

Injury Trends in Major League Baseball Over 18 Seasons: 1998-2015

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Abstract

Since Major League Baseball (MLB) expanded to its current size of 30 teams in 1998, a comprehensive and longitudinal study of injury trends has not been performed. The purpose of this work is to report the epidemiology of injuries in MLB over that time utilizing disabled list (DL) data. Additionally, we sought to determine the financial impact of these injuries for MLB teams. During this analysis, we focused special attention on injuries of the medial ulnar collateral ligament (MUCL) and conducted a comprehensive review of all MUCL reconstructions ever performed on MLB players.

Over the study period, there were a total of 8357 DL designations (mean of 464 annually). Players lost a total of 460,432 days (25,186 days annually) due to injury. Both the number of DL assignments and number of DL days increased from year to year ($P < .001$ and $P = .003$, respectively). Average length of DL assignments remained steady over time at 55.1 days ($P = .647$). Although

shoulder injuries decreased ($P = .023$), this was met with a reciprocal increase in elbow injuries ($P = .015$). The average annual cost of designating players to the DL was \$423,267,634 and a total of \$7,618,817,407 was spent over the entire 18 seasons.

Regarding MUCL injuries, a total of 400 MUCL reconstructions were performed in MLB players between 1974 and 2015, and the mean time to return to MLB competition was 17.1 months. The annual incidence of MUCL reconstructions increased dramatically from year to year ($P < .001$) and nearly one-third ($n = 131$, 32.8%) of all procedures performed over the 42-year period occurred in the last 5 years (2011 to 2015).

In summary, overall injury rates and DL assignments continue to rise. Although shoulder injuries are declining, this improvement is countered by increasing elbow injuries, and these injuries continue to represent a significant source of lost revenue.

While the exact origins of the game of baseball are commonly debated, one thing is certain: statistics have been an integral part of the game since its existence.¹⁻³ This is true at nearly every level of baseball, especially in Major League Baseball (MLB). As our knowledge and technical capabilities advance, new statistical measures of baseball performance are added at a rapid pace.^{1,3} One example is the Pitch f/x video tracking system (Sportvision, Inc.), which now analyzes over 60 variables on each of the estimated 660,000 pitches thrown in the MLB annually. In addition to measuring performance and production,

these advancements are being leveraged to better understand the epidemiology and impact of injuries in MLB players.^{4,5} As with any sport, performance at the most elite level is highly dependent upon player health and functional capacity. Accordingly, player injuries can have a profound impact not only on individual performance but also on the success of the team as a whole.

The first epidemiologic study of injuries in professional baseball was published by Conte and colleagues⁴ in 2001. This work utilized publically available disabled list (DL) data to perform a comprehensive review of injury patterns in MLB from

Authors' Disclosure Statement: The authors report no actual or potential conflict of interest in relation to this article.

1989 to 1999. They demonstrated that injuries were on the rise and that pitchers were more commonly injured (48.4% of all DL reports) and had greater time out of play compared to players of other positions.⁴ Shoulder and elbow injuries were responsible for 49.8% of all DL assignments, distantly followed by knee (7.3%), wrist/hand (6.1%), and back (5.0%).⁴ In a later study, Posner and colleagues⁵ analyzed DL data spanning the 2002 to 2008 seasons. Similarly, they found that injuries continued to increase, and over half (51.2%) of DL assignments occurred secondary to upper extremity injuries.⁵ Although the DL is primarily designed as a roster management tool rather than an injury database, it has provided valuable epidemiologic injury information through the years. Out of concern for player health and well-being, MLB and the MLB Players Association (MLBPA) worked together to create and implement an electronic medical record and Health and Injury Tracking System (HITS) for all MLB and Minor League Baseball (MiLB) players. Now active for over 5 seasons, this database has provided valuable, detailed reports regarding specific injuries occurring in professional baseball, such as hamstring strains and concussions.^{6,7}

