



Original Research

Musculoskeletal lower limb injuries in Major League Baseball

Hamza A. Salhab^{a, b}, Mohamad Y. Fares^{a, b}, Hussein H. Khachfe^{a, b}, Jawad Fares^{c, *}^a Faculty of Medicine, American University of Beirut, Beirut, Lebanon^b Neuroscience Research Center, Faculty of Medical Sciences, Lebanese University, Beirut, Lebanon^c Department of Neurological Surgery, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

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ABSTRACT

Objectives: To explore the epidemiological patterns and musculoskeletal characteristics of lower limb injuries in Major League Baseball (MLB).**Design:** Descriptive epidemiological study.**Setting:** The MLB was screened for injuries between 2010 and 2016, inclusive.**Participants:** Players that were placed on the Disabled List (DL) and had lower limb injuries.**Main outcome measures:** Our database entailed the player's position, injury location, injury cause, and time spent on the DL. Analysis of characteristics and mean incidence rates (MIR) were conducted, and P values < 0.05 were considered significant (CI 95%).**Results:** A total of 3546 injuries were recorded; 1053 injuries (29.7%) affected the lower limbs (n = 1053). On average, 150.4 players per season were placed on the DL for a mean of 45.7 days. Thighs were the most common site of injury, whereas hip injuries had the highest average days on DL (62 days). Fielders had a significantly higher MIR of lower leg injuries when compared to pitchers (P = 0.007) and catchers (P = 0.024), and a significantly higher MIR of foot injuries than that of pitchers (P = 0.035). April was the month with the highest number of injuries (224 injuries, 21.3%). Only 43(4%) injuries required surgical intervention.**Conclusion:** Lower limb injuries are increasing in the MLB. Understanding the neuromuscular patterns of injuries will help in extrapolating better prevention policies.

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Introduction

Baseball is a North American bat-and-ball game played between two opposing teams who take turns batting and fielding. Sprinting and running constitute a major part of the sport; therefore, lower limb injuries pose a threat that affects the athletes and their respective clubs (Ahmad et al., 2014).

Lower limb injuries are the most common injuries occurring in sports today (Hussain, 2010). They are widely prevalent in sports like football, baseball, basketball, MMA, and track-and-field (Hussain, 2010; Fares, Dimassi, Baydoun, & Musharrafieh, 2019; Fares, Fares, Fares & Abboud, 2019b,c; Fares, Fares, Baydoun, & Fares, 2019; Fuller, Junge, & Dvorak, 2005). Given the high involvement of the lower limb in movements like sprinting, running, and jumping, it is understandable why this

anatomical region of the body is often prone to injury (Hussain, 2010). Consequently, these injuries may lead to functional impairment, psychological distress and reduction in quality of life for the injured athlete (Croisier, 2004; Elliott, Zarins, Powell, & Kenyon, 2011; Fares, et al, 2018a,b).

In Major League Baseball (MLB), the disabled list (DL) is a method that was created in 1915 to remove injured players from the team roster. At that time, only two injured players from each team could be removed from the roster for a ten-day recovery period. Since then, the DL has evolved into a more flexible system that can include any player incapable of competing, allowing teams to replace all their injured players with healthy substitutes. The list would also help in better understanding injury patterns and risk factors, with the aim of ultimately optimizing the players' physical wellbeing.

Several studies focused on the biomechanics and treatment of these injuries in baseball; however, little was published on the epidemiology of these injuries (Fleisig, Andrews, Dillman, & Escamilla, 1995; Park, Loebenberg, Rokito & Zuckerman,

* Corresponding author. Department of Neurological Surgery, Northwestern University, Feinberg School of Medicine, Chicago, IL, 60611, USA.

E-mail address: jawad.fares@northwestern.edu (J. Fares).

2002a,b; Werner, Gill, Murray, Cook, & Hawkins, 2001). The aim of this work is to explore the epidemiological patterns and neuromuscular characteristics of lower limb injuries in the MLB. Analysis of characteristics and incidence rates (IR) would help better understand the dynamics of these injuries, assess risk factors, and extrapolate effective prevention policies.

