Analysis of Injuries and Pitching Performance Between Major League Baseball and Nippon Professional Baseball

A 2-Team Comparison Between 2015 to 2019

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Investigation performed at Los Angeles Angels, Anaheim, California, USA

Background: There has been minimal research investigating injury and pitching performance differences between Major League Baseball (MLB) and other professional leagues.

Purpose/Hypothesis: This 2-team comparison between MLB and Japan's Nippon Professional Baseball (NPB) involved affiliated players over 5 years. We hypothesized that teams would differ in the injury incidence, mechanism of injury, pitch velocity, and pitch type usage.

Study Design: Descriptive epidemiology study.

Methods: Between 2015 and 2019, pitching data as well as injury statistics for the highest level and minor league affiliates of the Los Angeles Angels (MLB) and the Hiroshima Toyo Carp (NPB) were reviewed for significant differences in the injury prevalence, injury type, mechanism of injury, and days missed. In total, 3781 MLB and 371 NPB injuries were studied.

Results: MLB-affiliated players were significantly younger, taller, and heavier ($P < .001$) than were NPB-affiliated players. MLB-affiliated pitchers threw faster than did their NPB counterparts ($P = .026$). MLB minor league pitchers threw more curveballs than did NPB minor league pitchers ($P = .004$), and MLB minor league relief pitchers threw more sliders than did NPB minor league relief pitchers ($P = .02$). The MLB team had a 3.7-fold higher incidence of injuries versus the NPB team (0.030 vs 0.008 injuries per player-game, respectively) as well as more repeat injuries, with fewer days missed per injury (15.8 ± 54.7 vs 36.2 ± 55.1 days, respectively; $P < .001$). The MLB team also had a higher percentage of injuries that were throwing related ($P < .001$), were contact related ($P < .001$), and occurred outside of competition ($P < .001$) compared with the NPB team.

Conclusion: This is the first empirical study examining injury trends and pitching characteristics between MLB and NPB athletes. MLB-affiliated pitchers threw faster and relied more on breaking pitches in comparison with NPB-affiliated pitchers. From injury data, MLB players were younger, taller, and heavier with a higher percentage of throwing-related injuries, contact injuries, and injuries sustained outside of competition. Overall, the MLB team indicated a 3.7-fold higher rate of reported injuries with fewer days missed per injury than did the NPB team. Competitive conditions are distinctly different between MLB and NPB, and thus, more extensive research collaborations in the future can identify best practices to advance health and performance for both leagues.

Keywords: baseball; epidemiology; pitching; injury

Injury surveillance in Major League Baseball (MLB)–based research is conducted by using data provided by the Health and Injury Tracking System (HITS) database. The database is extensive and contains important metadata on each diagnosis including anthropometry, hand dominance, age, reporting, event and clearance dates regarding injuries, days missed, mechanism, environment, and level of play. This database has become an important knowledge source regarding baseball injuries, and findings from analyses using the database have been presented at MLB Winter Meetings as well as in peer-reviewed studies.

Outside of MLB, less information is known about the health of baseball players in other professional leagues. Japan's Nippon Professional Baseball (NPB), second in popularity to MLB, differs from MLB competitively and organizationally, as there are fewer in-season games

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(143 games in the regular season, followed by playoffs and the Japan Series) than the 162 played in North America and <100 players per club including minor league teams, as compared to approximately 300 players per team in MLB. NPB starting pitchers throw on a 6-man rotation, meaning that each pitcher makes a debut after 6 days of rest compared with MLB, which has a 5-man rotation, offering its players 1 less recovery day. NPB prefers starting pitchers to pitch complete games if successful in maintaining a lead over an opponent. This tradition stems from an elite high school tournament in Japan called Koshien, where top pitchers can throw >700 pitches and participate in >50 innings over a 6-game tournament.[12] NPB also has every Monday off from competition and less travel strain compared with coast-to-coast travel in North America for MLB teams, as the farthest flight spans 2.5 hours of travel time. NPB does not offer extra innings beyond 12 and can award ties, which can lessen strain on bullpens and players in the days after an extended game.

