

# Short-Term Outcomes of Concussions in Major League Baseball

## A Historical Cohort Study of Return to Play, Performance, Longevity, and Financial Impact

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**Background:** The short-term outcomes of concussions within Major League Baseball (MLB) warrant further consideration beyond a medical standpoint given that performance, career, and financial data remain unknown. The perception of this injury directly affects decision making from the perspective of both player and franchise.

**Purpose:** To evaluate the effect of concussion on MLB players by (1) establishing return-to-play (RTP) time after concussion; (2) comparing the career length and performance of players with concussion versus those who took nonmedical leave; and (3) analyzing player financial impact after concussion.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** Contracts, transactions, injury reports, and performance statistics from 2005 to 2017 were analyzed by comparing matched players who sustained a concussion versus those who took nonmedical leave. Of the 4186 eligible MLB players, 145 sustained concussions resulting in the activation of concussion protocol and 538 took nonmedical leave. RTP time was recorded. Career length was analyzed in reference to an experience-based stratification of full seasons remaining after the concussion. Changes in player performance and salary before and after concussion were compared with the same parameters for players who took nonmedical leave.

**Results:** The mean RTP time was 26 days (95% CI, 20-32 days) for athletes with concussion and 8 days (95% CI, 6-10 days) for those who took nonmedical leave. Athletes with concussion had a mean of 2.8 full seasons remaining, whereas athletes who took nonmedical leave had 3.1 seasons remaining ( $P = .493$ ). The probability of playing in the MLB after concussion compared with the nonmedical leave pool was not significantly lower ( $P = .534$ , log-rank test; hazard ratio, 1.108). Postconcussion performance decreased significantly in position players, including a lower batting average and decreased on-base percentage in the players with concussion compared with those returning from nonmedical leave. Players who sustained a concussion lost a mean of US\$654,990 annually compared with players who took nonmedical leave.

**Conclusion:** This study of the short-term outcomes after concussion in limited-contact MLB athletes demonstrates that concussions may not decrease career spans but may result in decreased performance in addition to financial loss when compared with matched controls who took nonmedical leave. In sports such as baseball that are not subject to repetitive head trauma, career spans may not decrease after a single concussive event. However, sentinel concussions have deleterious short-term effects on performance and compensation among MLB players.

**Keywords:** concussion; baseball; financial loss; return to play

Players in Major League Baseball (MLB) are exposed to a range of game-play situations that present concussion risk.<sup>2,4</sup> The deleterious effects between sports-related concussion (SRC) and performance have been established in

repetitive-contact sports such as boxing, football, and hockey, yet a paucity of studies have examined the impact of SRC in limited-contact sports such as baseball.<sup>24,25</sup> As with most other professional organizations confronting SRC, the MLB has faced media scrutiny and the treatment policy has undergone transformation to improve vigilance and safe play.<sup>1,5</sup> In 2011, a series of major rule and protocol changes were implemented to increase screening of SRC on

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the field and treat players accordingly, and a standard 7-day disabled list protocol after SRC was instituted.<sup>11</sup> Similarly, in 2014, the MLB introduced a new protocol to reduce home plate collisions to further mitigate the risk of player-to-player collisions at home plate.<sup>15</sup> Today, postconcussion management typically involves rest, placement on the league's disabled list, neurological evaluation prior to return to play (RTP), and no same-day RTP.<sup>14</sup> The risk of traumatic brain injury is not new to the sport, with long-term outcomes increasingly investigated.<sup>7</sup> Although full-contact sports with repetitive neurotrauma have been linked to neurocognitive changes, the study of the short-term considerations after a player sustains SRC in limited-contact sports is also clinically relevant.<sup>25</sup> Performance and financial changes have relevance to individual players as well as franchises in strategic decision making regarding contract negotiations, trades, and acquisitions.

Despite best efforts from the MLB to promote safety and increase screening for SRCs during game-play, these injuries may be unavoidable, and thus investigation from the athlete's perspective is warranted. Prior reports examining the epidemiological patterns, mechanisms, and effects of SRC in MLB have demonstrated a high percentage of retirement and, in some cases, decreased on-field performance associated with missed play.<sup>7,21,24</sup> These reports include landmark studies by Wasserman et al<sup>24</sup> and Schwindel et al.<sup>21</sup> Wasserman et al<sup>24</sup> compared 66 position players with concussion versus 68 athletes taking bereavement or paternity leave and found that players with concussion had significantly lower batting averages and on-base plus slugging percentage at 2 weeks after return ( $P < .05$ ). Schwindel et al<sup>21</sup> found a similar trend in a smaller pool of 31 players ( $P < .05$ ), in which players missed an average of 32 days. The impact of SRC on career longevity and short-term financial compensation, however, remains unaddressed in the literature.