Materials and methods

Study design

This is a descriptive epidemiological study targeting lower limb injuries in the MLB. The MLB is a baseball league comprised of 30 different clubs that span over the United States and Canada. Each club has 163 games scheduled over a six-month season. The season usually begins late March or early April and ends on the last week of September (Werner et al., 2001). MLB players that are injured are placed on the MLB's DL. The data in our study was compiled using the transaction database found on the MLB website ([Major League Baseball Transactions, 2018](#)), which includes players who are added on the DL.

Participants

Players with lower limb injuries that were added to the DL between 2010 and 2016 (inclusive) were included. In order to be placed on the DL, MLB rules dictate that players must be diagnosed by the team physician and labeled as incapable to play (Dick et al., 2007a; Dick et al., 2007b). Players can remain on the list for as much time as they need to fully recover from their injuries; however, once placed on the list, the player must remain inactive for a minimum of 15 days.

Definitions

Baseball constitutes several playing positions. The pitcher is the player who throws the baseball from the pitcher's mound toward the catcher, the receiver of the ball, to begin each play. An infielder is stationed at one of four defensive "infield" positions on the baseball field (first base, second base, third base or shortstop). An outfielder is a player who tries to catch long fly balls before they hit the ground, or to quickly catch or retrieve and return to the infield any other balls entering the outfield. Outfielders normally play behind the infielders.

For the purpose of this study, we considered any type of physical harm or damage pertaining to the lower limb area that lead to placing any baseball player on DL for more than 1 day to be an injury. We divided lower limb injuries into six major anatomical zones: (1) The hip zone included injuries affecting the "hip," "hip flexor," "gluteal," and "sacroiliac joint"; (2) the thigh zone included the "thigh," "quadriceps," "groin," and "hamstring" injuries; (3) the knee zone included the "knee," "ACL," "meniscus," and "patella"; (4) the lower leg included "lower leg," "calf," "fibula," "tibia," and "shin" injuries; (5) the ankle zone included the "ankle" and "Achilles" injuries; and (6) the foot zone included injuries involving the "foot," "heel," "metatarsal," and "toe".

Data processing

Data pertaining to the player's position (pitcher, catcher, infielder, and outfielder); anatomic position of injury (hip, thigh, knee, lower leg, ankle, and foot); cited cause of injury (tendinitis, inflammation, strain, and other); time spent on the DL (1–30 days, 31–60 days, and >60 days); and whether injuries required surgery were collected. Injuries listed were the ones that occurred during

training, regular season, or post-season play, and caused a loss in game time for the player. Injuries during off-season were not included since they do not relate to baseball activity.

Statistical analyses

To calculate the IR of injury, we considered all the teams to be 25-men roster teams. We also assumed that each team played 162 games during the seven seasons studied; as such, every game was defined as an athletic exposure (AE).

For categorical variables, analyses were based on frequencies and percentages, whereas mean differences (MD) and standard deviations were used for comparison of continuous variables. To determine whether a significant difference exists between the IR of different anatomical injuries and players' positions, we used the one-way analysis of variance (ANOVA) test. In case of ANOVA significance, Tukey's Multiple Comparison test was done to tell which specific groups were significantly different from each other. P-values <0.05 were considered statistically significant (CI 95%). All analyses were performed with Statistical Package for the Social Sciences for Windows software version 25.0 (IBM SPSS, 2017).

Results

In the seven seasons studied (2010–2016), a total of 3546 injuries were recorded in the MLB. Of all documented injuries, 1053 injuries (29.7%) affected the lower limbs ($n = 1053$). Every season, an average of 150.4 players was placed on the DL due to lower limb injuries. Only 43 injuries (4%) required surgical intervention. Thigh injuries were the most common type of lower limb injuries, followed by knee injuries; whereas hip injuries were the least common (Table 1). All lower limb injuries of each anatomical zone were stratified according to their type (Table 2).

Time loss

To assess the healing time of lower limb injuries, we studied the time that injured athletes spent on the DL during the seven seasons. On average, a lower extremity injury placed MLB baseball players on the DL for 45.7 days (range 4–183 days). Hip injuries had the highest average days on DL with 62 days, whereas thigh injuries had the lowest with an average of 35 days on the DL (Table 3). Players with hip injuries were placed for a significantly longer period on the DL than thigh ($P < 0.001$; CI [14.2, 43.9]) and lower leg injuries ($P = 0.027$; CI [1.34, 38.04]). Players with thigh injuries spent significantly less days on DL when compared to knee ($P < 0.001$; CI [-30.2, -12.3]), ankle ($P < 0.001$; CI [-31.5, -8.0]), and foot injuries ($P = 0.48$; CI [-24.7, -0.1]) (Table 4).