Characteristic differences between NPB and MLB conditions may give rise to a contrast in injury data in which results can inspire efforts to improve reporting consistency between leagues to foster collaboration in advancing player health. Thus, the purpose of this study was to compare injury rates, injury mechanisms, and injury characteristics between a single club within MLB and a single club within NPB and to concurrently examine velocity and pitch type usage between these same teams. We hypothesized that the teams would differ in the injury incidence, mechanism of injury, pitch velocity, and pitch type usage.

METHODS

Injury Analysis

We received permission from MLB to study deidentified data in the HITS database that contained injury diagnoses including a variety of metadata (eg, height, weight, position, event, reporting and clearance dates, event details). Permission was also granted to use deidentified data from the NPB team studied in which similar metadata were associated with player listings. Approval from an institutional review board was waived, as all data were deidentified. Inconsistency in reporting terms between leagues was rectified by 4 authors (M.I., P.C., B.J.E., K.K.). All descriptions were examined independently, and each injury was categorized into the MLB standard classification system. Injury metadata included player batting-side dominance, player throwing-side dominance, injury type (acute vs overuse), injury activity (eg, base running, batting, conditioning, fielding, pitching, throwing), injury mechanism (contact with ball, contact with base, contact with bat, contact with boundary, contact with ground, contact with person, noncontact, and graduate onset), and injury timing (batting practice, game, off premises, postgame, and workout).

Our analysis included 3781 injuries in the Los Angeles Angels system and 371 injuries in the Hiroshima Toyo Carp system during the 2015 through 2019 seasons. Players were deemed to have an injury if they were seen by an athletic trainer or team physician for an ailment and an incident report was created in the teams' databases (for the MLB team, entries were integrated into the MLB HITS). These injuries were assigned 653 unique player identification numbers in the Los Angeles Angels system and 111 unique player identification numbers in the Hiroshima Toyo Carp system. There were 7 teams in the Los Angeles Angels system, each with approximately 29 players, for a total of 203 players. Given that the 2 rookie teams (60 players total) played 55 and 76 games, the minor league teams (120 players total) played 140 games, and the major league team (24 players) played 162 games, this resulted in a weighted average of 121 games per season over the 5 seasons, for a total of 123,420 player-games. There were 3 teams in the Hiroshima Toyo Carp system with a total of 71 to 77 players. They played 143 games at the major league level and 100 games at the minor league level, for a total of 45,140 player-games over the 5 seasons. Injury incidences were calculated by dividing injury rates by the number of player-games per year to account for the differences in roster size and season length between teams. Exposure data outside of games, such as for practices, pregames, and postgames, were not available.

Pitching Characteristic Analysis

Pitching data were extracted using a TrackMan database (http://trackmanbaseball.com) that included all pitches for the Los Angeles Angels major league and minor league (AA, AAA) levels in addition to Hiroshima Toyo Carp away

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Ethical approval was not sought for the present study.