Therefore, this study sought to objectively quantify the importance of SRC in a manner that can be understood by players, organizations, and providers alike by addressing the impact in the short term. The specific aim of this study was to evaluate the effect of SRC on MLB players by (1) establishing RTP time after concussion; (2) comparing the career length and performance of players with concussion with players who took nonmedical leave; and (3) analyzing player financial impact after concussion. In line with previous studies examining the short-term effects of SRC in

the National Football League (NFL) and National Hockey League (NHL), we hypothesized that decreased career length, performance, and compensation would be observed for players after SRC.<sup>16,17</sup>

## METHODS

### Study Design

Injury reports and performance records were retrospectively obtained from publicly available MLB statistical publications across 13 seasons from January 1, 2005, to December 31, 2017, in line with previous methods using publicly reported data.<sup>9</sup> MLB players who sustained SRC that resulted in a concussion protocol or injured reserve status were compared with a pool of players who took nonmedical leave during the same 2005 to 2017 measuring period. Players in the concussed and nonmedical leave pools were matched for age, experience, and position. Three analyses were performed: After baseline demographic statistics and mean RTP were established, a historical cohort analysis was conducted to compare the 2 groups of players in terms of their respective career lengths; a second retrospective analysis compared these 2 pools in terms of players' pre- to postconcussion performance metrics; and a third retrospective analysis compared the annual dividend of the players' contract at concussion with the next contract signed afterward.

### Study Population and Inclusion Criteria

All MLB players who were on an active roster during the seasons of 2005 through 2017 were included in the study. To be included in the concussed population, the player must have endured an SRC documented in the MLB's official injury report (with the words "concussion" or "head trauma") noted by injured reserve status or implementation of the concussion protocol. The MLB Health and Injury Tracking System includes only SRCs occurring from 2011 onward. Therefore, we searched public websites including MLB.com, sportrac.com, proSPORTstransactions.com, and baseball-reference.com to ensure accuracy and include the entire 13-year period. Players in affiliated minor league programs were not included in the study.

A total pool of 4186 players were available for analysis. Of this pool, 145 players met the criteria for inclusion in the concussion pool. These 145 players sustained a total of 168

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Ethical approval was not sought for the present study.

SRCs during the 13-year study period. For athletes sustaining multiple SRCs during their career, only the first concussion was included in the analysis. A cohort of 538 players took nonmedical leave, serving as a control group. Reasons for nonmedical leave included paternity leave and bereavement but not probation for performance-enhancing drugs.

### Career Length

The players' career lengths were analyzed by means of an experience-based stratification of full seasons remaining. Specifically, we compared the number of prior seasons played at the time of SRC or at the time of nonmedical leave. On the basis of this number of prior seasons in the MLB, players with concussion and those who took nonmedical leave were compared to determine the number of full seasons remaining for each player. This analysis was designed to study the aggregate impact and to stratify the effect of SRC based on the stage of a player's career, controlling for other factors that may be unrelated to concussion resulting in retirement. A stringent definition of a "full season" of MLB experience was applied, using the MLB cutoff for "rookie" status: a minimum of 130 at-bats for a position player or 50 innings pitched for a pitcher.<sup>21</sup> If a player endured multiple SRCs during his career, only his first concussion data point was included.

### Performance

Performance metrics were obtained for all players who appeared on MLB rosters from 2005 through 2017, except during the 1994-1995 MLB strike period.<sup>8,22</sup> The concussed and nonmedical leave player pools were compared for changes in performance metrics. Athletes with concussion were analyzed by measuring the mean change in performance from the season before versus after their first SRC. The nonmedical leave pool served to control for potential confounders due to time away from the field. If an athlete in either pool did not play in the season before (eg, was a rookie) or after the SRC (eg, retired or took extended leave), that athlete was excluded, as no performance change data were available. Because of the variability in the number of games played between athletes in MLB, performance statistics were normalized to appropriate player experience data points. Data for batters were standardized by dividing individual statistics by the number of games played or at-bats taken in the same season. Data for pitchers were standardized by dividing individual player metrics by the number of innings pitched.