With shoulder and elbow injuries in pitchers representing the greatest proportion of DL assignments in recent years, a large body of literature on these injuries, particularly medial ulnar collateral ligament (MUCL) injuries, has been published.⁸⁻¹³ Since the initial description of MUCL reconstruction, or "Tommy John surgery," by Dr. Frank Jobe in 1986, much has been done to improve the technique and rehabilitation to maximize player performance following surgery.^{10,14-16} Despite this increased attention, large-scale epidemiologic reporting of MUCL injuries in MLB is lacking, but such a report is desirable. The purpose of this work is to: 1) provide a large-scale analysis of injuries occurring in MLB baseball over the course of 18 seasons (1998-2015); 2) highlight the financial implications of these injuries; and 3) detail the evolution of MUCL injuries and reconstructive surgery since it was first performed on a MLB pitcher in 1974. Our study represents the largest longitudinal analysis of MLB injuries since the league expanded to its current level of 30 teams in 1998. It is our hope that this work will serve as a framework for future study of the most common and highest impact injuries occurring in baseball.

Materials And Methods

We performed a retrospective review of the MLB DL from 1998 to 2015. Data analyzed included

player demographics such as club, year of placement, age, and position. Injury-specific variables included date of placement on DL, length of time on DL, date of reinstatement, body part injured, diagnosis, and cost of replacement. If a player was put on the DL multiple times during a season, each placement was viewed as a different injury, even if it was to the same body part. If a player was put on the DL for injuries to multiple body parts, the primary injury was analyzed.

Disabled List Data

Although the DL has existed since 1916, this current study covers 18 seasons from 1998 to 2015. The 1998 season was chosen as a starting point because this is the year when MLB expanded to 30 teams. Since then, the number of teams and the active roster limits (25 players) have remained constant, allowing for reliable comparisons across seasons. Initially designed as a roster management tool to allow injured players to temporarily be replaced with healthy players, the DL was not created as an injury database. However, the rules and regulations of the DL have remained fairly constant over the last 18 years, allowing reasonable comparisons of injury data and trends across this time-span. In order for a player to be assigned to the DL, the nature and extent of injury must be certified by a physician. Once designated for the DL, a player cannot return to the major league team for a minimum of 15 days. If the injury is severe, the player can remain on the DL for the remainder of the season or until he is deemed healthy enough to return to play by a physician. One notable exception is the treatment of concussions. Since 2011, a player diagnosed with a concussion may be placed on the DL for a minimum of 7 days rather than 15. The introduction of the HITS database in 2010 should allow for more detailed and reliable study of injuries in baseball moving forward. Although it contains robust data for every injury that has occurred in MLB and MiLB over the last 5 seasons, it does not allow for epidemiologic and longitudinal study of injury patterns and trends in baseball prior to 2010.

Cost of Placing Players on the DL

The dollars lost were calculated by prorating the injured player's daily salary and multiplying by the number of days missed on the DL. For example, if a player's annual salary is \$1,820,000, his daily salary for the 182 day season is \$10,000. If assigned to the DL for 15 days, \$150,000 is paid to

that player while he is inactive and unable to play. An additional cost is the salary of the replacement

player who fills the roster spot. For this work, the replacement player's prorated, daily salary was assumed to be the league minimum for that specific year. For example, if the league minimum for a given season is \$182,000, and the season is 182 days long, a replacement player earns a minimum of \$1,000 per day while he is on the 25-man active roster. Thus, the dollars paid to the replacement would be \$15,000. In this scenario, that brings the team's total cost to \$165,000 (\$150,000 plus \$15,000). Because the league minimum salary changes year to year, salaries specific to the year of injury were utilized in this analysis.