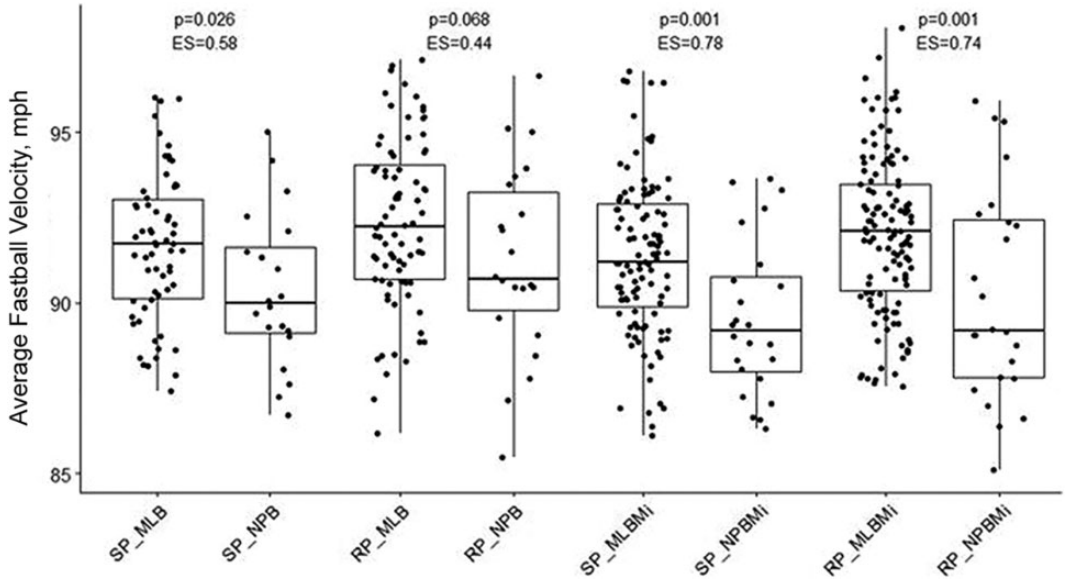

Figure 1. Average fastball velocities for pitchers by position and league. ES, effect size; MLB, Major League Baseball; MLBMi, MLB minor league; NPB, Nippon Professional Baseball; NPBMi, NPB minor league; RP, relief pitcher; SP, starting pitcher.

games (data only available for NPB stadiums outfitted with a TrackMan system) between 2016 and 2019. Owing to TrackMan equipment availability, only Hiroshima Toyo Carp away games (ie, 50% pitch capture rate) and 33% (4/12) of Hiroshima Toyo Carp minor league (NPBMi) games were captured. Data were grouped by starting pitchers and relief pitchers for both the major and the minor leagues. Because the analysis spanned multiple years, a single pitcher in theory could have multiple designations (ie, progressing from the minor to major leagues). There were a total of 472 pitchers spread across the 8 designations (MLB starting pitchers: 63; MLB minor league [MLBMi] starting pitchers: 108; NPB starting pitchers: 20; NPB minor league [NBPMi] starting pitchers: 25; MLB relief pitchers: 80; MLBMi relief pitchers: 128; NPB relief pitchers: 23; NPBMi relief pitchers: 25). Additionally, 2 side-arm pitchers were removed from the MLB and MLBMi data, as their average and maximum fastball velocities were considered outliers (slower) with respect to their peers.

Statistical Analysis

Performance data underwent normality (Shapiro-Wilk) and heteroscedasticity (Levene) tests to determine if parametric tests (1-way analysis of variance and independent t test for post hoc comparisons) or nonparametric tests (Kruskal-Wallis and Mann-Whitney U tests for post hoc comparisons) should be used, with position as the independent variable. Post hoc tests were planned comparisons (MLB starting pitchers vs NPB starting pitchers, MLB relief pitchers vs NPB relief pitchers, MLBMi starting pitchers vs NPBMi starting pitchers, and MLBMi relief pitchers vs NPBMi relief pitchers), and the Holm-Bonferroni correction was applied to the original alpha level of .05 indicating significance to combat type I errors. Cohen effect sizes were also calculated for pairwise post hoc tests and interpreted as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$).

All performance analyses were performed using R (V3.6; R Core Team), whereas all injury analyses were conducted using Excel (Version 16; Microsoft Corp) and SPSS (Version 26; IBM Corp). The number of player-games for each system was calculated by multiplying the number of players per team by the number of games per team per year by the number of years. Discrete variables were compared using chi-square tests. Continuous variables were compared using t tests and Mann-Whitney U tests as appropriate based on data normality, as determined using the Kolmogorov-Smirnov test. P values $<.05$ were considered significant.

RESULTS

Player Characteristics

The injured Hiroshima Toyo Carp players were significantly older (26.6 ± 5.7 years) than were the injured Los Angeles Angels players (24.7 ± 4.4 years) ($P < .001$), and anthropometric analysis between groups revealed that the MLB players were statistically heavier (89.4 ± 9.9 3 kg) than were the NPB players (86.6 ± 9.95 kg) ($P < .0001$; effect size, 0.28). MLB players were taller (1.85 ± 0.06 m) than were NPB players (1.82 ± 0.05 m) ($P < .0001$; effect size, 0.57), but body mass index differences were not significant between groups ($P = .48$).

