A Quantitative Analysis on Injury Rates in Major League Sports

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Introduction

"Sports build good habits, confidence, and discipline. They make players into community leaders and teach them how to strive for a goal, handle mistakes, and cherish growth opportunities." - Julie Foudy. As one of the biggest industries in the world, the sports market has long been a unifying aspect of many cultures, with events such as the Super Bowl and FIFA World Cup. While its cultural significance has been greatly emphasized, the financial aspect of sports should not be neglected. With teams like the Dallas Cowboys and New York Yankees worth billions of dollars, the sports industry is a driving force of society's entertainment and economy. However, not all is good with sports. One factor that is often overlooked is the prevalence of injuries in sports. Whether it be the NBA, NFL, or MLB, every season, numerous injuries occur that change the landscape of the sports industry.

In this observation study, data will be compiled from the two most popular sports leagues in the United States, the NFL and NBA. Numerous statistical tests, such as confidence interval tests and significant tests, will be conducted to analyze the breadth and significance of the injuries in the two leagues. Additionally, the financial aspects of these injuries will be analyzed to see just how detrimental these injuries are to teams and they athletes themselves.

Trends in the National Football League (NFL)

The National Football League (NFL) has slowly taken over America as the most popular sports league, which comes as no surprise. With young phenoms like Patrick Mahomes II of the Kansas City Chiefs and Khalil Mack of the Chicago Bears, the NFL has transcended into a premier sports league that raked in a mammoth $14.2 billion this past season.



Patrick Mahomes II won the 2018 NFL AP MVP award in just his second season



Khalil Mack earned a 6 year, $141 million deal after his stellar play

That said, the NFL has always had to shake off its reputation as being a physical and taxing sport, with players constantly hit in the head and facing concussions that can lead to disastrous disorders in the future, including chronic traumatic encephalopathy (CTE).

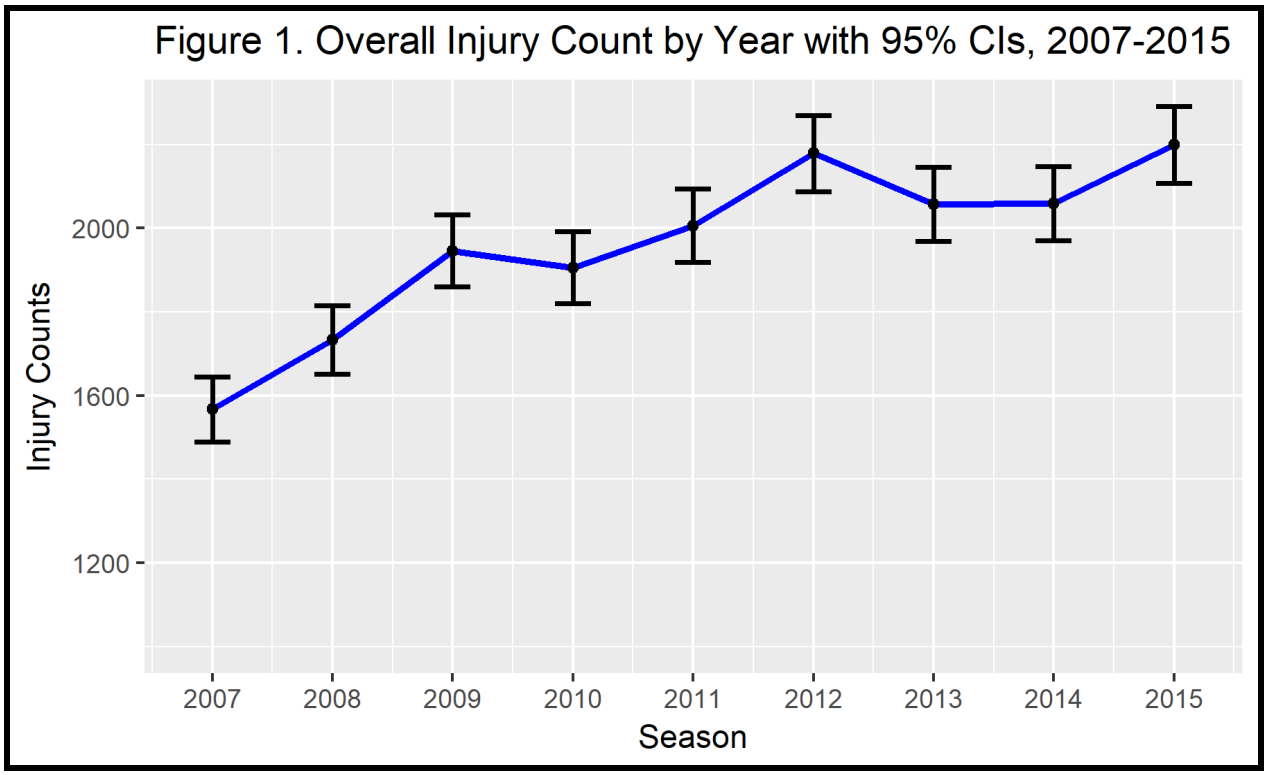
The 2018-19 season was a great season for the NFL as it earned record profits, but in a way it covered up what can only be described as a medically disastrous 2017-18. Injury numbers peaked as 550 players were placed on injury reserve throughout the season, including star players like QB Aaron Rodgers of the Green Bay Packers, DE J.J. Watt of the Houston Texans, and WR Odell Beckham Jr. of the New York Giants. Compare this to only 496 and 469 players on IR in 2016 and 2015, respectively. Perhaps the most memorable injury that essentially encapsulates the injury riddled 2017 season is that of LB Ryan Shazier of the Pittsburgh Steelers, who suffered a spinal injury during a Monday Night Football Game against the Cincinnati Bengals. Immediately rushed to the hospital, Shazier faced a serious threat of paralysis, but is now in improving condition after undergoing spine stabilization.