### Financial Impact

The contract details for the 2005 to 2017 concussed and nonconcussed MLB player pools were compiled regarding the individual per-year dividends and dates of contracts signed. The salaries for both were measured at a specific reference point and were compared with the value of the first year on the next MLB contract signed afterward. For

the concussed and nonmedical leave populations, this reference point included the player's preseason compensation for the year in which he sustained SRC or took leave. The potential base salary payouts for a full season were used to normalize for players who were forced to miss games and lost salaries. If a player did not sign an additional MLB contract after the reference point, either postinjury or post-leave, the next annual salary of \$0 was recorded. If an athlete was still playing on his reference point contract, he was excluded from analysis.

### Statistical Analysis

Release rates of players with and without concussion were compared by use of a 2-tailed, unpaired *t* test after data distribution satisfied tests for normality. A log-rank test was performed to analyze the difference between the 2 player groups regarding years remaining in the league. For players with concussion, the change in performance was calculated as a mean with standard deviation and was compared with the control population by a 2-tailed, unpaired *t* test. Changes in salary were measured as means with 95% CIs and were compared with a 2-tailed, unpaired *t* test. Age differences between concussed and nonmedical leave pools were evaluated with a 2-tailed, unpaired *t* test. All statistical analysis was performed by use of STATA v 15.

## RESULTS

Of the 145 players in the concussed pool, 14 were pitchers and the remaining 131 were position players. The nonmedical leave cohort ( $n = 538$ ) consisted of 306 position players and 232 pitchers. No statistically significant difference was found between the concussed and nonmedical leave pools with regard to age ( $P = .23$ ), as shown in Figure 1. The two groups varied in position representation, with catchers comprising a larger percentage in the concussed pool than the nonmedical leave pool (26% vs 7%, respectively) and pitchers comprising a smaller percentage in the concussed pool than the nonmedical leave pool (8% vs 43%, respectively) ( $\chi^2$  test 37.8,  $P < .00001$ ).

### Career Length

Figure 2 demonstrates via an experience-based stratification that players with concussion had a mean of 2.8 full seasons remaining whereas athletes who took nonmedical leave had 3.1 seasons remaining, although this difference was not significant ( $P = .493$ , 2-way analysis of variance) across comparisons. In further analysis of athletes who retired during the length of the study, the probability of playing 1, 3, and 5 years (with 1 year played defined as 1 at-bat or 1 inning pitched) in MLB after concussion versus after nonmedical leave of absence was 73.8% versus 85.9%, 46.2% versus 47.3%, and 23.1% versus 28.6%, respectively.

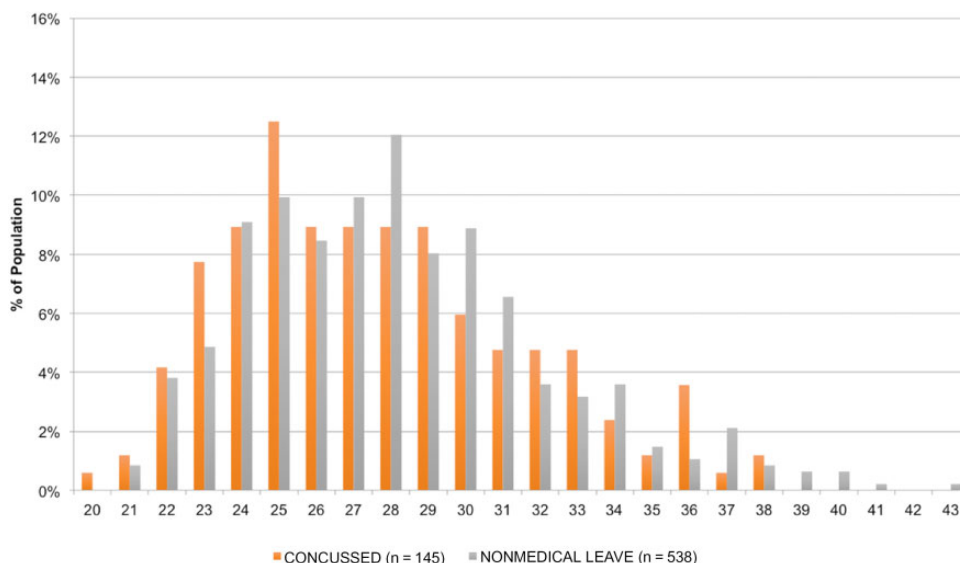


Figure 1. Age distribution for baseball players with concussion and those who took nonmedical leave.