Table 1. Demographics of Disabled List Designations Over Time

Year	Players on DL	Total DL Days	Avg DL Length
1998	387	21,132	54.7
1999	424	23,360	55.1
2000	460	24,611	53.5
2001	461	27,299	59.2
2002	447	24,741	55.3
2003	413	22,484	54.4
2004	435	25,008	57.5
2005	410	23,483	57.3
2006	413	22,252	53.6
2007	478	27,242	57.1
2008	529	28,385	53.9
2009	476	26,173	55
2010	459	23,579	50.9
2011	515	25,285	49.1
2012	504	29,706	58.9
2013	519	29,204	56.3
2014	488	26,186	53.9
2015	536	30,302	56.5
Totals	8357	460,432	55.1

Abbreviation: DL, disabled list.

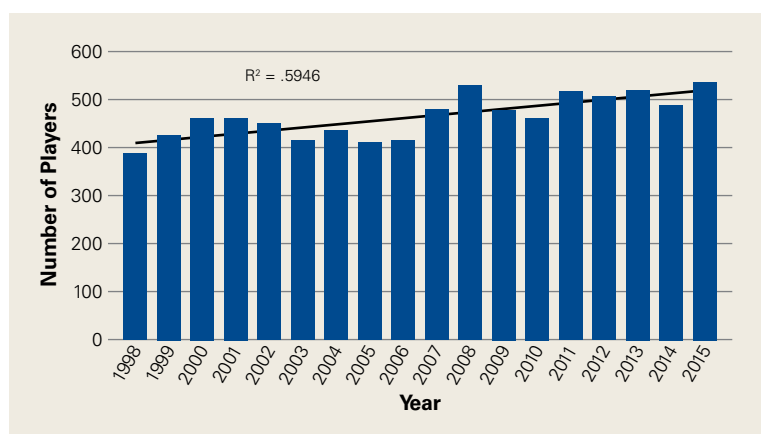


Figure 1. Number of players assigned to the disabled list based on year. This demonstrates a trend of increasing disabled list assignment over the years ($P < .001$).

MUCL Injury Analysis

In order to better understand the evaluation of MUCL injuries over time, all MLB players undergoing MUCL reconstruction ("Tommy John surgery") were analyzed separately. Similar to prior studies of UCL injuries, these players were identified using DL data, team websites, and publically available internet databases (primarily www.heatmaps.com).^{9,12,17-19} Variables studied include the number of procedures, year of surgery, player position, and mean time until return to play at the MLB level. All MLB players undergoing MUCL reconstruction since 1974 (the year the first procedure was performed) were included.

Statistical Methods

Epidemiologic data are reported using descriptive statistics (mean, range, and percentage) where indicated. To determine the significance of trends over time, a best-fit line was generated to illustrate the change over the years. These lines are reported with corresponding R^2 values. To assess the trend for significance, the slope was compared to a line with a slope of zero (no change over time) using t tests. For all statistical comparisons, the threshold for alpha was set to $P < .05$.

Results

Between 1998 and 2015, there were 8357 placements of players on the DL, at an average rate of 464 designations per year (**Table 1, Figure 1**). This resulted in 460,432 days lost to injury, with a mean of 25,186 days out of play per season (**Table 1, Figure 2**). The mean length of DL assignment per year was 55.1 days per injury, with a low of 49.1 days in 2011 and a high of 59.2 days in 2001 (**Table 1, Figure 3**). During the study period, the number of players placed on the DL and the total number of DL days steadily increased ($P < .001$ and

$P = .003$, respectively), while the average length of DL assignments remained steady ($P = .647$). When analyzing the data by body region injured, the shoulder (20.6%) and elbow (19.6%) were the 2 leading causes of time out of play (Table 2). This was followed distantly by the chest/back/spine (13.7%), wrist/hand/fingers (10.1%), lower leg/knee (9.8%), and the upper leg/thigh (9.5%). Although the percentage of injuries occurring to the upper extremity remained stable, the rate of shoulder injuries steadily decreased ($P = .023$) as elbow injuries increased ($P = .015$) (Table 3, Figure 4). This inverse relationship was also demonstrated for the annual number of DL days for shoulder ($P = .033$) and elbow ($P = 0.005$) injuries (Figure 5).