Pitching Characteristics

One-way analysis of variance determined statistical significance for both average ($P < .001$) and maximum ($P = .001$) fastball velocities (Figures 1 and 2). Post hoc tests

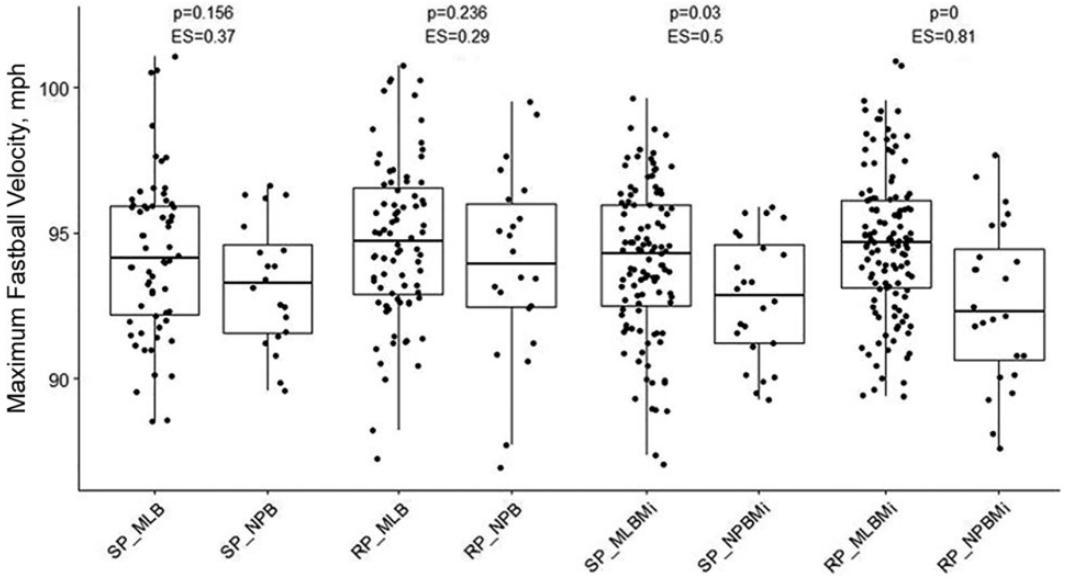

Figure 2. Maximum fastball velocities for pitchers by position and league. ES, effect size; MLB, Major League Baseball; MLBMi, MLB minor league; NPB, Nippon Professional Baseball; NPBMi, NPB minor league; RP, relief pitcher; SP, starting pitcher.