The peak in injury numbers warranted a change in player safety, which is why NFL owners voted for a new rule that fined players lowering their heads to make contact with opposing players.



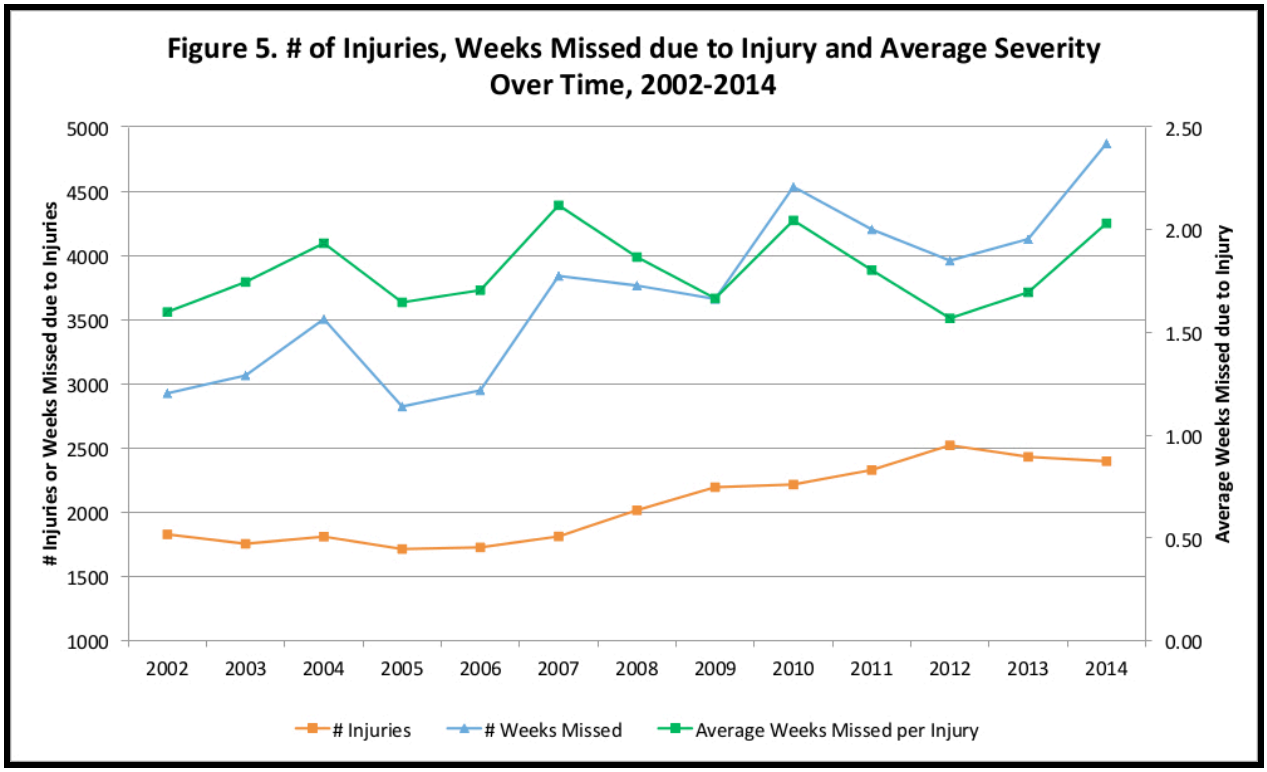
When the injury happened, Ryan Shazier could not move for over 10 minutes. His injury resulted from a head on collision with a fellow teammate

The rule could have not been passed at a better time, as player injury rates were slowly on the rise, as shown by the graphs below by Football Outsiders.



Utilizing a 95% confidence interval, we see that from 2007 to 2015, there is a significant difference in injury counts (the confidence intervals do not overlap for those years). It is interesting to note the high number of injuries in 2011, as a lockout was imposed during the season from March 12 to July 25. Although no official games were played, training camps were halted, yet injuries for that season were high, compared to seasons prior. Additionally, one would assume that with improvements in technology and rule changes meant to help players, injury numbers would decrease, but the opposite trend is happening.

Another graph showing the games missed from injuries over the years corroborates these findings.



A least squares linear regression test yields a positive correlation coefficient, meaning that we can confirm that injuries have steadily been on the rise. Weeks missed, on the other hand, vary widely at first glance, but a least squares linear regression test also yields a positive correlation coefficient, despite the r-value being less than that for number of injuries. On average, players missed anywhere from 1.75 to 2.25 weeks, which could mean anywhere from one to three games missed.

Now, let's look at some numbers from this past season, the first in which the aforementioned rule was implemented. Below are tables posted by the NFL of concussion rates.

Incidence of Concussion – 2012-2018

Year	Preseason			Regular Season			Preseason + Regular Season		
	Practice	Game	Total	Practice	Game	Total	Practice	Game	Total
2012	42	43	**85**	3	173	**176**	45	216	**261**
2013	39	38	**77**	4	148	**152**	43	186	**229**
2014	42	41	**83**	8	115	**123**	50	156	**206**
2015	29	54	**83**	9	183	**192**	38	237	**275**
2016	26	45	**71**	6	166	**172**	32	211	**243**
2017	45	46	**91**	12	178	**190**	57	224	**281**
2018	45	34	**79**	8	127	**135**	53	161	**214**

A quick glance at the data shows that concussions peaked in the 2017-18 season, while numbers from 2012 to 2017 have remained widely inconsistent, epitomized by the 10% drop in injuries from 2013 to 2014, followed by a shocking 33.4% increase from 2014 to 2015.