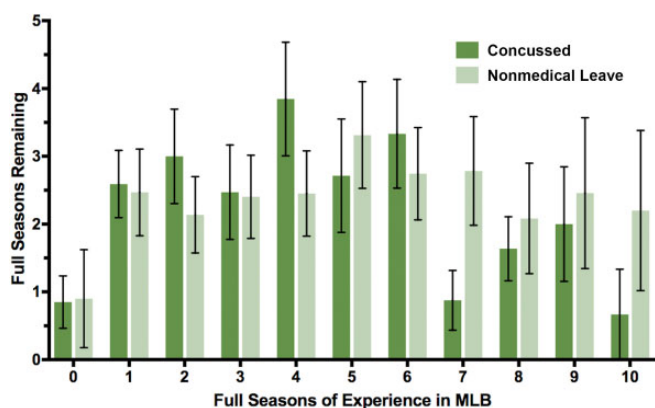


Figure 2. Full seasons remaining for MLB players with concussion and those who took nonmedical leave, by experience.

Performance

Players with concussion returned to play at a mean of 26 MLB season days (95% CI, 20-32 days) after their injury, whereas athletes who took nonmedical leave returned to play at an average of 8 days (95% CI, 6-10 days). Statistically significant performance metric reductions from the season before to after the reference point were found among all fielding positions (Table 1), specifically in the areas of batting average, on-base percentage, and stolen bases ( $P < .05$  for all). Position players post-SRC had a decrease in batting average of 0.024 compared with a 0.011 decrease observed for players returning from a nonmedical leave of absence ( $P = .043$ ). Regarding projected performance statistics measuring change over the course of a season, athletes with concussion had 4.6 fewer hits and 7.6 fewer total bases earned post-SRC. This was compared against the 2.1 and 3.8 losses in hits and total bases, respectively, in the season after a leave of absence, although these changes

TABLE 1  
Performance Changes for Position Players Who Had Concussion and Those Who Took Nonmedical Leave

	Concussion (n = 88)	Nonmedical Leave (n = 234)	P Value <sup>a</sup>
Games (G) <sup>b</sup>	5.159	-2.393	.369
Batting average (BA) <sup>b</sup>	-0.024	-0.011	<b>.043</b>
On base percentage (OBP) <sup>b</sup>	-0.025	-0.009	<b>.049</b>
Slugging percentage (SLG) <sup>b</sup>	-0.040	-0.019	.115
On base + slugging percentage (OPS) <sup>b</sup>	-0.064	-0.028	.067
OPS+ <sup>b</sup>	-15.894	-7.333	.099
Hits (H) <sup>c</sup>	-4.591	-2.177	.067
Home runs (HR) <sup>c</sup>	-0.180	-0.260	.879
Runs batted in (RBI) <sup>c</sup>	-1.540	-1.208	.799
Total bases (TB) <sup>c</sup>	-7.592	-3.838	.155
Runs scored (R) <sup>c</sup>	-2.574	-0.907	.191
Strikeouts (SO) <sup>c</sup>	-0.190	0.000	.922
Intentional base on balls (IBB) <sup>c</sup>	-0.075	0.144	.348
Sacrifice hits (SH) <sup>c</sup>	-0.568	-0.196	.283
Caught stealing (CS) <sup>d</sup>	-0.160	-0.144	.933
Stolen bases (SB) <sup>d</sup>	-1.636	-0.309	<b>.009</b>
Double plays grounded into (GDP) <sup>d</sup>	0.173	-0.061	.521

<sup>a</sup>Boldface indicates significant between-group difference.

<sup>b</sup>Raw performance changes, calculated as [After] - [Before].

<sup>c</sup>Performance changes through season, calculated as [(Performance After ÷ At-Bats) × 202] - [(Before ÷ At-Bats) × 202], where 202 is the league average at-bats per season.

<sup>d</sup>Performance changes through season, calculated as [(Performance After ÷ Games Played) × 66] - [(Before ÷ Games Played) × 66], where 66 is the league average number of games played for consideration of the Gold Glove Award.

were not statistically significant. Changes in the number of strikeouts, double plays grounded into, and times caught stealing were not statistically significant ( $P > .05$ ).

TABLE 2

Position-Level Performance Changes for Position Players Who Had Concussion and Those Who Took Nonmedical Leave