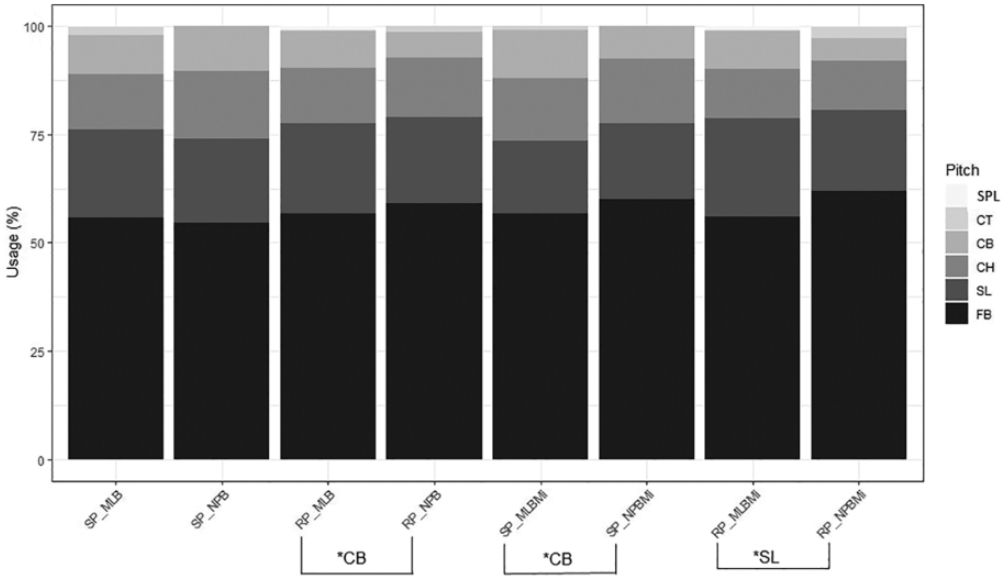

Figure 3. Pitch usage for pitchers by position and league. Curveball (CB) usage was significantly greater for Major League Baseball (MLB) relief pitchers (RPs) versus Nippon Professional Baseball (NPB) RPs ($P < .05$) and for MLB minor league (MLBMi) starting pitchers (SPs) versus NPB minor league (NPBMi) SPs ($P < .05$). Slider (SL) usage was significantly greater for MLBMi RPs versus NPBMi RPs ($P < .05$). The asterisk indicates that the differences in pitch usage for the particular pitches mentioned were significant between the two groups. CH, changeup; CT, cutter; FB, fastball; SPL, splitter.

demonstrated that, on average, starting pitchers in MLB threw significantly faster (91.7 ± 2.2 mph) than did their NPB counterparts (90.4 ± 2.3 mph) ($P = .026$). Starting and relief pitchers in MLBMi also, on average, threw faster than did their NPBMi counterparts (starting pitchers: 91.3 ± 2.3 vs 89.5 ± 2.3 mph, respectively [$P = .001$]; relief pitchers: 92.0 ± 2.3 vs 90.2 ± 3.1 mph, respectively [$P = .001$]).

Post hoc tests demonstrated that maximum fastball velocity was not significantly different between MLB and NPB for both starting and relief pitchers. Starting and relief pitchers in MLBMi also, on average, threw faster than did their NPBMi counterparts (starting pitchers: 94.0 ± 2.6 vs 92.8 ± 2.1 mph, respectively [$P = .03$]; relief pitchers: 94.7 ± 2.5 vs 92.6 ± 2.8 mph, respectively [$P < .001$]).

TABLE 1
Proportion of Injured Players by Player and Injury Characteristics[a]

Variable	Los Angeles Angels	Hiroshima Toyo Carp	*P* Value
Player characteristic			
Pitcher	46 (1728/3781)	46 (172/371)	.808
Right-handed batter	52 (1949/3781)	69 (257/371)	**<.001**
Right-handed thrower	77 (2922/3781)	88 (326/371)	**<.001**
Injury type			**.008**
Acute	79 (2481/3146)	72 (210/291)	
Overuse	21 (665/3146)	28 (81/291)	
Injury activity			**<.001**
Base running	16 (408/2561)	11 (30/277)	
Batting	22 (574/2561)	18 (51/277)	
Conditioning	6 (145/2561)	16 (45/277)	
Fielding	19 (490/2561)	18 (50/277)	
Pitching	20 (508/2561)	34 (95/277)	
Throwing	17 (436/2561)	2 (6/277)	
Injury mechanism			**<.001**
Contact with ball	23 (645/2753)	17 (44/265)	
Contact with base	3 (76/2753)	0 (0/265)	
Contact with bat	2 (42/2753)	0 (1/265)	
Contact with boundary	2 (44/2753)	0 (0/265)	
Contact with ground	6 (178/2753)	1 (3/265)	
Contact with person	3 (94/2753)	2 (6/265)	
Noncontact	33 (921/2753)	51 (136/265)	
Gradual onset	27 (753/2753)	28 (75/265)	
Injury timing			**<.001**
Batting practice	3 (113/3670)	0 (0/189)	
Game	59 (2165/3670)	63 (120/189)	
Off premises	9 (348/3670)	0 (0/189)	
Postgame	2 (75/3670)	0 (0/189)	
Pregame	11 (419/3670)	33 (63/189)	
Workout	15 (550/3670)	3 (6/189)	

[a]Data are reported as % (n/N). Bold values indicate a statistically significant difference between groups ($P < .05$).