Regarding the financial impact of these injuries, the mean annual cost of replacing players on the DL was \$423,267,633.78 (Table 4). This ranged from a low of \$136,397,147 in 1998 to a high of \$694,835,359 in 2015. There was a steady increase in the cost of replacement during the study period ($P < .001$) that coincides with the increasing salaries during that time span (Figure 6). In total, \$6,732,167,180 was paid to players assigned to the DL and \$886,650,228 was spent to fill their posi-

tions. This brings the total cost of DL assignments to \$7,618,817,407 for the study period.

Table 2. Disabled List Assignments Based on Body Region Injured

Body Part	Placement %	DL Days %
Shoulder	20.6%	26.2%
Arm/elbow	19.6%	28.2%
Chest/back/spine	13.7%	10.1%
Wrist/hand/fingers	10.1%	8.1%
Lower leg/knee	9.8%	8.9%
Upper legs/thighs	9.5%	5.8%
Ankle/foot/toes	6.0%	5.0%
Pelvis/hips	5.7%	4.1%
Head	2.3%	1.5%
Internal organs	1.1%	0.8%
Neck	0.8%	0.6%
Nonspecific	0.4%	0.3%
Not listed	0.3%	0.2%
Totals	100.0%	100.0%

Abbreviation: DL, disabled list.

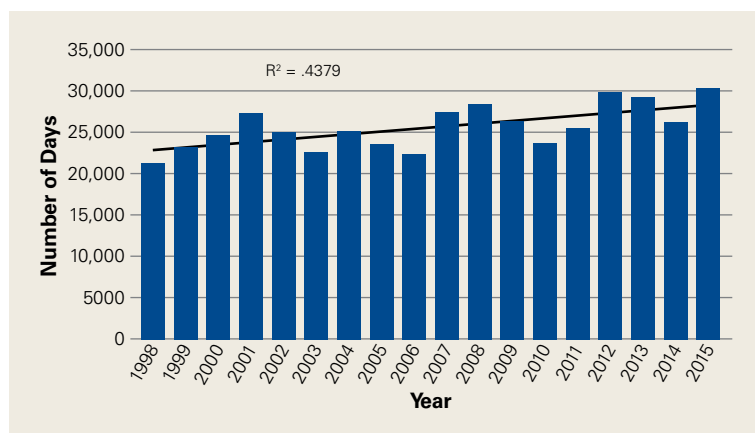


Figure 2. Total number of days actually spent on the disabled list by Major League Baseball players continues to rise from year to year ($P = .003$).

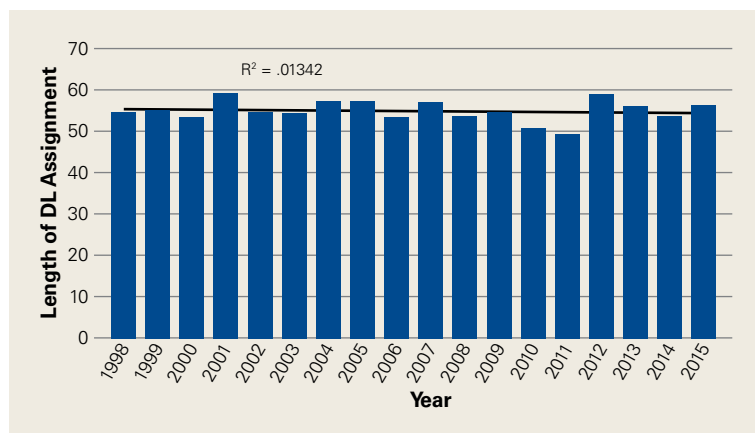


Figure 3. The average length of each assignment to the disabled list (DL) has remained relatively stable over time ($P = .647$).