Player position and injury incidence

Changes in IR of lower limb injuries according to the different player positions were inspected and analyzed. Between 2010 and 2013, lower limb IR increased by 30.6% for fielders, and decreased by 43.6% for pitchers and 31.5% for catchers. Nevertheless, these changes reversed between 2013 and 2016, where IR decreased by 10.2% for fielders, and increased by 75.5% for pitchers and 100% for catchers. The general trend of lower limb IR did not significantly change by player position over the studied period. The coefficient of determination (R^2) measured was 0.18 for catchers, 0.06 for fielders and 0.04 for pitchers. In general, the total IR of lower extremity injuries increased between 2010 and 2016 ($R^2 = 0.32$) (Fig. 1 and Table 5). Analysis of injuries by player position showed that pitchers had a significantly lower mean incidence rate (MIR) of lower limb injuries than fielders ($P < 0.001$; CI [-1.1, -0.6]) and

Table 1
Demographics of lower limb injuries in Major League Baseball (2010–2016).

		Injury Location						Total N(%)
		Hip	Thigh	Knee	Lower Leg	Ankle	Foot	
Position	Fielders	29	272	132	62	74	61	630 (60)
	Pitchers	34	134	69	20	30	31	318 (30)
	Catchers	3	31	43	5	12	11	105 (10)
Season	2010	14	57	31	16	13	20	151 (14)
	2011	8	54	24	16	16	18	137 (13)
	2012	11	54	38	13	19	17	152 (14)
	2013	8	64	36	11	18	10	147 (14)
	2014	8	73	34	12	16	10	153 (15)
	2015	6	58	38	9	17	16	144 (14)
	2016	11	77	43	10	17	12	170 (16)
Total N(%)		66 (6)	437 (42)	244 (23)	87 (8)	116 (11)	103 (10)	1053

Table 2
Types of lower limb injuries in Major League Baseball stratified by anatomical zone (2010–2016).

	Bruise	Fracture	Inflammation	Sprain	Strain	Surgery	Tear	Other Injuries	Total N(%)
Hip	4	2	15	0	24	7	7	7	66 (6)
Thigh	0	1	1	0	407	2	14	12	437 (42)
Knee	19	0	63	42	13	26	39	41	244 (23)
Lower leg	6	15	5	1	57	0	3	0	87 (8)
Ankle	6	4	13	61	11	6	15	1	116 (11)
Foot	14	32	24	17	6	2	8	0	103 (10)
Total N(%)	49 (5)	54 (5)	121 (11)	121 (11)	518 (49)	43 (4)	86 (8)	53 (5)	1053

Table 3
Classification of lower limb injuries in Major League Baseball by days placed on Disabled List (2010–2016).

	0–30 days	31–60 days	>60 days	Average days on DL
Hip	24	21	21	62.5
Thigh	263	118	56	35.1
Knee	88	83	73	56.2
Lower leg	47	21	19	45.8
Ankle	44	36	36	54.4
Foot	44	29	30	47.9
Total N(%)	510 (48)	308 (29)	235 (22)	45.7

catchers (P = 0.002; CI [-1.2, -0.4]) (Table 6).

Player position and anatomical location of injury

Analysis of lower limb injury MIR for the six anatomical zones indicated that fielders had a significantly higher MIR of hip injuries than catchers (P = 0.011; CI [0.002, 0.02]). For thigh injuries, fielders had a significantly higher MIR than pitchers (P = 0.034; CI [0.003, 0.086]). For knee injuries, catchers had significantly higher MIR when compared to both fielders (P = 0.005; CI [0.013, 0.073]) and pitchers (P < 0.001; CI [0.039, 0.098]). For lower leg injuries, fielders significantly had the highest MIR when compared to

pitchers (P = 0.007; CI [0.005, 0.023]) and catchers (P = 0.024; CI [0.002, 0.027]). For foot injuries, fielders had a significantly higher MIR than that of pitchers (P = 0.035; CI [0.001, 0.030]) (Table 6).

