessed on 28 September 2023) by searching for the author.

Conflicts of Interest: The author declares no conflict of interest.

Notes

1 Authors calculations for NFL and MLB from https://www.spotrac.com/, accessed on 28 September 2023.

2 Taken from (3 November 2023) https://sportsbrief.com/boxing/35797-what-average-salary-a-boxer-details-explained/.

3 The compensation scheme contains three tiers. Former players suffering from amyotrophic lateral schlerosis (ALS) receive up to USD 5 million. Those with serious dementia can receive up to USD 3 million, while early dementia sufferers receive up to USD 25,000. Players do not need to prove they contracted the disorders from playing football. At least 18 former NFL players died from ALS who played at anytime over the 1959–1988 seasons. See https://www.mercurynews.com/2018/06/06/before-dwight-clark-a-dozen-other-nfl-players-dealt-with-als/, accessed on 28 September 2023.

4 An excellent summary of concussion litigation in the NHL is Sherman (2021).

5 A seminal paper is Markowitz (1952).

6 Ex-NHL players won a class action lawsuit in 2018 that saw the league pay a total compensation package of roughly USD 100,000 per player. They did not fair as well as their NFL counterparts and the NHL continues to deny a link between CTE injuries and NHL play. More recently (August 2023), 380 former professional rugby players launched a class action lawsuit that has yet to be decided against World Rugby and the governing rugby bodies in England and Wales.

7 This ignores the possibility that the player saves a portion of the higher salary in the good state as his or her own compensation in the bad state. This would move the analysis outside of the expected wealth framework used here.

8 One could think of this situation as negative wealth in the bad state resulting in negative utility, however a utility function that obeys the properties of ordinal utility is sufficient, that is, that a traumatic injury is the worst state of the world for the player scaled at zero wealth.

9 Examples can be found in Venter (1983). They must satisfy the conditions that $U' > 0$, $U'' < 0$ and the Arrow–Pratt measure of absolute risk aversion, U''/U', is decreasing in W.

10 The derivative of (10) with respect to p can be shown to be only a very small term that is dependent upon the value of p.

[11] The NFL 88 plan was established in 2007 to provide benefits to retired players who suffer from dementia, Alzheimer's disease, Parkinson's disease and amyotrophic lateral sclerosis (ALS). The plan had paid out USD 9.7 million to 132 former players by the end of 2010. The plan currently pays a maximum of USD 160,000 per year for medical expenses to players who qualify for the benefit. The NHL does not currently have a disability plan for former players.

[12] Annual salaries in F1 ranged from USD 1 million to USD 55 million in 2023 with an average salary of USD 10.5 million and a median salary of USD 5 million (Rencken and Butterworth 2023).

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