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Original Research

Hamstring Injury Trends in Major and Minor League Baseball

Epidemiological Findings From the Major League Baseball Health and Injury Tracking System

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Investigation performed at Henry Ford Hospital, Detroit, Michigan, USA

Background: Hamstring strains are the most common injury for professional baseball players and can result in significant time on the disabled list. To date, no study has reported the current trends in hamstring strains in professional baseball.

Hypothesis: Professional baseball players would have an increased incidence of hamstring strains from 2011 through 2016.

Study Design: Descriptive epidemiology study.

Methods: Injury data were prospectively collected from 2011 through 2016 for every Major League Baseball (MLB) and Minor League Baseball (MiLB) team and was recorded in the MLB Health and Injury Tracking System. Data collected for this study included date of injury, activity during injury, time lost, primary injury or reinjury status, and imaging findings as well as player demographic information related to level of play, age, and position for all hamstring injury events. Injury rates were reported as hamstring injuries per number of games.

Results: From 2011 to 2016, there were 2633 hamstring strains in professional baseball players. The rate of hamstring strains increased in MLB from a low of 1 injury every 39 games in 2011 to a high of 1 injury every 30 games in 2016. In MiLB, there were 2192 hamstring strains, with 1 injury every 35 games in 2011 compared with 1 injury every 30 games in 2016. The majority of injuries occurred in the infielder positions (37.5%) and resulted from base running (>50%), most commonly from home to first base. The most common hamstring injury was a grade 2 injury to the distal biceps femoris. The mean time missed after a hamstring injury was 14.5 days. Grade 3 and grade 2 hamstring strains resulted in significantly more days missed compared with grade 1 injuries ($P = .005$ and $P = .002$, respectively). The rate of recurrent hamstring injuries was 16.3% for MLB and 14.2% for MiLB. Recurrent hamstring injuries resulted in more time lost than primary injuries (mean, 16.4 vs 14.5 days, respectively; $P = .02$). A total of 42 injuries were treated with platelet-rich plasma, and 19 were treated with surgery. The number of injuries treated with platelet-rich plasma increased in successive years.

Conclusion: The rate of hamstring strains in professional baseball players has increased over the past 6 years and has resulted in a significant loss of playing time. Study results indicated that these injuries are affected by injury characteristics, position played, running to first base, seasonal timing, and history of hamstring injuries.

Keywords: Major League Baseball; MLB; Minor League Baseball; injury; muscle strain; hamstring

Hamstring injuries represent a common injury in professional athletes, with incidence rates approaching 29% of all injuries in various sports.[1,3,9,15,18,19,21] These injuries are the most common reason for time out of play in Major League Baseball (MLB) and Minor League Baseball (MiLB) players, and they cause a significant amount of disability.[1,4] Recent epidemiological studies have found an injury rate of 0.7 per 1000 athlete-exposures in professional baseball players.[1]

After a hamstring injury, MLB athletes are subject to prolonged recovery and a high reinjury rate. A previous study of hamstring injuries during a single season found that, on average, MLB players miss 24 games after sustaining a hamstring injury.[1] In that study, reinjury rates after a hamstring injury were found to be as high as 20% in MLB and 8% in MiLB.[1,8] To reduce injuries as well as disability caused by hamstring injuries, it is important to identify the risk factors for an injury.[6,12] A prior investigation identified

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epidemiological factors involving hamstring injuries during 1 MLB season.[1] Although this work has provided valuable insight into the magnitude of hamstring injuries in baseball, it was limited in that it only covered a single season and did not include analysis based on trends over time, treatment rendered, injury grade, injury location, or number of muscles/tendons involved. Accordingly, additional investigation is warranted to better inform future injury prevention programs.

The purpose of our study was to identify current hamstring injury trends in MLB and MiLB players in an effort to understand factors influencing these injuries. More specifically, we sought to determine (1) if the incidence of hamstring injuries increased over time, (2) what the effect of player/injury characteristics was on time out of play, and (3) how the grade of injury on magnetic resonance imaging (MRI) correlated with return to play (RTP). Once factors leading to an injury are identified, programs can be created to target injury prevention.

METHODS

Health and Injury Tracking System Database

The MLB Health and Injury Tracking System (HITS) is a comprehensive database that contains deidentified medical information relating to any injury that results in time lost from competition for all MLB and MiLB players. The database is organized as separate injury events, with pertinent information attached to each event, the timing and nature of each injury, basic demographic information for the injured player, MRI and radiographic findings, and relevant operative reports. Injury diagnosis and data entry are performed by team athletic trainers and physicians. All professional baseball players provide consent for their information to be electronically recorded in this database before the start of the competitive season, and permission by the MLB Research Committee is required to obtain the deidentified information.