Fortunately, it seems that the new targeting rule worked, as concussion numbers decreased from 281 to 214 from 2017 to 2018 - a 23.8% decrease. A quick significance test with a significance level of 0.05 yields a p-value of 0.0195, so it is safe to conclude that there is a significant difference in the number of concussions from 2017 to 2018. It is good to see that the new rule has lead to positive results, but medical professionals still should not be satisfied, instead looking for ways to further decrease these numbers.

Outside of concussions, the most common type of injuries in football are leg injuries, specifically dealing with the knee. The following tables were posted by the NFL regarding ACL and MCL tears, which are most common ligament tears in the knee.

Incidence of ACL Tears – 2012-2018

Year	Preseason			Regular Season			Preseason + Regular Season		
	Practice	Game	Total	Practice	Game	Total	Practice	Game	Total
2012	13	16	**29**	5	28	**33**	18	44	**62**
2013	15	10	**25**	3	33	**36**	18	43	**61**
2014	12	10	**22**	0	27	**27**	12	37	**49**
2015	13	16	**29**	5	25	**30**	18	41	**59**
2016	9	11	**20**	7	29	**36**	16	40	**56**
2017	15	16	**31**	2	21	**23**	17	37	**54**
2018	10	18	**28**	5	24	**29**	15	42	**57**

Includes ACL tears reported as primary, secondary, or tertiary. A single injury event may result in both an ACL tear and MCL tear; in this analysis, those injuries are counted in both the ACL and MCL tables. An ACL tear that occurred during conditioning in 2015 is excluded from this table.

Incidence of MCL Tears – 2012-2018

Year	Preseason			Regular Season			Preseason + Regular Season		
	Practice	Game	Total	Practice	Game	Total	Practice	Game	Total
2012	19	26	**45**	9	77	**86**	28	103	**131**
2013	20	25	**45**	4	85	**89**	24	110	**134**
2014	16	23	**39**	3	98	**101**	19	121	**140**
2015	12	38	**50**	6	102	**108**	18	140	**158**
2016	15	21	**36**	3	86	**89**	18	107	**125**
2017	17	20	**37**	9	97	**106**	26	117	**143**
2018	13	23	**36**	1	94	**95**	14	117	**131**

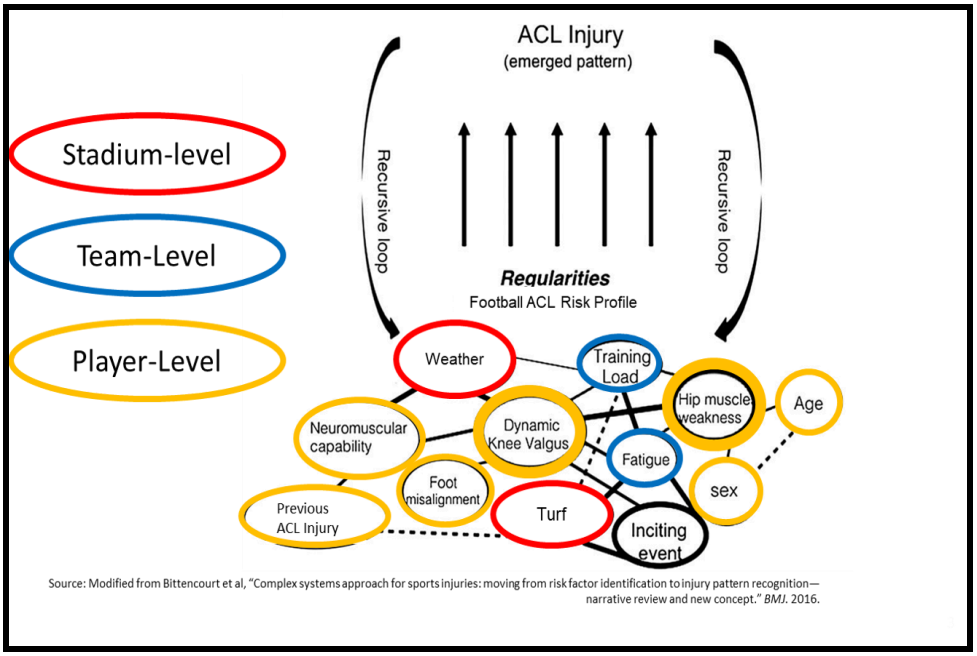
2012-2014 includes injuries that met a "reportable injury" definition; 2015-2018 includes injuries that resulted in removal from participation and inability to take full part in football activities following the injury.

Includes MCL tears reported as primary, secondary, or tertiary. A single injury event may result in both an ACL tear and MCL tear; in this analysis, those injuries are counted in both the ACL and MCL tables. An MCL tear that occurred during conditioning in 2015 is excluded from this table.

A quick glance at the data shows that number vary from year to year, with no consistent increase or decrease. The number of MCL tears is more than double the number of ACl tears, which is not surprising as most ACL tears occur without contact as a player may accidently twist their knee or suddenly stop from top speed running. On the other hand, MCL injuries typically occur from an unnatural, inward position of the knee that usually occur with contact. A least squares linear regression slope test was conducted to prove that the slopes of the linear regression of ACL and MCL tears were not significantly nonzero, which the tests to confirm.

- **Statistical Significance of ACL Tears? (Assuming $\alpha = 0.05$):** No, there is no statistical significance that ACL tears have been on the rise (**P-Value:** 0.576)
- **Statistical Significance of MCL Tears? (Assuming $\alpha = 0.05$):** No, there is no statistical significance that MCL tears have been on the rise (**P-Value:** 0.329)

The following graphic by Football Outsiders shows some possible reasons as to why ACL injuries occur. Most factors can be duplicated to MCL injuries as well.