With respect to pitch usage, fastballs were thrown most often (group average: 56.8% ± 11.5%), with no significant differences in use between groups (Figure 3). The slider was the second most commonly used pitch (group average: 24.8% ± 13.3%), with a significant difference in use between MLBMi relief pitchers (28.9% ± 14.0%) and the NPBMi (21.5% ± 9.6%) ($P = .02$) (Figure 3). The changeup was the third most commonly used pitch (group average: 14.7% ± 10.3%), but its use was not significantly different between groups (Figure 3). The fourth most commonly used pitch was the curveball, with a significant difference in use between relief pitchers in MLB and NPB (22.0% ± 14.0% vs 11.8% ± 7.2%, respectively; $P = .03$) and starting pitchers in MLBMi and NPBMi (17.2% ± 9.5% vs 10.6% ± 5.9%, respectively; $P = .004$) (Figure 3). The cutter and splitter were not commonly used pitches across groups.

Injury Incidence

There were no significant differences between MLB and NPB in the proportion of injuries that occurred in pitchers

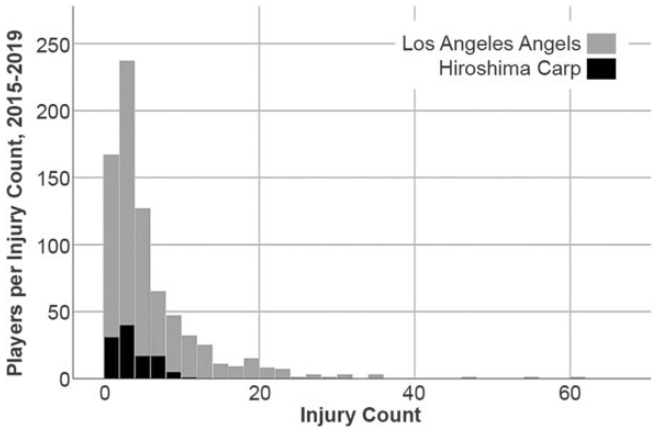

Figure 4. Stacked histogram of the number of players by injury count (for players with ≥1 injury) between 2015 and 2019. For example, almost 250 Los Angeles Angels players and nearly 50 Hiroshima Toyo Carp players experienced 4 injuries over the 5 seasons studied.

($P = .808$) (Table 1). There were significant differences in throwing-side dominance. While right-side dominance was more prevalent among those injured than was left-side dominance in both teams, the proportion of right-side dominance was significantly higher among Hiroshima Toyo Carp injuries than among Los Angeles Angels injuries ($P < .001$) (Table 1). When the total injury number was considered, the injury incidence was 0.030 injuries per player-game for the Los Angeles Angels, and 0.008 injuries per player-game for the Hiroshima Toyo Carp, which was over 3.7-fold lower. When repeat injuries were excluded, the injury incidence was 0.005 injuries per player-game for the Los Angeles Angels and 0.002 injuries per player-game for the Hiroshima Toyo Carp, demonstrating more injuries per player-game for MLB athletes. Thus, more players in the Los Angeles Angels system sustained multiple injuries; however, with repeat injuries removed, the MLB team had an 83% reduction in the incidence of injuries, while the NPB team had a 75% decrease, indicating that repeat injuries significantly affected both teams. Moreover, 2 Los Angeles Angels players had >50 injuries, and 29 players had ≥20 injuries; however, only a single player in the Hiroshima Toyo Carp system sustained >10 injuries (Figure 4). Analysis of the injury types for the most injured Los Angeles Angels players (3 players with >40 injuries) revealed a significant variation in injury types for each player as opposed to a repetition of the same injury types. For instance, for the most frequently injured player, diagnoses included hamstring spasms, upper respiratory infections, contusions in nearly every region of the body, ulnar collateral ligament sprains of the thumb, concussions, ankle ligament sprains, arm biceps strains, and thoracic spine sprains, among others. Similar trends were seen for the other 2 players who sustained >40 injuries.