The collection and analysis of the deidentified HITS data were reviewed and approved by the Henry Ford Health System Institutional Review Board and performed in accordance with federal guidelines.

Inclusion Criteria

The HITS database was used to specifically identify all injury events classified as hamstring strains, hamstring spasms, and hamstring tears that caused all MLB and MiLB players to miss at least 1 day from practices or games during the 2011 to 2016 seasons. Players suffering from hamstring injuries that occurred during the regular season were included in the study population; this included any injury that occurred between the months of April and September. Injuries that occurred during spring training, the postseason, or the off-season were excluded.

HITS Data Extraction

For all events that met inclusion criteria, information extracted from the HITS database included injury date, number of days missed, injury activity (eg, batting, running, sliding, throwing), body side, primary injury or reinjury, if the injury was season ending, whether the injury was treated with an injection or surgery, and whether MRI was performed. If MRI was performed, images were reviewed to determine muscle involvement, grade of injury, and location of injury. Grade 1 injuries (hamstring strain) were defined as $<5\%$ muscle disruption, grade 2 injuries (partial hamstring tear) as $>5\%$ muscle disruption but without retraction of muscle ends, and grade 3 (complete hamstring tear) as complete discontinuity of muscle fibers with retraction of muscle ends. Basic demographic information for each player was also collected, including age, position, and level of play at the time of injury. Injury rates were reported as 1 injury per "X" number of games. Total numbers of games played in each league were reported from MLB. Injury rates per "X" number of games were then calculated by dividing the total number of games played in a year by the number of injuries sustained. Similar to previous studies, the injury rate per 1000 athlete-exposures was also calculated. This was determined by dividing the total number of game injuries by athlete-exposures $\times$ 1000. Athlete-exposures were determined by multiplying the total number of team games by the mean number of participants per MLB (28 players, 14 per team) or MiLB game (26 players, 13 per team).

Statistical Analysis

Summary statistics were calculated for injury information and player demographic data. The total number of hamstring injuries per position was collected. To account for multiple players in certain positions, the number of injuries per position on the field was modified by dividing the

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Ethical approval for this study was obtained from the Henry Ford Health System Institutional Review Board (No. 11273).

TABLE 1
Hamstring Injury Characteristics[a]

	Major League Baseball	Minor League Baseball
Total	441 (16.7)	2192 (83.3)
Injury type		
Grade 1 (hamstring strain)	52 (11.8)	572 (24.8)
Grade 2 (partial tear)	377 (85.5)	1609 (74.7)
Grade 3 (complete tear)	12 (2.7)	11 (0.5)
Injury side		
Left	252 (57.1)	1107 (51.5)
Right	187 (42.4)	1061 (48.4)
Both	2 (0.5)	24 (1.1)
Initial injury or reinjury		
Initial injury	369 (83.7)	1880 (85.8)
Reinjury	72 (16.3)	312 (14.2)
Season-ending injury		
Yes	15 (3.4)	86 (3.9)
No	426 (96.6)	2106 (96.1)
Surgery required		
Yes	9 (2.0)	10 (0.5)
No	432 (98.0)	2182 (99.5)
Position		
Infielder	163 (37.0)	826 (37.7)
Outfielder	162 (36.7)	781 (35.6)
Pitcher	89 (20.2)	368 (16.8)
Catcher	26 (5.9)	217 (9.9)
Designated hitter	1 (0.2)	0 (0.0)

[a]Data are shown as n (%).

number of infielder injuries by 4 and outfielder injuries by 3 and keeping catcher and pitcher injury totals unchanged. Injury events categorized as "season ending" were excluded from all time-loss analyses. Chi-square analyses were used to determine differences in days missed from competition as well as differences in the injury mechanism frequency for hamstring injury types. Wilcoxon rank-sum tests were used to determine significant differences in time lost between first and recurrent injuries, month of injury, and time lost as well as differences between MLB and MiLB players for age at the time of injury and time lost from competition. Poisson regression models were used to analyze the association between age at the time of injury and time lost. For all hypothesis tests, statistical significance was defined by the probability of a type I error rate less than .05.