Why are injury numbers high in the first place? A probable cause is the introduction of "Thursday Night Football" in the 2006 season, which has reduced the number of days for recovery after a Sunday game. Many players have voiced their disappointment towards the scheduling of Thursday Night Games, yet no amendments have been suggested by any team owners. CB Richard Sherman of the San Francisco 49ers, who ruptured his Achilles Tendon on Thursday Night Football in 2017 and subsequently lead him to being cut by the Seattle Seahawks for his injury, perfectly summarizes the concerns of the players in the Players Tribune.



"Thursday Night Football is just another example of the NFL's hypocrisy: The league will continue a practice that diminishes the on-field product and endangers its players, but as long as the dollars keep rolling in, it couldn't care less… As long as fans are tuning in and advertisers are paying to be featured on Thursday Night Football, it's not going anywhere. So I don't know what the solution is." - Richard Sherman

Another problem is the lack of consistency by the league, which has led to perpetual debate. While the new head-to-head rule has been passed, that does not necessarily mean it is always upheld. The subjectivity of NFL officials during games cannot be 100% corrected by nature, but consistent calls are definitely desired. Perhaps the most divisive call this past season was during the NFC Championship Game between the Los Angeles Rams and New Orleans Saints: during the waning moments of the fourth quarter, QB Drew Brees of the Saints threw a pass to WR Tommylee Lewis, but immediately CB Nickell Robey-Coleman initiated head-to-head contact with Lewis, resulting in an incomplete pass. Despite being consistently flagged during the regular season, no flag was thrown - yet days after the game, which saw the Rams headed to Super Bowl 53, Robey-Coleman was fined $26,739 for his hit. How could a player be fined yet not penalized during the game? To these multi-million dollar athletes $26,739 is miniscule, and any one of them would take a trip to the Super Bowl over having to a pay a fine. In order to keep head injury rates low, referees must look and flag violations more often.



Nickell Robey-Coleman (right) lays a vicious head-to-head hit on Tommylee Lewis (left) without any penalty. He was later fined $26,739, but this no-call would spark massive criticism towards the NFL's inconsistency towards helmet-to-helmet hits.

Perhaps the more important question to ask rather than why injuries are occuring is what can we do to reduce them. One rule proposed by the NFL Players Association (NFLPA) is to shorten the preseason to two or three games rather than the standard four games. Additionally, to mitigate the effects of increased injury risk during Thursday Night Football, the NFLPA and owners have proposed to have teams only play a game on Thursday after a bye week, which would grant players close to two weeks time for recovery. Both rules have yet to be voted on.

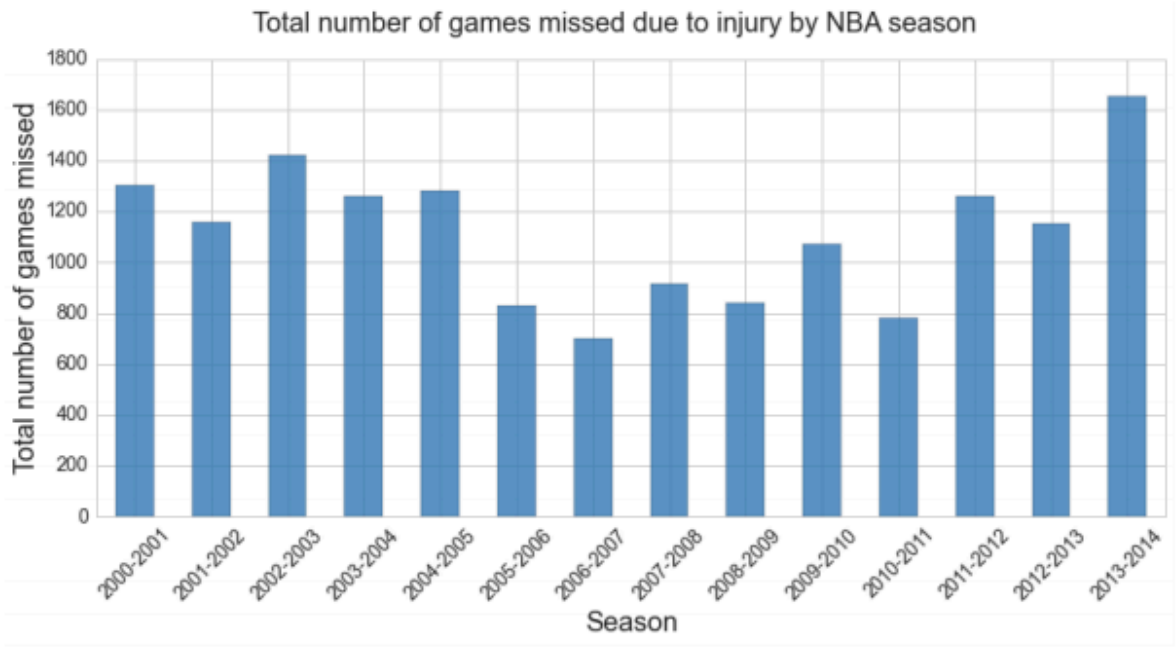
Some processes have already been implemented to reduce exacerbation of injuries and have led to positive results. Despite the high number of concussions in 2017, self-reported concussions peaked as 47% of all concussions were self-reported in some way. For those that are not, numerous protocols exist to make sure that concussions are diagnosed as soon as possible. If players continue to play despite hits to the head, the injury could worsen and could sideline players longer than anticipated. As per other injuries, rules such as flagging teams for chop blocking (one offensive player blocks a defensive player in the area of the thigh or lower while another offensive player engages that same defensive player above the waist) and for illegal blocks in the back have helped stabilize the injury numbers. The integration of technology in protective equipment also warns doctors for any abnormalities, allowing them to pull players from the game and check up on them, preventing players from aggravating injuries.