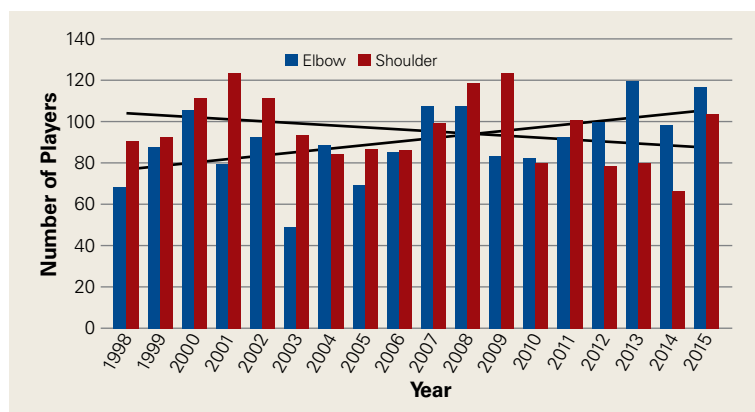


Figure 4. Although the annual number of disabled list designations for shoulder injuries is on the decline ($P = .023$), the number of elbow injuries continues to rise ($P = .015$).

Table 3. Details of Disabled List Assignments for Shoulder and Elbow Injuries

Year	DL Placements for Elbow Injury	DL Days for Elbow Injury	DL Placements for Shoulder Injury	DL Days for Shoulder Injury
1998	68	5263	90	6897
1999	87	6449	92	6631
2000	105	7490	111	7718
2001	79	6602	123	9307
2002	92	5979	111	7978
2003	64	5202	93	6566
2004	88	7781	84	5635
2005	69	5381	86	6169
2006	85	6174	86	6238
2007	107	8265	99	7220
2008	107	7862	118	8038
2009	83	7329	123	7707
2010	82	5414	80	6022
2011	92	5512	100	7159
2012	100	9439	78	5866
2013	119	10,344	80	5523
2014	98	9314	66	3683
2015	116	10,000	103	6382
Totals	1641	129,800	1723	120,739

Abbreviation: DL, disabled list.

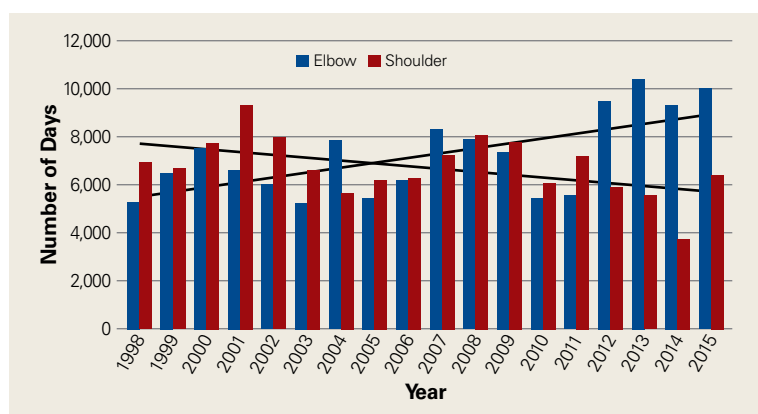


Figure 5. The annual number of disabled list (DL) days for shoulder injuries is declining ($P = .033$) while the number of days spent on the DL for elbow injuries is rising ($P = .005$) each year.