RESULTS

Overview

From 2011 to 2016, there were a total of 2633 hamstring injuries in professional baseball, with 441 occurring in MLB and 2192 in MiLB (Table 1). This resulted in an injury rate of 1.09 per 1000 athlete-exposures, or 1 injury every 33 games in MLB. In MiLB, there was an injury rate of 1.17 per 1000 athlete-exposures, also 1 injury every 33 games. Of the 2633 injuries, 1986 (75.4%) were partial hamstring tears, 624 (23.7%) were hamstring strains, and 23 (0.9%) were complete hamstring tears. Moreover, 16.3% of MLB hamstring injuries and 14.2% of MiLB hamstring injuries were recurrent injuries. Only 3.4% of MLB injuries and 3.9% of MiLB injuries were season ending, while 2.0% of MLB injuries and 0.5% of MiLB injuries required surgery. Forty-two injuries were treated with platelet-rich plasma (PRP), and 19 were treated with surgery (11 resections, 7 repairs, 1 tenosynovectomy/debridement). Of the 19 injuries requiring surgery, 4 were proximal hamstring injuries, 11 were distal hamstring injuries, and 4 were of unknown location. The number of injuries treated with PRP increased from 2 in 2011 to 14 in 2016.

Trends in Number of Hamstring Injuries

From 2011 to 2016, the rate of hamstring injuries significantly increased for MiLB players ($R^2 = 0.88$; $P = .005$) but not significantly for MLB players ($R^2 = 0.29$; $P = .27$) (Figure 1). Overall, the total number of hamstring injuries from both leagues combined significantly increased from 400 to 488 per year ($R^2 = 0.91$; $P = .003$).

Hamstring Injuries by Position

When evaluating the total number of injuries by position, infielders suffered the most hamstring injuries, with a combined total of 989; however, after adjusting for the number of players for each position on the field, the pitcher position was found to have the highest rate of hamstring injuries compared with each outfielder, infielder, and catcher, with 457, 314, 248, and 243 injuries, respectively (Figure 2). This pattern was consistent for both MLB and MiLB. When stratified by league, there were a similar number of injuries for American League (AL) pitchers (n = 216) and National League (NL) pitchers (n = 241).

Activity

Table 2 displays the activity performed during the injury for each type of hamstring injury. Regardless of injury type, the vast majority of hamstring injuries resulted from base running (65%), specifically to first base (59%). Pitching accounted for only a small percentage of hamstring injuries (6%), as did hitting (3%).

Seasonal Timing

When analyzing the number of injuries by month, April and May accounted for 40% of all MLB hamstring injuries and had the highest injury rates compared with other months. Specifically, MLB had a rate of 1 injury every 26 and 27 games in April and May, respectively, compared with 1 injury every 42 games in both July and August (Table 3). In MiLB, there was a similarly high rate of 1 injury every 20 and 22 games in April and May, respectively, compared with 1 injury every 42 and 49 games in July and August, respectively (Table 4). This equates to a 1.6-fold higher rate of hamstring injuries in April and May compared with July and August in MLB.