Looking into the future, the best course of action is to continue valuing player safety, even over audience satisfaction and revenue. Maintaining this balance will become a major struggle for the NFL, especially as it looks to expand its appeal while also trying to clean up its reputation as a dangerous sport. That said, the future does look bright, a great sign for a great sport.

Trends in the National Basketball Association (NBA)

Despite not being as physical as the NFL, the NBA also faces a nasty injury problem that professionals have tried to counter for years.

Figure 1A: Total games missed due to player injuries. Distribution of total games missed due to player injuries. Total salary loss was computed on a per-team basis over the entire time period of 2010-2015.



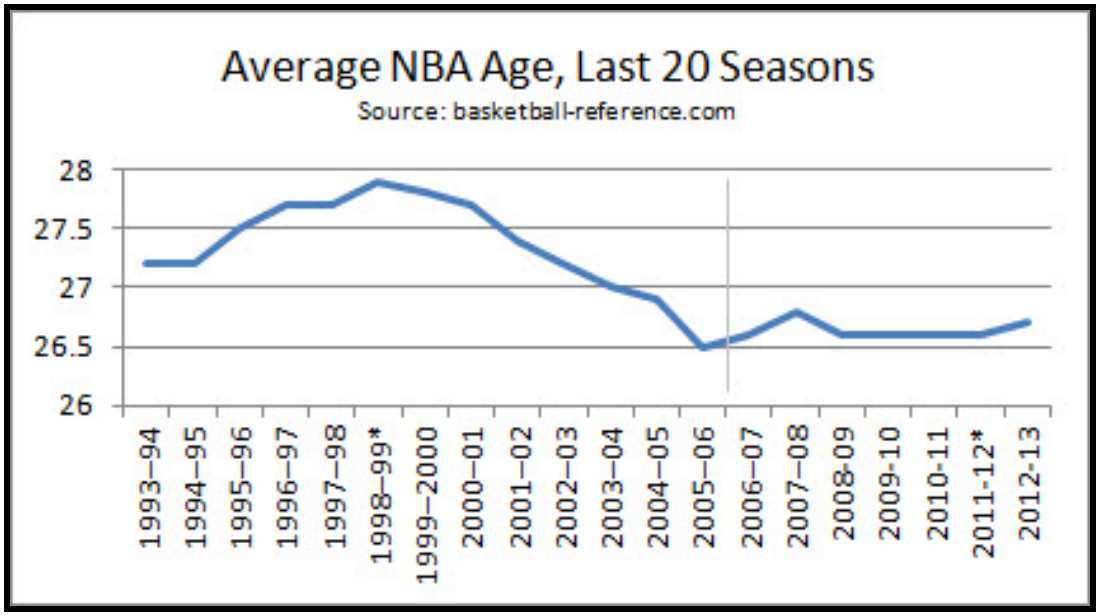
Splitting the graph into two sections shows some interesting trends. From the 2000-2001 season to the 2006-2007 season, injuries trended downwards, with a minimum of about 700 injuries in the 2006-2007 season. Suddenly, injuries skyrocketed from 700 injuries to close to 900 injuries in the following 2007-2008 season, and since then injury numbers have trended upwards. This seems counterintuitive, as one would assume improvements in technology and training protocols over the years should decrease injury rates. What are some factors and possible solutions to explain this sudden shift?

The most obvious answer is the increasing competitiveness of games and sheer number of games that NBA athletes play - hypothetically, a player could play as many as 110 games in a season, as opposed to a maximum of 20 games for NFL players. Also given the extremely short turnaround - sometimes even less than a day - players are put in a situation where they must either choose to preserve their body or play the game (the term “load-management” has become especially notorious as players have intentionally sat out games, to the dismay of fans who paid hundreds of dollars to watch them play, in order to preserve their bodies). The term “injury-bug” has hence been thrown around frequently in the NBA, as players who are simply not built for the taxing NBA season are frequently hit with injuries.