Looking specifically at MUCL injuries, a total of 400 MUCL reconstructions have been performed on MLB players since the procedure was first developed in 1974. The vast majority of these were performed in pitchers ($n = 361$, 90.3%) followed by outfielders ($n = 16$, 4.0%), infielders ($n = 14$, 3.5%) and catchers ($n = 9$, 2.3%) (**Table 5**). The mean time to return to competition at the MLB level was 17.8 months for pitchers, 11.1 months for outfielders, 9.6 months for infielders, and 10.5 months for catchers. The overall mean time to return was 17.1 months. The annual number of MUCL reconstructions continues to rise dramatically ($P < .001$) (**Figure 7**). During the first 12 years (1974-1985), a total of 8 (2.0%) MUCL reconstructions were performed on MLB players. In subsequent decades, this number increased to 44 (11.0%) from 1986-1995, 123 (30.8%) from 1996-2005, and 225 (56.3%) from 2006-2015. Of all Tommy John surgeries performed over 42 years, nearly one-third ($n = 131$, 32.75%) were performed in the last 5 years alone (2011-2015).

Discussion

To date, a number of studies have been published on injuries in professional baseball. These can primarily be categorized as either studies with a detailed focus on a single injury type or body region^{6-13,17,19} or broader reviews that are limited by the relatively short time span covered.^{4,5} The purpose of this work was to provide a comprehensive review of injury trends in MLB since the league expanded to 30 teams in 1998 while paying special attention to the financial impact of those injuries. Additionally, we sought to provide an up-to-date review of MUCL injuries and surgeries since the procedure was first developed in 1974. Ultimately, this data demonstrates that injuries continue to rise in MLB and this increase is accompanied by increased expense for teams. Thankfully, the rates of DL assignments for shoulder injuries are on the decline; however, this decrease is countered by a reciprocal increase in elbow injuries. Similarly, the rates of MUCL reconstruction have also risen dramatically in recent years.

The fact that injury rates are on the rise is confirmed by other published reports. This trend was demonstrated in prior analyses of DL data from the 1989 to 1998⁴ and 2002 to 2008 seasons.⁵ These 2 studies represent the only comprehensive reviews of MLB injury trends to date, and each provides valuable information. Both are consistent with the current study findings that pitchers are the most

commonly injured players and that shoulder and elbow injuries represent about half of all injuries.^{4,5} Similar injury rates and characteristics have been reported at the collegiate²⁰ and minor league levels.²¹ Despite this consistency, this analysis of injuries from 1998 to 2015 is the first to report that DL designations for shoulder injuries are on the decline while designations for elbow injuries continue to rise. Although the exact etiology of this decline in shoulder injuries remains unknown, there are a number of possible explanations. In recent years, increased emphasis has been placed on shoulder rehabilitation, reduction of glenohumeral internal rotation deficits, scapular stabilization, and overall kinetic chain balance and coordination. However, this does not explain why elbow injuries continue to rise annually.

With this increase in injuries, the cost of maintaining an active 25-man roster is also climbing. As expected, this growing expense is primarily due to the increased number of DL days each year as well as the increase in league salaries. Fortunately, this increased financial strain has been met with steadily increased annual revenues in professional baseball. In 2014, the prorated salary cost to players designated to the DL and their replacements was \$579,568,059. This figure represents an estimated 6.4% of the \$9 billion in total revenue for MLB that same year.²² Although this may represent a small percentage of the whole, it still embodies an exceptionally large financial responsibility. This does not include the medical expenses incurred to treat and rehabilitate the players' injuries.

Every injury that occurs in MLB players has the potential to adversely affect players, teams, and MLB as a whole. With its increasing prevalence, need for surgical treatment, and prolonged return to play, injuries to the MUCL of the elbow may represent the most costly of all injuries. Although a multitude of reports on MUCL injuries, treatments, techniques, rehabilitation, and outcomes have been reported,^{8,9,12,14-19,23-25} to our knowledge, a comprehensive and longitudinal incidence study in MLB players has not yet been published. By including every MUCL reconstruction that has been performed on a MLB player, our study demonstrates the dramatic increase in the annual incidence of MUCL surgeries. Studies performed over shorter time intervals corroborate these findings. A recent review of a privately insured patient database revealed an annual increase in MUCL reconstructions of 4.2% in that cohort.²⁶ When looking

Table 4. Cost of Paying Players Assigned to the Disabled List, Their Replacements, and Total Expenditures