	Infielders			Outfielders			Catchers		
	Concussion (n = 38)	Nonmedical Leave (n = 124)	P Value <sup>a</sup>	Concussion (n = 28)	Nonmedical Leave (n = 79)	P Value <sup>a</sup>	Concussion (n = 22)	Nonmedical Leave (n = 31)	P Value <sup>a</sup>
Games (G) <sup>b</sup>	-3.684	-5.234	.905	5.036	-1.658	.661	20.591	7.097	.399
Batting average (BA) <sup>b</sup>	-0.029	-0.011	<b>.048</b>	-0.025	-0.006	.115	-0.013	-0.021	.563
On base percentage (OBP) <sup>b</sup>	-0.031	-0.006	<b>.022</b>	-0.031	-0.004	<b>.050</b>	-0.005	-0.036	.092
Slugging percentage (SLG) <sup>b</sup>	-0.047	-0.020	.202	-0.037	-0.011	.259	-0.030	-0.032	.944
On base + slugging percentage (OPS) <sup>b</sup>	-0.078	-0.026	.085	-0.069	-0.016	.128	-0.035	-0.068	.435
OPS+ <sup>b</sup>	-19.035	-6.456	.114	-18.845	-3.637	.094	-6.712	-20.265	.228
Hits (H) <sup>c</sup>	-5.925	-2.129	<b>.046</b>	-4.933	-1.330	.135	-1.849	-4.532	.345
Home runs (HR) <sup>c</sup>	-0.359	-0.400	.964	0.347	-0.260	.439	-0.542	0.296	.499
Runs batted in (RBI) <sup>c</sup>	-2.374	-1.811	.792	-1.182	-0.486	.726	-0.556	-0.636	.981
Total bases (TB) <sup>c</sup>	-9.372	-3.918	.193	-7.304	-2.463	.295	-4.885	-7.019	.690
Runs scored (R) <sup>c</sup>	-2.883	-1.410	.473	-5.171	-0.315	<b>.024</b>	1.262	-0.404	.505
Strikeouts (SO) <sup>c</sup>	-0.842	0.097	.651	-1.410	-0.882	.880	2.489	1.863	.916
Intentional base on balls (IBB) <sup>c</sup>	-0.113	0.224	.363	-0.002	0.133	.742	-0.103	-0.148	.925
Sacrifice hits (SH) <sup>c</sup>	-0.298	-0.426	.714	-0.473	-0.215	.596	-1.154	0.770	.169
Caught stealing (CS) <sup>d</sup>	-0.220	-0.002	.467	-0.077	-0.306	.481	-0.162	-0.303	.681
Stolen bases (SB) <sup>d</sup>	-1.275	-0.434	.400	-3.127	-0.205	<b>.000</b>	-0.362	-0.077	.405
Double plays grounded into (GDP) <sup>d</sup>	-0.156	-0.080	.880	0.322	0.325	.995	0.554	-0.974	.172

<sup>a</sup>Boldface indicates significant between-group difference.

<sup>b</sup>Raw performance changes, calculated as [After] - [Before].

<sup>c</sup>Performance changes through season, calculated as [(Performance After ÷ At-Bats) × 202] - [(Before ÷ At-Bats) × 202], where 202 is the league average at-bats per season.

<sup>d</sup>Performance changes through season, calculated as [(Performance After ÷ Games Played) × 66] - [(Before ÷ Games Played) × 66], where 66 is the league average number of games played for consideration of the Gold Glove Award.

Position-level performance changes are reported in Tables 2 and 3. Pitchers had no significant performance metric reductions following SRC compared with athletes who took nonmedical leave (Table 3).

### Financial Impact

Salary differences were observed between MLB athletes with and without concussion in the contract following SRC and the athlete's career midpoint, respectively. The mean annualized next contract salary changes for all players postconcussion revealed a US\$182,549 increase (95% CI, -\$89,060 to \$454,157) after concussion compared with a \$837,539 increase (95% CI, \$659,089 to \$1,015,989) following nonmedical leave. In an aggregate, this is a net loss of \$654,990 to the expected salary increase postconcussion when compared with players who took nonmedical leave, as seen in Figure 3.

### DISCUSSION

This study established RTP after SRC and found that concussions may have a negative impact on the performance and earnings of MLB players, although not on longevity. Although we were unable to account for potential confounders such as postconcussion injuries or to perform a

meaningful matching statistical analysis, we found that players with concussion had an average RTP of 26 days, whereas athletes who took nonmedical leave had an average RTP of 8 days. Schwindel et al<sup>21</sup> reported a comparable RTP time of 32 days from 2001 to 2010. Players with concussion faced a lower probability of remaining in the league at 1, 3, and 5 years compared with athletes who took nonmedical leave, although this change was not significant. Players with concussion had a mean of 2.8 full seasons remaining before retirement, whereas those players who took nonmedical leave had 3.1 full seasons remaining. Athletes with concussion experienced financial loss, up to \$654,990 per year on their next contract, compared with mean salary increases experienced by nonmedical leave peers. This trend held true for all player positions. A decline in multiple performance metrics after SRC was noted for position players, which may or may not be relevant for players and franchises.