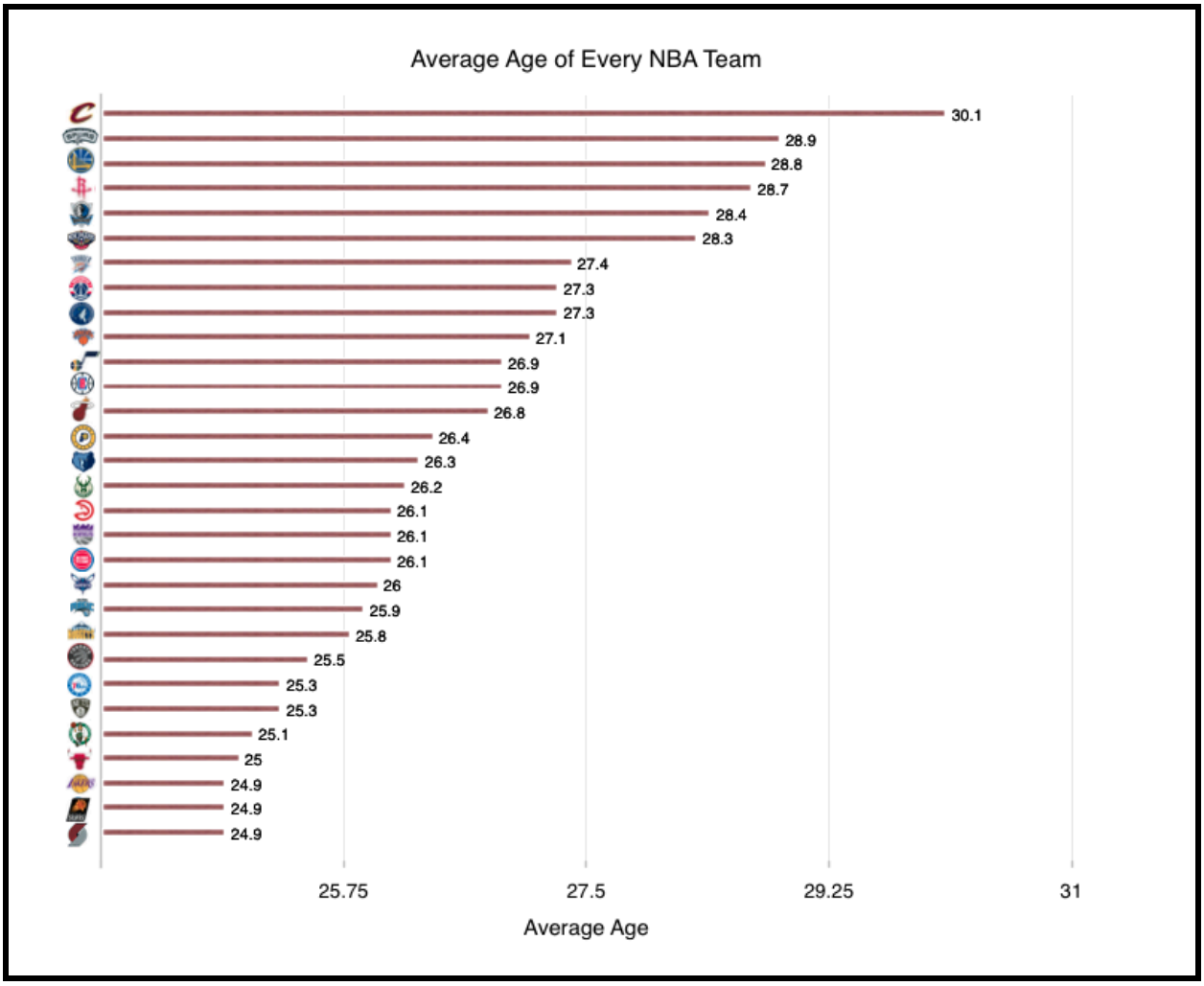


In order to keep their superstar players healthy, teams like the Lakers, 76ers, and Raptors have benched players like Lebron James (left), Joel Embiid (top-right), and Kawhi Leonard (bottom-right). Uncoincidentally, all three players were selected as NBA All-Stars as rest allowed them to up their play.

Also, the "specialization" of athletes in their younger years could possibly explain this increase in injuries. Unlike the NFL, where players must attend college for 3 years before they can declare for the draft, players in the NBA can follow the "one and done" rule where they simply play for one year and declare for the draft. This rule was actually implemented recently, as players before did not even have to attend college and could declare for the draft directly after their senior year of high school. Also, whereas the NFL draft has a total of 7 rounds, the NBA draft only has 2 rounds, meaning the competition to be drafted by a team is massive. Because of this increasing competition, athletes who aspire to play in the NBA are forced to specialize in basketball as early as elementary school itself and only focus on that sport. The problem that arises from this is that these young athletes do not develop a full range of motion that other athletes who partake in many sports experience. The following graph shows how the average NBA age has drastically decreased from the 1990s (the line after 2005-06 indicated the implementation of the aforementioned "one and done" rule).



A further dive can reveal more information on the spread of ages in the NBA. The following graph compiles age data from the 2017-18 season.



It is interesting to note that even the oldest team in the league, the Cleveland Cavaliers, were "only" 30.1 years old. Compare this to teams in the 1990s, where simply the average age of *all* players, not just players on one team, was close to 28 years old. Additionally, the parity in ages (the youngest teams were 24.9 years old) and the skew of the graph to the right shows that majority of teams are very young, which can lead to an increase in injuries as players transition from the speed of the game at the collegiate level to the professional level.

A third reason for these high number of injuries is the unbelievable physical growth of athletes. To show this problem, look at the following two player profiles - Lebron James and 19 year old phenom Zion Williamson of Duke. Both players are forwards and have gone or will go at the top of the NBA draft. The following shows both players at age 18.



Height: 6’8” Weight: 240 lbs Vertical: 33’



Height: 6’8” Weight: 284 lbs Vertical: 40’

While heights are the same, the other two statistics are simply jaw-dropping. Williamson weighs 18.3% more and jumps 21% higher than James, who is one of the greatest players of all time. It is unfathomable to think Zion is only 18 years old, and he will only continue to get better. With an increasing number of physical specimens like Zion entering the league, it is probable that injury numbers have increased as a result due to an increase in physicality.

Looking at the actual numbers for injuries in the NBA, the following statistics were compiled from the 2017-18 season (the 2018-19 season is still underway)

- 19.3 per 1000 athlete exposures; 95% confidence interval, 18.3 - 20.4; $p < 0.05$
- 11.6 per 1000 athlete exposures; 95% confidence interval, 10.8 - 12.4; $p < 0.05$ when it comes to lower extremity injuries

The data show that over half of all injuries in the NBA come from lower extremity injuries - the most common injuries being ankle sprains and patellofemoral inflammation. This makes sense: NBA players are forced to pace up and down the court, and over the course of countless games this can put a toll on the body. Also, the aforementioned massive frames of players puts much more stress on the lower half of their bodies. Players like Shaquille O'Neal and the late Manute Bol, who each measured in over 7 feet over 280 lbs in their primes, constantly faced knee injuries throughout their respective careers.