Year	Dollars Paid to Players on DL	Dollars Paid to Replacement Players	Total Costs
1998	\$116,658,098	\$19,739,050	\$136,397,147
1999	\$179,236,163	\$25,670,330	\$204,906,493
2000	\$232,067,148	\$27,045,053	\$259,112,201
2001	\$306,924,995	\$29,998,901	\$336,923,896
2002	\$285,253,363	\$27,187,910	\$312,441,273
2003	\$379,118,306	\$37,061,540	\$416,179,846
2004	\$318,850,868	\$41,221,981	\$360,072,849
2005	\$323,683,438	\$40,772,681	\$364,456,119
2006	\$327,748,953	\$39,980,238	\$367,729,191
2007	\$381,146,971	\$56,878,899	\$438,025,870
2008	\$444,401,262	\$60,824,994	\$505,226,256
2009	\$445,748,582	\$57,523,073	\$503,271,655
2010	\$361,486,001	\$51,821,978	\$413,307,979
2011	\$430,043,961	\$57,516,429	\$487,560,389
2012	\$495,427,373	\$78,345,495	\$573,772,868
2013	\$586,403,803	\$78,626,154	\$665,029,957
2014	\$507,628,499	\$71,939,560	\$579,568,059
2015	\$610,339,397	\$84,495,962	\$694,835,359
Totals	\$6,732,167,180	\$886,650,228	\$7,618,817,407

Abbreviation: DL, disabled list.

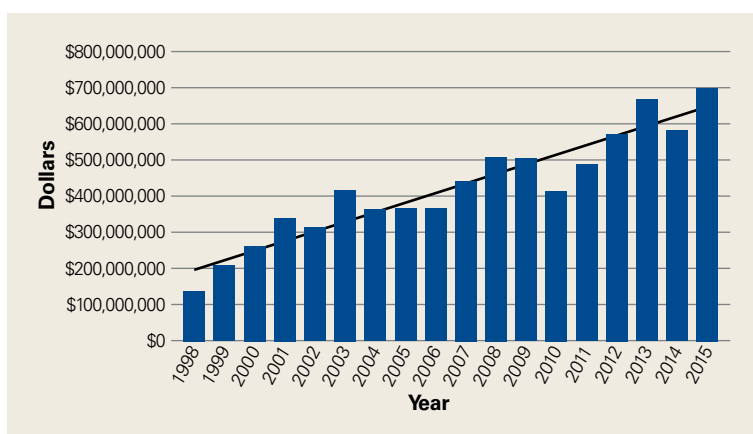


Figure 6. The total cost of paying the salaries of players assigned to the disabled list and their replacements has steadily increased over the last 18 seasons ($P < .001$).

specifically at the MLB, a recent survey of all 30 clubs found that 25% (96 of 382) of MLB pitchers and 15% (341 of 2324) of minor league pitchers have undergone MUCL reconstruction.⁸ Because it occurs so frequently and requires a mean of 17 months to return to sport, MUCL injuries represent a very significant cause of time out of play.

While this study represents a unique epidemiologic report on injuries in baseball, it is certainly not without its limitations. As stated previously, it relies on DL data that was initially intended to serve as a roster management tool rather than an injury database. Accordingly, detailed and specific information about every injury is not always available. The limitations of DL data will largely be overcome in future studies thanks to the implementation of the HITS database in 2010. Moving forward, this system will allow for more detailed analysis of injury patterns, characteristics, time out of play, treatments rendered, etc. Its main

limitation is that the earliest data dates back to 2010, making it less applicable for longitudinal studies like the present one. Another limitation of this study is the estimations used for the cost of replacing players designated to the DL. For each injury, it was assumed that the replacement player was paid a prorated portion of the league minimum salary while on the major league roster, but in some instances, that may not have been the case. It is possible that some players filling roster spots were already under contract for amounts higher than the league minimum. Since that player would be making that amount regardless of the level of play, the team may not have paid them any additional salary while filling the position of the injured player. The strengths of this study are its comprehensive nature and inclusion of 18 years of data, making it the longest such study of injuries in MLB. It also represents the first report of cost of replacement for players designated to the DL. To our knowledge, this study also represents the first comprehensive report of every MUCL surgery that has been performed on MLB players.