Injury and seasonal timing

Over the 7 seasons studied, April had the highest number of lower limb injuries with 224 injuries (21.3%), followed by May with 222 injuries (21.1%). September had the least number of injuries with a total of 32 injuries (3%) (Fig. 2).

Discussion

Our study shows that baseball is frequently impacted by lower limb injuries as they account for 29.7% of all injuries. These results conform to the ones obtained by Posner, Cameron, Wolf, Belmont, and Owens (2011) and McFarland and Wasik (1998) who noted that 30.6% and 27% of baseball injuries, respectively, were related to the lower extremity. Furthermore, our study shows that thigh injuries are more common than any other lower limb injury, as it had the highest incidence in all seasons, followed by knee injuries. These findings are similar to prior reports that studied hamstring and knee injuries in the MLB (Ahmad et al., 2014; Camp et al., 2018; Dahm et al., 2016). Nevertheless, this study uniquely explores in

Table 4
Mean difference (MD) of days spent on Disabled List stratified by injuries of different anatomical zones in Major League Baseball (2010–2016). *P value < 0.05. (Negative value → Row value < Column value).

	Foot		Ankle		Lower Leg		Knee		Thigh		Hip	
	MD	P value	MD	P value	MD	P value	MD	P value	MD	P value	MD	P value
Hip	16.7	0.079	9.3	0.643	19.7	0.027*	7.8	0.709	29	<0.001*	–	–
Thigh	–12.4	0.048*	–19.7	<0.001*	–9.4	0.33	–21.2	<0.001*	–	–	–29	<0.001*
Knee	8.9	0.393	1.5	0.999	11.9	0.151	–	–	21.2	<0.001*	–7.8	0.709
Lower Leg	–3	0.995	–10.4	0.428	–	–	–11.9	0.151	9.4	0.33	–19.7	0.027*
Ankle	7.4	0.739	–	–	10.4	0.428	–1.5	0.999	19.7	<0.001*	–9.3	0.643
Foot	–	–	–7.4	0.739	3	0.995	–8.9	0.393	12.4	0.048*	–16.7	0.079