Fortunately, concussions are not a major problem in the NBA. According to a study conducted from 2006 to 2014, only 134 concussions were reported, or an average of 14.9 concussions per season. The key word here, however, is "reported," as many teams cover up potentially game-changing injuries from the media. The most recent example of this is the injury Lebron James had in the 2017-18 playoffs. After colliding with F Jayson Tatum on the Boston Celtics in the Eastern Conference Semifinals, James was taken to the locker room but came back out minutes later, despite looking like he was guaranteed diagnosed with a concussion. This raises the question - how do players balance their own bodies with team success?



"I think Shaq was having health issues that would've prohibited us from going on these big runs. If you think of his body – you think about the size of this man with his agility – at some point, it starts chipping away." - Kobe Bryant, teammate of O'Neal

As the NBA has become much more competitive, teams have been put in a position to play their stars more than intended. Last year in the playoffs, Lebron James played *all* 48 minutes of multiple playoff games in order to lead his team to the finals, which is definitely not safe, regardless of how great of a player he is. During this year's NBA Playoffs matchup between the Portland Trail Blazers and Denver Nuggets, Nuggets' C Nikola Jokic played 65 minutes of high intensity basketball as Game 3 lingered until the fourth overtime session. In the Golden State Warriors and Houston Rockets matchup, Warriors' F Kevin Durant averaged over 42 minutes per game until his body finally gave out and he suffered a non-contact leg injury that many feared to be an Achilles Tendon rupture (it was ultimately diagnosed as a calf strain). As teams look to quench their championship thirst, the extent of which they have stressed their stars has come into question.

What can we do about this - how can we make the NBA just as competitive while prioritizing player safety? The most obvious answer to this problem is to shorten the NBA season - however, this does not bode well to NBA owners who wish to maximize revenue in order to account for the astronomical costs of maintaining a team. While the NFL has a hard cap of $188.2 million, the NBA only has a cap of $99 million, but teams are allowed to use the luxury tax, a form of soft cap, in order to accommodate for the lower cap. Therefore, the real cap numbers of NBA teams can balloon to well over $300 million dollars. The problem with this, however, is that teams hand out massive contracts, sometimes to “subpar” players just because they have so much money - for example, the Charlotte Hornets currently pay F Nicolas Batum $120 million over 5 years, but he is not even a top 5 scorer on his team. To show the disparity of contracts, the most expensive player in the NFL right now is QB Russell Wilson of the Seattle Seahawks, who makes $140 million over 4 years with a $65 million signing bonus. This number pales in front of the highest paid NBA player, PG Stephen Curry of the Golden State Warriors, who earns a whopping $201.16 million all in guaranteed money over the course of 5 years.

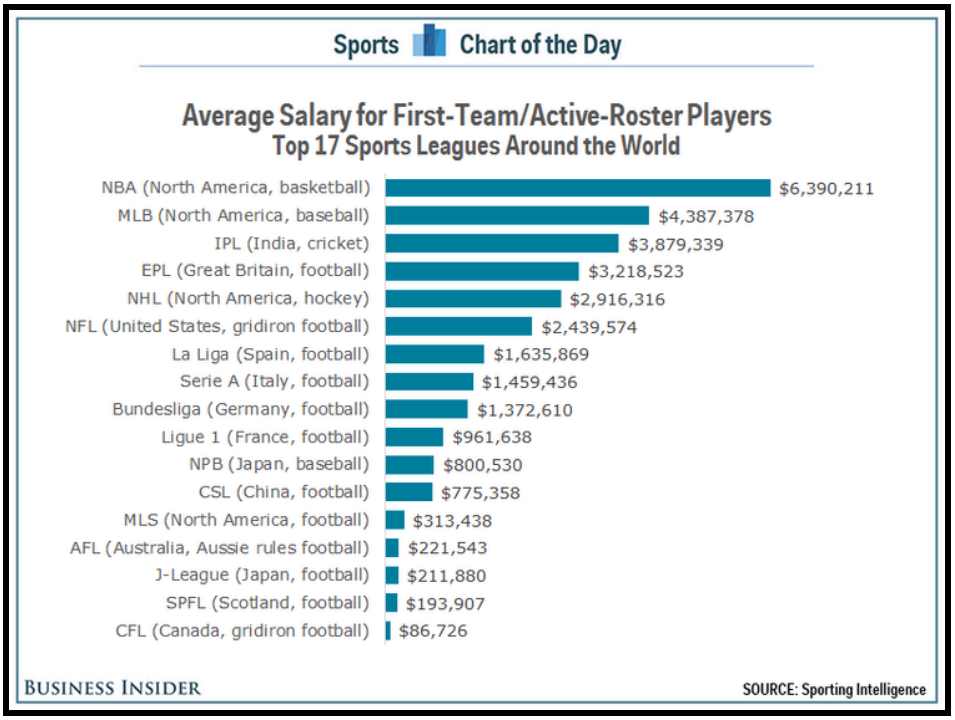


The two highest paid players in the league, PG Russell Westbrook of the Oklahoma City Thunder and PG Steph Curry of the Golden State Warriors, rake in $35.65 million and $37.46 million per year, respectively.