Major league hitters are most commonly evaluated based on batting average, on-base percentage, and slugging percentage.<sup>10,19,23</sup> Overall, position players had a significant decrease in batting average, on-base percentage, and stolen bases compared with those who took nonmedical leave, although catchers did not have a significant change in any performance metrics. The changes, although statistically significant, may or may not be meaningful from a

TABLE 3  
Performance Changes for Pitchers Who Had Concussion  
and Those Who Took Nonmedical Leave

	Pitchers Who Had Concussion (n = 9)	Pitchers Who Took Nonmedical Leave (n = 159)	P Value
Games pitched (G) <sup>a</sup>	9.667	0.300	.420
Innings pitched (IP) <sup>a</sup>	14.240	-6.140	.066
Earned run average (ERA) <sup>a</sup>	0.352	-0.760	.626
ERA+ <sup>a</sup>	-4.444	-16.272	.754
Fielding independent pitching (FIP) <sup>a</sup>	0.791	0.468	.623
Walks + hits / inning pitched (WHIP) <sup>a</sup>	0.118	0.129	.931
Home runs (HR9) <sup>b</sup>	0.389	0.224	.652
Walks (BB9 or W9) <sup>b</sup>	0.756	0.380	.492
Strike outs (SO9) <sup>b</sup>	-0.167	0.025	.798
Strike outs/walks ratio (SO/W) <sup>b</sup>	-1.052	-0.140	.120
Shutouts (SHO9) <sup>b</sup>	-0.012	-0.002	.334
Saves (SV9) <sup>b</sup>	0.023	0.178	.766
Runs allowed (R9) <sup>b</sup>	0.539	0.787	.792
Wild pitches (WP9) <sup>b</sup>	0.039	0.022	.910
Wins (W) <sup>c</sup>	1.797	-0.353	.062
Losses (L) <sup>c</sup>	0.159	0.171	.990
Games finished <sup>c</sup>	-1.399	0.738	.322

<sup>a</sup>Raw performance changes, calculated as [After] - [Before].

<sup>b</sup>Performance changes through 9 innings, calculated as [(Performance After ÷ Innings Pitched) × 9 Innings] - [(Before ÷ Inning Pitched) × 9 Innings], where 9 innings represents a change over the course of a complete game pitched.

<sup>c</sup>Performance changes through the season, calculated as [(Performance After ÷ Games Pitched) × 27] - [(Performance Before ÷ Games Pitched) × 27], where 27 is the league average number of games pitched per season.

performance standpoint (eg, 0.024 decrease in batting average for players after SRC). Pitchers had no significant change in performance after SRC compared with the nonmedical leave cohort, although only 9 pitchers with concussion were available for analysis. The tendency for fielding players to sustain greater performance changes following SRC suggests that the mechanism of concussion, additional time away from the sport, or impact of persistent deficits following concussion may vary between player positions. Green et al,<sup>7</sup> who studied 307 minor and major league players, showed a predisposition for catchers to sustain SRCs and reported a median time loss of 9 days.

In prior analyses of the short-term impact of SRC in the NFL and NHL, significant reductions in career longevity, performance, and player compensation were demonstrated in athletes sustaining SRC compared with nonconcussed controls.<sup>16,17</sup> In contrast, in the present study, career longevity was not significantly different compared with the nonmedical leave cohort, suggesting that SRCs in baseball tend to have comparable immediate impacts on an athlete without enduring consequence on the athlete's career trajectory. Thus, the repetitive nature of head impact in

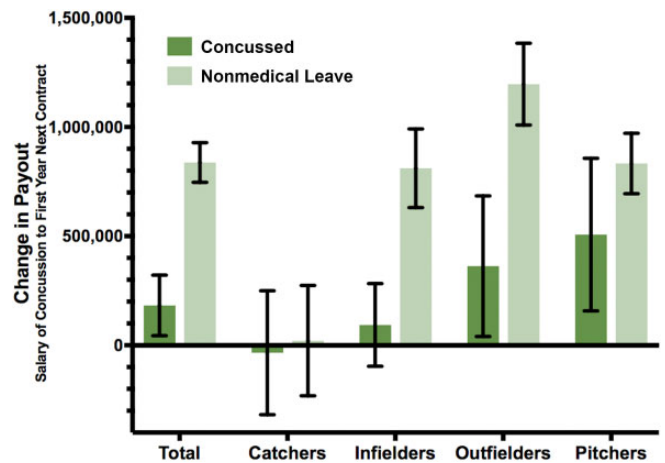


Figure 3. Mean change in next contract salary for players with concussion and those who took nonmedical leave.