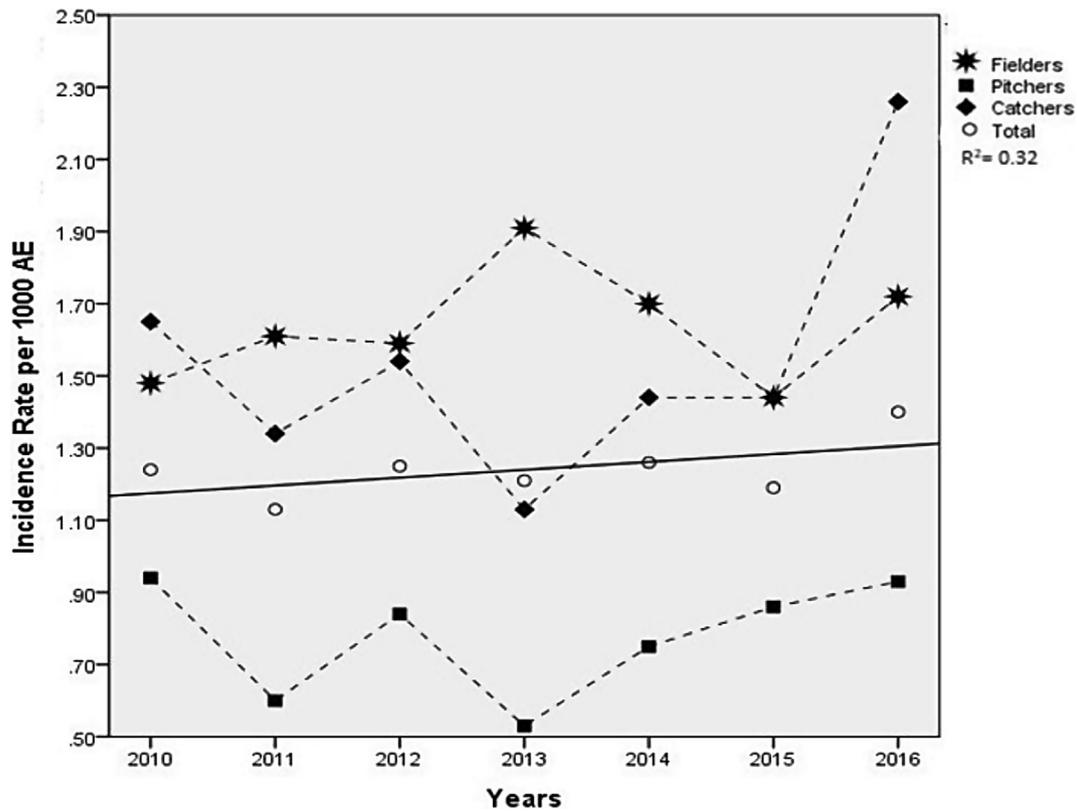


Fig. 1. Injury incidence rates of all players (fielders, pitchers, and catchers) in Major League Baseball over the studied seasons (2010–2016).

Table 5
Incidence rate of lower limb injuries (per 1000 Athletic Exposure) for each playing position in Major League Baseball.

	2010	2011	2012	2013	2014	2015	2016
Fielders	1.48	1.61	1.59	1.91	1.7	1.44	1.72
Pitchers	0.94	0.6	0.84	0.53	0.75	0.86	0.93
Catchers	1.65	1.34	1.54	1.13	1.44	1.44	2.26

detail the types of injuries, days missed, and incidence rates related to all anatomical zones of the lower limb as per player position and time.

The IR of lower extremity injury in the MLB increased over the seven seasons studied. Conte, Requa, and Garrick (2001) had previously found that the number of players on DL had increased between 1989 and 1999, which shows an increasing trend of injuries over time. This might be partly due to the emergence of more sophisticated diagnostic criteria that led to the diagnosis of a higher number of lower limb injuries, and the increased popularity and professional practice of the sport over the years.

Our study found that fielders and catchers had significantly higher incidence of lower limb injuries than pitchers. Fielders are

more involved in running and sprinting, while catchers play in a bending position that places stress on the lower limb joints. The throwing motion of the pitcher places less stress on the pitcher's lower limb, and accordingly, it is understandable why fielders and catchers have a higher IR of lower limb injuries when compared to pitchers.

Catchers had significantly the highest incidence of knee injuries, while fielders had the highest incidence of lower leg injuries when compared to other positions. The fact that catchers have more knee injuries than other positions might be explained by their frequent bending of the knee for prolonged periods during the game. On the other hand, we believe that the long sprints that fielders are required to run during the game make them more prone to lower leg injuries.

Joint injuries involving the hip, knee, and ankle were found to put players on the DL for a longer period compared to thigh, lower leg, and foot injuries. The complexity of the joint, the vulnerability of its ligaments and tendons, and their susceptibility to rupture and tear place joint injuries among the costliest sports injuries due to their frequent surgical requirement and lengthy rehabilitation programs (Joseph et al., 2013; Fares et al., 2019b).

On average, a lower limb injury caused a time loss of 45.7 days/

Table 6
Mean incidence rate (Mean IR) of lower limb injuries with respect to different playing positions in Major League Baseball (2010–2016). *P value <0.05. (Negative value → MIR of latter position > MIR of former position).

	All		Hip		Thigh		Knee		Lower Leg		Ankle		Foot	
	Mean IR	P value	Mean IR	P value	Mean IR	P value	Mean IR	P value						
Fielder-Pitcher	0.857	<0.001*	0.0043	0.352	0.0443	0.034*	0.0257	0.096	0.0171	0.007*	0.0186	0.054	0.0157	0.035*
Fielder-Catcher	0.093	0.808	0.0100	0.011*	0.0271	0.239	-0.0429	0.005*	0.0143	0.024*	0.0057	0.723	0.0029	0.874
Catcher-Pitcher	0.764	0.002*	-0.0057	0.175	0.0171	0.549	0.0686	<0.001*	0.0029	0.831	0.0129	0.217	0.0129	0.093