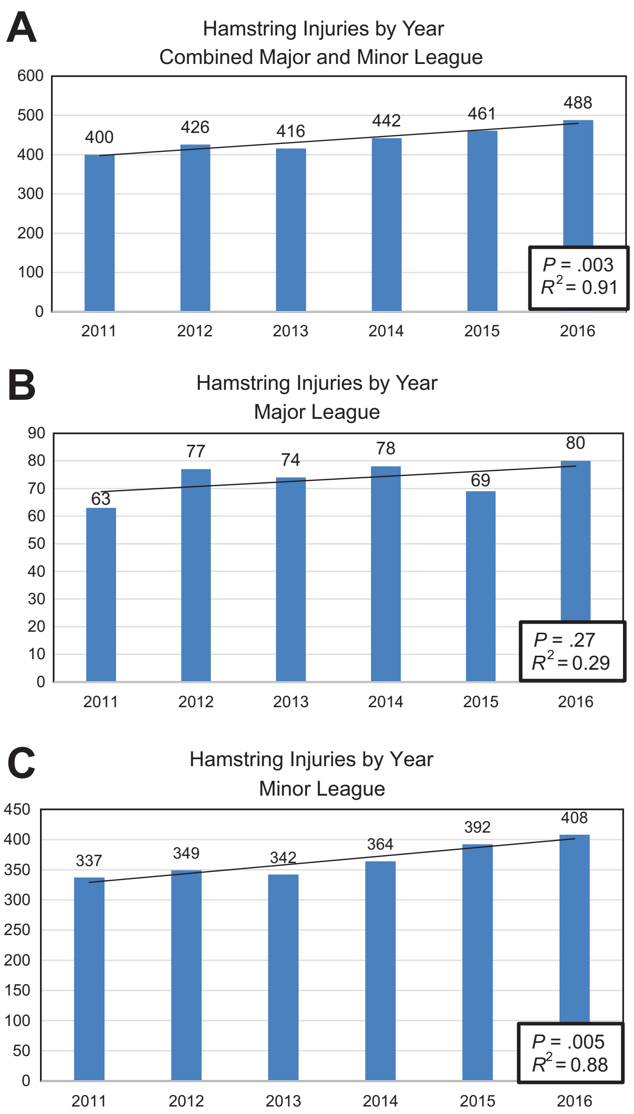

Figure 1. Hamstring injuries by year. Best-fit lines are calculated to determine trends in the number of hamstring injuries for (A) both Major League Baseball (MLB) and Minor League Baseball (MiLB) combined, (B) MLB only, and (C) MiLB only. A significant increase in the trend of hamstring injuries was found in combined MLB and MiLB injuries and in isolated MiLB injuries.

Time Lost

From 2011 to 2016, the mean time missed per hamstring injury remained consistent at 14.5 days. Overall, over half of hamstring strains in both MLB and MiLB resulted in more than 7 days of time lost (Table 5). In addition, 16% of MLB and 10% of MiLB players missed more than 30 days because of an injury. When evaluating the effect of treatment type, our study found an increase in RTP time in those treated with surgery and those treated with PRP when compared with players treated nonsurgically. The mean number of days missed for players undergoing

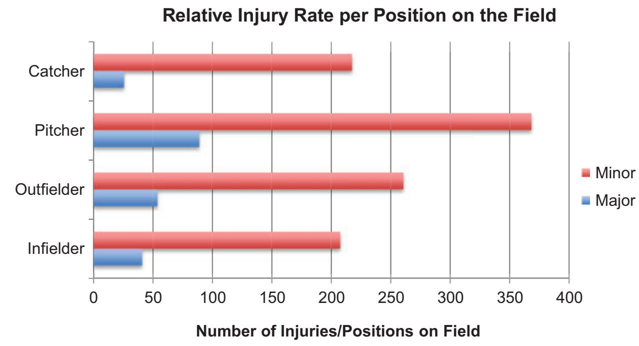

Figure 2. Hamstring injuries by position on the field (normalized by infielder/4, outfielder/3, pitcher/1, catcher/1, designated hitter/1). Pitchers were found to have the highest hamstring injury rate in Major League Baseball and Minor League Baseball.

TABLE 2
Mechanism of Injury for Hamstring Injuries[a]

	Injury Type		
	Grade 1	Grade 2	Grade 3
Base running	354 (57)	1249 (63)	18 (78)
Fielding	107 (17)	292 (15)	2 (9)
Unknown	3 (1)	15 (1)	1 (4)
Pitching	27 (7)	133 (7)	1 (4)
Hitting	41 (7)	47 (2)	0 (0)
Conditioning/weight training	38 (6)	174 (9)	0 (0)
Other/throwing/observing	54 (9)	76 (4)	1 (4)

[a]Data are shown as n (%).

TABLE 3
Hamstring Injuries by Month for Major League Baseball

Month	n (%)	No. of Games Played	Injury Rate	Injury Rate per 1000 Athlete-Exposures
April	85 (19)	2189	26	1.4
May	93 (21)	2536	27	1.3
June	81 (18)	2433	30	1.2
July	55 (12)	2303	42	0.9
August	60 (14)	2533	42	0.8
September	67 (15)	2419	36	1.0

TABLE 4
Hamstring Injuries by Month for Minor League Baseball

Month	n (%)	No. of Games Played	Injury Rate	Injury Rate per 1000 Athlete-Exposures
April	393 (18)	8047	20	1.9
May	462 (21)	10,312	22	1.7
June	414 (19)	14,674	35	1.1
July	451 (21)	18,897	42	0.9
August	371 (17)	18,213	49	0.8
September	101 (5)	1747	17	2.2

TABLE 5
Time Lost From Competition[a]

	Major League Baseball	Minor League Baseball
1-3 d	138 (32)	520 (25)
4-7 d	61 (14)	356 (17)
8-15 d	60 (14)	541 (26)
16-30 d	100 (24)	468 (22)
>30 d	67 (16)	221 (10)

[a]Data are shown as n (%). Season-ending injuries are excluded.