contact sports, including recurrent microtrauma, may have more enduring consequences on a player's career than the single impacts sustained by athletes in limited-contact sports.<sup>3,12</sup>

Our study is not without limitations. This analysis did not fully control for other comorbidities or additional injuries sustained that may affect financial and performance changes. There were likely multiple players not included in the analysis who sustained SRCs that were either not detected or reported; conversely, false positives are also possible. Furthermore, it is possible that athletes sustained unaccounted-for SRCs before entering MLB. All publicly reported SRCs resulting in lost playing time over the study period were captured in this study, although publicly reported data are limited by potential inaccuracies, further compounded by the ambiguous nature of diagnosing SRC. Because the MLB Health and Injury Tracking System reports concussion data from 2011 and later, the use of public data provides a greater sample size of SRC over time, although comparison with medical records is lacking. Additionally, decreased time on the field and differences in individual experience, specifically the 16 additional days that injured players were away from baseball compared with nonmedical leave, may independently contribute to the noted decline in career performance metrics. Although ages between the players with concussion and those who took nonmedical leave were not different, age distribution may affect years remaining in the league on a more discrete basis. An important consideration not controlled for in our study was player position, which was unevenly distributed with predominantly catchers and few pitchers; this could potentially have affected the longevity and performance results, as catchers have shorter career spans and pitchers have variable performances depending on the role. Although matching was performed, the absence of statistical power based on the few athletes from each position and age group in the concussed pool precluded analysis. Finally, nonmedical leave allows athletes to take paternity leave, which has faced criticism in recent years and therefore may

have independent effects on the athlete's career due to decisions made by coaching staff and team management.<sup>18</sup>

The MLB has increased scrutiny, awareness, and monitoring of player SRC with several protocol changes, which may have a secondary impact on this study's findings.<sup>13,15,16,20</sup> Protocol changes implemented in 2011 included increased on-field screening for SRC and appropriate treatment, including 7 days on the disabled list following concussion.<sup>15</sup> We noted an increase in the number of reported SRCs in 2011 to 2017 (16.1 SRCs per year) compared with 2005 to 2010 (9.2 SRCs per year), suggesting that protocol changes may have resulted in an increased recognition and reporting of SRCs. However, the elusiveness of a consensus definition of concussion and detailed medical record documentation limits the ability to determine the true cause for this noted difference. A 2014 protocol change aimed at reducing home plate collisions was shown to be effective in a study by Gary et al,<sup>6</sup> although the specific mechanism of head trauma was not addressed in the present study. Performance analytics did not take trades or player movement into account, which may confound the results. The steady incidence of SRCs across the study period suggests that the presentation, diagnosis, and management of SRC vary greatly by team, and postconcussion injury protocols may require continued reevaluation over a longer term course for these at-risk athletes.<sup>2</sup>

Despite limitations, the findings of this study demonstrate the negative impact of SRC, whereby diminished career longevity, reduced performance, and lower financial compensation are not infrequent. This information has the potential to improve immediate and long-term decision making with regard to concussion among MLB players, personnel, and physicians.

## CONCLUSION

This study of the short-term outcomes after concussion in MLB athletes demonstrates that concussions may not decrease career spans but may result in decreased performance and financial losses for players returning after concussion compared with nonmedical leave-matched controls.