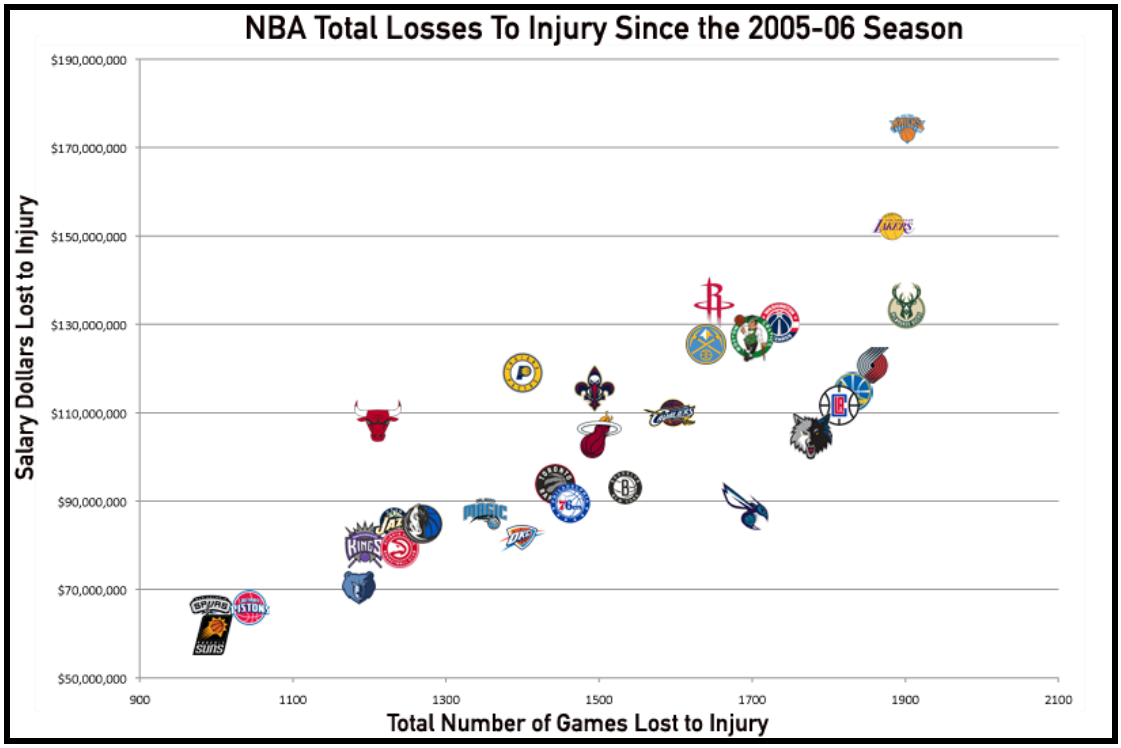
Because of these high salaries, NBA owners are put in a position to increase funds in order to accommodate for stars on their teams, meaning that they need to maximize the number of home games they have. In theory, a shorter NBA season would lead to less revenue, and less revenue is a push factor for stars - a bad prospect for these NBA owners.

Another aspect of the injury problem in the NBA is that contracts are fully guaranteed in the NBA, so when a player is injured NBA teams still have to pay them. The most prominent example of this case is PG John Wall of the Washington Wizards. A 5 time NBA All-Star, Wall recently inked a max contact that owes him $169.2 million dollars over 4 years. The problem: Wall hasn't played a minute of basketball after rupturing his Achilles that has sidelined him for the 2018-19 season and now threatens his availability for the 2019-20 season.

The following graph from Business Insiders epitomized just how much teams tend to ink massive contracts, even to unproven players.



This next graph shows the money lost from injury for all 30 teams in the NBA.



Ironically, the two teams that have lost the most money, the Lakers and Knicks, are also the most bankable teams in the NBA, as stars are lured by the high profile cities and media coverage that comes with these teams. The profits earned from games at the Staples Center or Madison Square Garden offset the costs incurred by these teams, but other teams like the Minnesota Timberwolves and Orlando Magic do not fare as well with their small markets.

The financial aspects of the NBA make it difficult to reduce the season in order to lessen injury rates. However, hope still does exist with the integration of new protocols and technologies, much like that in the NFL. As the popularity of basketball continues to soar throughout the world and the competitive nature of the league boosts ratings and revenue, the outlook of the league looks very bright.

Discussion

As the entire analysis above is an observational study, there are many shortcomings of the study that must be addressed. Aforementioned, all injury numbers above are based on what is reported, but many teams have been known to omit key players from injury reports in order to prevent media frenzy. This may skew many calculations performed above. First, with a prevalence of role players counted in the injury reports rather than star players, the treatment the role players undergo are much less aggressive, and the costs incurred are also lower as role players earn less that star players. For example, in the graph for the costs incurred by NBA teams, there is a possible case of confounding - in other words, multiple variables could explain the high costs incurred for high profile teams like the Lakers and Knicks. On one hand, these teams may indeed suffer numerous injuries that have driven up costs. On the other hand, another possible reason for the above trend is that these high profile teams tend to have higher payrolls, so they may not suffer as many injuries but because salaries are so high they suffer high costs.

Another major shortcoming of the observational study above is that it is a retrospective study - in other words, data from seasons past are compiled rather than data that professionals expect. The problem with this is that calculations are not as flexible as the numbers are already set in stone. Speaking of numbers, the data above might not even be all that accurate. For example, how do professionals in the NFL determine what constitutes as an ACL or MCL tear? Do partial tears and sprains that are misdiagnosed as tears still count in the data, or are only complete tears counted? As per concussions, even if an athlete isn't ultimately diagnosed for a concussion, does it count in the data if the athlete has underwent a concussion protocol?

As per the financial aspect of injuries, it is important to note that the data for costs incurred are in nominal dollars - in other words, it does not account for inflation. While the effects of inflation may be minimal, the bigger possible issue is that the rising cap space for NFL and NBA teams lead to an increase in contract prices, leading to an increase in costs incurred. Therefore, it is possible to assume that injury severity has remained constant, but the rising costs incurred may seem like it is not (this conclusion is proven wrong with other graphs, but if one were to look at only the graph of costs incurred, he or she could come up with that specific conclusion.

In essence, the retrospective observational study was more so an introductory paper to get acquainted with the demands of a research paper in college and beyond. Many conclusions in the paper may be erroneous upon scrutiny, but it definitely achieved its end purpose.

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