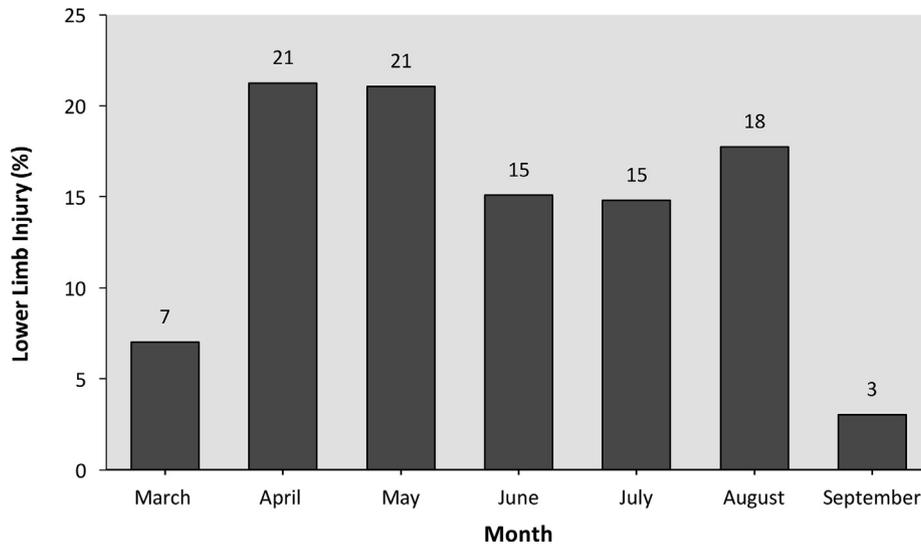


Fig. 2. Distribution of lower limb injuries in Major League Baseball by month (2010–2016).

injury. Given the fact that the injured player gets paid regardless of his ability to compete, this imposes a great financial burden on the clubs. The average annual player salary in MLB between 2010 and 2016 was 3.52 million USD. Given that a regular baseball season spans over 6 months, the player's salary amounts to 19,556 USD per day (USA Today, 2019). Thus, on average, lower limb injuries caused the MLB clubs an estimated loss of around 893,709.2 USD per injury and more than 134 million USD per season, excluding treatment costs, between 2010 and 2016.

The MLB season is divided into: spring training (mid-February – March), regular season (late March – late September), and post season (October) (Ciccotti et al., 2017). As suggested by other studies (Ahmad et al., 2014; Posner et al., 2011), our study found that the incidence of lower limb injuries was highest in the first two months (April and May) of the regular season, and lowest during its last month (September). Gabbett (2016) suggested that high intensity training is not the direct cause of increased injuries but the excessive and rapid increase in training loads. Other studies attribute the increase in musculoskeletal injury rates during this period to improper warm-up, fatigue, overload, and lack of flexibility (Kelly, Barnes, Powell, & Warren, 2004; Perry, 1983; Safran, Garrett, Seaber, Glisson, & Ribbeck, 1988).

Our study was limited to data presented on the DL, which does not account for injuries during pre-season training or minor injuries that do not require the player to be placed on the DL during the season. Moreover, to calculate the IR, we considered all the teams to be 25-men roster teams and assumed that each one of the 25 players had played all 162 games. Furthermore, our calculated AE could not account for the additional AE in training sessions or the less AE due to the games missed. Pre-season trainings might have also contributed to the injuries of MLB players during the season. Thus, our AE may lead to a slightly over-estimated IR.

Conclusion

This study described, in detail, the characteristics and MIR of injuries related to all anatomical zones of the lower limb in the MLB. Lower limb injuries constitute an important portion (29.7%) of all injuries in the MLB. MIR of lower limb injuries increased between 2010 and 2016. Fielders and catchers are more affected by these injuries than pitchers. Joint injuries are more hampering for the player and require longer periods on the DL. Catchers

significantly had the highest MIR of knee injuries, while fielders significantly had the highest MIR of lower leg injuries when compared to other positions. Finally, lower limb injuries were highest at the first two months of each season and lowest at the last month of the season.

Understanding the neuromuscular patterns of lower limb injuries in the MLB will help in the improvement of burden assessment and the extrapolation of more effective prevention policies. Future studies can explore the effect of pre-season training, off-season, and minor injuries to better understand the epidemiological patterns of lower limb injuries in baseball.

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Conflict of interests

None Declared.

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