TABLE 2
Proportion of Injuries by Body Region for the Los Angeles Angels[a]

Body Region	Unspecified Mechanism	Contact	Noncontact	Total
Abdomen	48 (56/116)	4 (5/116)	47 (55/116)	4 (116/3280)
Chest	12 (13/106)	25 (26/106)	63 (67/106)	3 (106/3280)
Dermatological	100 (53/53)	0 (0/53)	0 (0/53)	2 (53/3280)
Elbow	2 (4/221)	19 (43/221)	79 (174/221)	7 (221/3280)
Face	42 (88/212)	52 (110/212)	7 (14/212)	6 (212/3280)
Foot	7 (21/310)	61 (189/310)	32 (100/310)	9 (310/3280)
Forearm	2 (2/103)	35 (36/103)	63 (65/103)	3 (103/3280)
Gastrointestinal	100 (119/119)	0 (0/119)	0 (0/119)	4 (119/3280)
Hand	10 (31/323)	67 (218/323)	23 (74/323)	10 (323/3280)
Hip	4 (4/92)	16 (15/92)	79 (73/92)	3 (92/3280)
Knee	3 (7/208)	40 (84/208)	56 (117/208)	6 (208/3280)
Lower leg	2 (4/181)	67 (122/181)	30 (55/181)	6 (181/3280)
Neck	31 (33/107)	8 (9/107)	61 (65/107)	3 (107/3280)
Respiratory	100 (132/132)	0 (0/132)	0 (0/132)	4 (132/3280)
Shoulder	4 (14/357)	21 (76/357)	75 (267/357)	11 (357/3280)
Spine	10 (17/173)	8 (14/173)	82 (142/173)	5 (173/3280)
Thigh	5 (15/313)	12 (36/313)	84 (262/313)	10 (313/3280)
Upper arm	6 (3/51)	41 (21/51)	53 (27/51)	2 (51/3280)
Wrist	3 (3/103)	61 (63/103)	36 (37/103)	3 (103/3280)

[a]Data are reported as % (n/N). The distribution of injuries across the body was significantly different between teams ($P < .001$).

TABLE 3
Proportion of Injuries by Body Region for the Hiroshima Toyo Carp[a]

Body Region	Unspecified Mechanism	Contact	Noncontact	Total
Abdomen	0 (0/19)	11 (2/19)	89 (17/19)	5 (19/365)
Chest	15 (2/13)	8 (1/13)	77 (10/13)	4 (13/365)
Dermatological	100 (2/2)	0 (0/2)	0 (0/2)	1 (2/365)
Elbow	0 (0/29)	0 (0/29)	100 (29/29)	8 (29/365)
Face	24 (4/17)	76 (13/17)	0 (0/17)	5 (17/365)
Foot	18 (3/17)	29 (5/17)	53 (9/17)	5 (17/365)
Forearm	0 (0/7)	43 (3/7)	57 (4/7)	2 (7/365)
Gastrointestinal	100 (27/27)	0 (0/27)	0 (0/27)	7 (27/365)
Hand	19 (3/16)	56 (9/16)	25 (4/16)	4 (16/365)
Hip	0 (0/8)	0 (0/8)	100 (8/8)	2 (8/365)
Knee	7 (1/15)	40 (6/15)	53 (8/15)	4 (15/365)
Lower leg	5 (1/22)	41 (9/22)	55 (12/22)	6 (22/365)
Neck	35 (6/17)	6 (1/17)	59 (10/17)	5 (17/365)
Respiratory	100 (40/40)	0 (0/40)	0 (0/40)	11 (40/365)
Shoulder	8 (3/37)	3 (1/37)	89 (33/37)	10 (37/365)
Spine	7 (3/43)	2 (1/43)	91 (39/43)	12 (43/365)
Thigh	3 (1/29)	3 (1/29)	93 (27/29)	8 (29/365)
Upper arm	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/365)
Wrist	57 (4/7)	29 (2/7)	14 (1/7)	2 (7/365)

[a]Data are reported as % (n/N). The distribution of injuries across the body was significantly different between teams ($P < .001$).