Table 5. Demographics of Medial Ulnar Collateral Ligament Reconstruction Based on Position, Including Mean Time to Return to Prior Level of Competition of Major League Baseball

Position	N (%)	Mean Time to Return to MLB (months)
Pitchers	361 (90.3%)	17.8
Outfielders	16 (4.0%)	11.1
Infielders	14 (3.5%)	9.6
Catchers	9 (2.3%)	10.5
Totals	400 (100%)	17.1

Abbreviation: MLB, Major League Baseball.

Conclusion

Injury rates continue to rise in MLB, and upper extremity injuries continue to represent approximately half of all injuries resulting in time out of play. Although shoulder injuries have been on the decline in recent years, this decline is offset by a steady increase in elbow injuries. Each year, MLB players are designated to the DL an average of 464 times for a total of 25,579.6 days. This results in a mean annual cost of over \$400 million dollars to replace players lost to injury. Looking specifically at MUCL injuries, a total of 400 MUCL reconstruc-

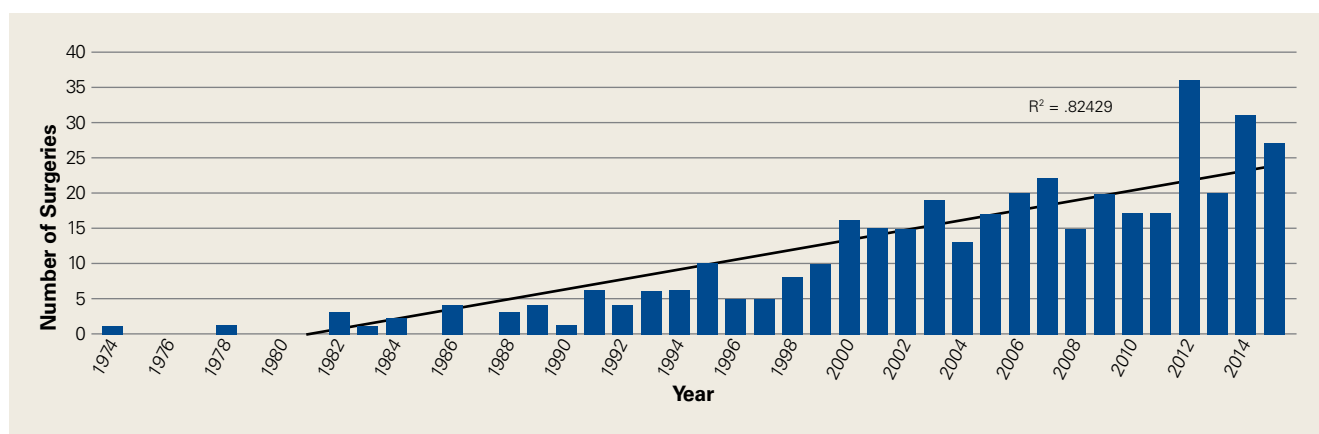


Figure 7. The first medial ulnar collateral ligament reconstruction was performed on a Major League Baseball player in 1974. Since that time, the rate of surgery has increased to a significant degree ($P < .001$).

tions have been performed in the MLB since 1974, and nearly one-third of these were performed in the last 5 years. Pitchers represent 90.3% of players requiring MUCL surgery, and the average time to return to sport for all players is 17 months. These data may serve as a foundation for identifying appropriate targets for continued study into the etiologies, strategies for prevention, and optimal treatments of injuries commonly affecting professional baseball players.

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