TABLE 6
Magnetic Resonance Imaging Findings for Hamstring Injuries

	n (%)	Return-to-Play Time, d
Total	327 (100.0)	29.5
Specific hamstring muscle affected		
Biceps femoris	181 (55.4)	30.0
Semitendinosus	68 (20.8)	31.2
Semimembranosus	34 (10.4)	32.5
Common hamstring	38 (11.6)	21.2
Other	6 (1.8)	29.0
Location of injury		
Proximal	134 (41.0)	27.8
Middle	36 (11.0)	32.9
Distal	146 (44.6)	31.9
Unknown	11 (3.4)	13.7
Injury type		
Grade 1	128 (39.1)	22.8
Grade 2	143 (43.7)	33.5
Grade 3	56 (17.1)	38.2

surgery was 148.3 days. Players treated with PRP missed, on average, 48 days.

Age had an impact on time lost because of an injury, with each additional year of age being associated with 0.23 more days lost per injury for MLB athletes ($P < .001$) compared with 0.08 fewer days for MiLB athletes ($P < .001$). Although statistically significant, this small effect may lack practical significance. Finally, recurrent hamstring injuries resulted in more time lost compared with primary injuries (mean, 16.4 vs 14.5 days, respectively; $P = .02$).

MRI Injury Characteristics

Lower extremity MRI scans of 327 athletes were available for review. A grade 2 (43.7%), distal (44.6%), and biceps femoris (55.4%) strain was the most common injury (Table 6). There were no significant differences in time lost because of an injury when comparing the specific hamstring muscles affected ($P > .05$). Grade 3 hamstring injuries resulted in significantly more time lost than grade 1 injuries (mean, 38.2 vs 22.8 days, respectively; $P = .005$). Grade 2 hamstring injuries also resulted in more time lost than grade 1 injuries (mean, 33.5 vs 22.8 days, respectively; $P = .002$). There was no significant difference in time lost between grade 2 and grade 3 injuries ($P = .44$). There were also no differences in time lost when comparing the location of injury ($P > .05$).

DISCUSSION

Our study used the MLB HITS database to identify trends in hamstring injuries in professional baseball from 2011 to 2016. We found that the rate of hamstring injuries in professional baseball has increased since 2011. Pitchers sustained more hamstring injuries than other player positions, and the most common injury mechanism was running to first base. Most injuries were grade 2 injuries of the distal biceps femoris, were found to occur in the month of April or May, and resulted, on average, in a loss of 2 weeks of play. There was a high rate of recurrent injuries in those sustaining a hamstring injury. Higher grade hamstring injuries and recurrent injuries required more recovery time than other injuries.

The incidence of hamstring injuries has been reported in the literature in athletes of various sports.[1,3,9,15,18,19,21] In evaluating 24 years of National Basketball Association (NBA) data, Jackson et al[15] found the highest incidence of muscle strains in the hamstring group, with an injury rate of 0.69 per 1000 athlete-exposures. On average, they found that NBA players with hamstring injuries miss almost 10 days from sport. In a 10-year study of National Football League (NFL) players, Elliott et al[9] found an incidence of 0.77 hamstring injuries per 1000 athlete-exposures; however, this study defined an athlete-exposure as participation in 1 practice or game. Looking at a single MLB season, Ahmad et al[1] found a hamstring injury rate of 0.70 per 1000 athlete-exposures, or 1 injury every 55 games in MLB and 1 injury every 61 games in MiLB.

Our study found a higher rate of hamstring injuries in our 6-year study period compared to the prior study. In MLB, we found an injury rate of 1.09 per 1000 athlete-exposures, or 1 injury every 33 games. In MiLB, there was an injury rate of 1.17 per 1000 athlete-exposures, also 1 injury every 33 games. These data suggest a higher incidence of hamstring injuries in professional baseball compared with other sports. The cause of increased hamstring injuries in baseball players compared with other sports is likely multifactorial; however, the constant switch from the static position to full dynamic activity may play a role. There is also a greater number of games played in a single MLB/MiLB season compared with the NBA and NFL seasons, which may contribute to fatigue. Various explanations can account for the increase in the incidence of hamstring injuries, specifically in baseball, over the years. Earlier commencement of the baseball season and increasingly more powerful players may play a role in this trend.