## REFERENCES

- Anderson R. The year of catcher concussions and MLB's battle to do better with head trauma. CBS Sports. <https://www.cbssports.com/mlb/news/the-year-of-catcher-concussions-and-milbs-battle-to-do-better-with-head-trauma/>. Published 2017. Accessed July 22, 2018.
- Athiviraham A, Bartsch A, Magestwaran P, et al. Analysis of baseball-to-helmet impacts in Major League Baseball. *Am J Sports Med*. 2012;40(12):2808-2814.
- Baugh CM, Stamm JM, Riley DO, et al. Chronic traumatic encephalopathy: neurodegeneration following repetitive concussive and sub-concussive brain trauma. *Brain Imaging Behav*. 2012;6(2):244-254.
- Camp CL, Curriero FC, Pollack KM, et al. The epidemiology and effect of sliding injuries in major and minor league baseball players. *Am J Sports Med*. 2017;45(10):2372-2378.
- Gaines C. Major League Baseball has another concussion problem and it nearly ended John Jaso's career. *Business Insider*. <http://www.businessinsider.com/major-league-baseball-concussions-john-jaso-tampa-bay-rays-2015-3>. Published 2015. Accessed July 22, 2018.
- Gary G, D'Angelo J, Coyles J, Valadka A. Effect of a rule change on concussions and other injuries in professional baseball. *Br J Sports Med*. 2017;51(11):A64-A65.
- Green GA, Pollack KM, D'Angelo J, et al. Mild traumatic brain injury in major and minor league baseball players. *Am J Sports Med*. 2015;43(5):1118-1126.
- Hadley L, Ciecka J, Krautmann AC. Competitive balance in the aftermath of the 1994 players' strike. *J Sports Econom*. 2005;6(4):379-389.
- Kumar NS, Chin M, O'Neill C, Jakoi AM, Tabb L, Wolf M. On-field performance of National Football League players after return from concussion. *Am J Sports Med*. 2014;42(9):2050-2055.
- Laby DM, Kirschen DG, De Land P. The effect of laser refractive surgery on the on-field performance of professional baseball players. *Optometry*. 2005;76(11):647-652.
- Major League Baseball. Major League Baseball and Major League Baseball Players Association announce new protocols on concussions. [http://mlb.mlb.com/content/primer\\_friendly/mlb/y2011/m03/d29/c17181944.jsp](http://mlb.mlb.com/content/primer_friendly/mlb/y2011/m03/d29/c17181944.jsp). Published 2011. Accessed April 14, 2018.
- Major League Baseball. MLB, MLBPA adopt experimental rule 7.13 on home plate collisions. <https://www.mlb.com/news/mlb-mlbpa-adopt-experimental-rule-7-13-on-home-plate-collisions/c-68268622>. Published 2014. Accessed April 14, 2018.
- Major League Baseball. MLB miscellany: rules, regulations and statistics. [http://mlb.mlb.com/mlb/official\\_info/about\\_mlb/rules\\_regulations.jsp](http://mlb.mlb.com/mlb/official_info/about_mlb/rules_regulations.jsp). Accessed April 14, 2018.
- Major League Baseball Players. Collective bargaining agreement 2017-2021. [http://www.mlplayers.com/ViewArticle.dbml?%20DB\\_OEM\\_ID=34000&ATCLID=211078089](http://www.mlplayers.com/ViewArticle.dbml?%20DB_OEM_ID=34000&ATCLID=211078089). Accessed April 7, 2018.
- McKee AC, Alosco ML, Huber BR. Repetitive head impacts and chronic traumatic encephalopathy. *Neurosurg Clin N Am*. 2016;27(4):529-535.
- Navarro SM, Pettit RW, Haerberle HS, et al. The short-term impact of concussion in the NHL: an analysis of player longevity, performance, and financial loss. *J Neurotrauma*. 2018;35(20):2391-2399.
- Navarro SM, Sokunbi OF, Haerberle HS, et al. Short-term outcomes following concussion in the NFL: a study of player longevity, performance, and financial loss. *Orthop J Sports Med*. 2017;5(11):2325967117740847.
- Nowak J. Baseball's first player takes paternity leave. *FMLA Insights*. <https://www.fmlainsights.com/baseballs-first-player-takes-paternity-leave/>. Published 2011. Accessed August 12, 2018.
- Poling A, Weeden MA, Redner R, Foster TM. Switch hitting in baseball: apparent rule-following, not matching. *J Exp Anal Behav*. 2011;96(2):283-289.
- Pollack KM, D'Angelo J, Green G, et al. Developing and implementing Major League Baseball's health and injury tracking system. *Am J Epidemiol*. 2016;183(5):490-496.
- Schwindel LE, Moretti VM, Watson JN, Hutchinson MR. Epidemiology and outcomes of concussions in Major League Baseball. *Ann Orthop Rheumatol*. 2014;2(3):1022. <https://pdfs.semanticscholar.org/f411/007f0a6f4e45d4397954c1ee03265cda070d.pdf>. Accessed April 7, 2018.
- Shiner D. The conscience of the game: baseball's commissioners from Landis to Selig (review). *NINE: A Journal of Baseball History and Culture*. 2008;16(2):126-127.
- van der List JP, Camp CL, Sinatro AL, Dines JS, Pearle AD. Systematic review of outcomes reporting in professional baseball: a call for increased validation and consistency. *Am J Sports Med*. 2018;46(2):487-496.
- Wasserman EB, Abar B, Shah MN, Wasserman D, Bazarian JJ. Concussions are associated with decreased batting performance among Major League Baseball players. *Am J Sports Med*. 2015;43(5):1127-1133.
- Yengo-Kahn AM, Zuckerman SL, Stotts J, et al. Performance following a first professional concussion among National Basketball Association players. *Phys Sportsmed*. 2016;44(3):297-303.