Player activity during hamstring injuries has been previously evaluated. Multiple studies have found that the majority of hamstring injuries during competitive activity occur while sprinting.[5,11,21] An analysis of 1716 hamstring strains over a 10-year period in the NFL found that 81.5% of injuries were found to be of a noncontact nature, with 74.4% occurring during sprinting.[9] A study evaluating hamstring injuries in the 2011 MLB season found that 68% of injuries occurred through a noncontact mechanism involving base running.[1] Our study found similar results after evaluating a 6-year period of hamstring injuries in MLB and MiLB. The majority of players in our cohort sustained noncontact hamstring injuries while running specifically to first base. Interestingly, pitchers were found to have the highest hamstring injury rate, although they do not frequently run to first base. Pitcher starting position was not delineated in the database, and these injuries may represent the pitcher covering first base or running to first base from a hit. However, it is important to note that there was no significant difference in the number of hamstring injuries between AL pitchers and NL pitchers, and only NL pitchers are required to bat and run bases; thus, it is likely that the majority of these injuries occur during fielding. Compared with other positions on the field, the pitcher is relatively stationary for the majority of the game. The sudden increase in muscle activity in an otherwise stationary pitcher may result in the increased hamstring injury rate in this population. This position presents an area for future injury prevention programs.

There is a high risk of sustaining a reinjury during the season following return from a hamstring injury.[10,13,14] Our study found a recurrence rate of 14.6% over 6 years of professional baseball play. This compares with a recurrence rate of 7.9% in MLB in 2011 and a rate of 16.5% in 10 years of NFL play. The high recurrence rate suggests that athletes who sustain hamstring strains are predisposed to a second hamstring injury. Of note, after a recurrent injury, athletes are found to lose more time than during their primary injury. Focused intervention on preventing recurrent hamstring injuries would save baseball teams/players valuable time and effort.

In various professional sports leagues (NFL, NBA, MLB), hamstring strains have been found to occur earlier in the season.[9] Our study found similar results, with the highest number of hamstring sprains in April and May; the rate of injuries steadily decreased as the regular season progressed. Possible mechanisms that may predispose players to hamstring strains earlier in the season include decreased core stability,[5,17] decreased lower extremity flexibility,[2,14,20] lower extremity weakness,[7,19] and fatigue.[16] These factors may have an association with poor conditioning at the start of the season.

RTP timing was previously evaluated by Ahmad et al.[1] They found an average RTP time of 24 days in MLB and 27 days in MiLB players after sustaining a hamstring injury. Our study found a lower RTP time, with a mean of 14.5 days. The difference in our results is likely because of a difference in exclusion criteria. Unlike the previous study, our study excluded season-ending injuries from RTP timing, as we believe that the time between seasons in a player with a season-ending injury erroneously increases the time before return to MLB and affects RTP timing calculations. Additionally, our study assessed other player/injury characteristics that could affect RTP. We found that higher grade injuries (grade 2 and 3) resulted in more time lost than grade 1 injuries. Recurrent injuries were also found to result in more time lost compared with primary injuries. These results provide valuable information to players/coaches on what to expect after hamstring injuries and present an opportunity to implement strategies to prevent recurrent injuries, which result in increased time out of play.

While it is intuitive that players undergoing surgery have longer RTP times than those undergoing nonsurgical management, the finding of increased RTP time in players treated with PRP is a new finding. The longer RTP time in players treated with PRP may be because of a more severe injury type treated with this modality. Additionally, PRP treatment requires a mandatory rest period, which may inflate RTP times. Further investigation of RTP time with PRP versus standard treatment should be evaluated in randomized controlled trials.

There are several limitations to our study. As with any study relying on a database for injury surveillance, the accuracy of these data is dependent on those responsible for input. Our institutional review board granted us data from the 2011 to 2016 seasons; therefore, injuries before the 2011 season were not reported. Additionally, injuries during spring training were not analyzed. For these reasons, recurrent injury rates may be underreported in our study. Clinical features such as physical examination findings and surgical procedures were not analyzed in this study. The type of procedure performed could alter the recovery duration and the risk of recurrence. Exposures were calculated indirectly using box scores and may not accurately reflect the number of players entering the game. Game location and weather during the injury events were not recorded, so we were unable to compare the incidence of injuries for warm versus cold weather games. Placing injured athletes on "disabled list" may skew RTP results.

CONCLUSION

The rate of hamstring strains in professional baseball players has increased over the past 6 years and results in a significant loss of playing time. Our study found that these injuries are affected by injury characteristics, position played, running to first base, seasonal timing, and history of hamstring injuries.

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