TABLE 4
Proportion of Noncontact, Nonillness Injuries by Body Region[a]

Body Region	Los Angeles Angels	Hiroshima Toyo Carp
Abdomen	47 (55/116)	89 (17/19)
Chest	63 (67/106)	77 (10/13)
Dermatological	0 (0/53)	0 (0/2)
Elbow	79 (174/221)	100 (29/29)
Face	7 (14/212)	0 (0/17)
Foot	32 (100/310)	53 (9/17)
Forearm	63 (65/103)	57 (4/7)
Gastrointestinal	0 (0/119)	0 (0/27)
Hand	23 (74/323)	25 (4/16)
Hip	79 (73/92)	100 (8/8)
Knee	56 (117/208)	53 (8/15)
Lower leg	30 (55/181)	55 (12/22)
Neck	61 (65/107)	59 (10/17)
Respiratory	0 (0/132)	0 (0/40)
Shoulder	75 (267/357)	89 (33/37)
Spine	82 (142/173)	91 (39/43)
Thigh	84 (262/313)	93 (27/29)
Upper arm	53 (27/51)	0 (0/0)
Wrist	36 (37/103)	14 (1/7)

[a]Data are reported as % (n/N).

Injury Type

Athletic trainers for the teams delineated each injury as acute or overuse at the time that the injury was entered into the databases. There were significant differences in injury acuity, with more acute injuries and fewer overuse injuries in the Los Angeles Angels than in the Hiroshima Toyo Carp ($P = .008$) (Table 1). The number of days missed because of an injury was also significantly greater among the Hiroshima Toyo Carp players (36.2 ± 55.1 days) than among the Los Angeles Angels players (15.8 ± 54.7 days) ($P < .001$). Injury activity significantly differed between systems, with batting and throwing being more common among Los Angeles Angels injuries and conditioning and pitching being more common among Hiroshima Toyo Carp

TABLE 5
Frequency of the 10 Most Common Diagnoses

	Los Angeles Angels		Hiroshima Toyo Carp	
Rank	Diagnosis	% (n/N)	Diagnosis	% (n/N)
1	Nonspecific injury	5 (205/3781)	Upper respiratory infection	11 (42/371)
2	Upper respiratory infection	2 (86/3781)	Gastrointestinal illness	4 (16/371)
3	Hand contusion	2 (85/3781)	Shoulder pain	4 (14/371)
4	Leg contusion	2 (82/3781)	Low back pain	2 (7/371)
5	Foot contusion	1 (52/3781)	Acute low back pain	2 (6/371)
6	Gastroenteritis	1 (52/3781)	Pain in left abdomen	1 (5/371)
7	Hamstring spasm	1 (51/3781)	Hamstring strain	1 (5/371)
8	Knee contusion	1 (51/3781)	Anterior neck pain	1 (4/371)
9	Subacromial bursitis	1 (48/3781)	Lumbar facet pain	1 (4/371)
10	Hamstring strain	1 (47/3781)	Elbow pain	1 (4/371)

injuries ($P < .001$) (Table 1). The injury mechanism also significantly differed between systems, with contact with the ball or ground being more common among Los Angeles Angels injuries and noncontact being more common among Hiroshima Toyo Carp injuries ($P < .001$) (Table 1). The proportion of MLB throwing injuries relative to total injuries was nearly 8-fold higher compared with the NPB team ($P < .001$) (Table 1).

Injury timing also significantly differed between systems, with injuries off premises and during workouts being more common among Los Angeles Angels players and pregame injuries being more common among Hiroshima Toyo Carp players ($P < .001$) (Table 1). The injured body region further significantly differed between systems, with the spine being more commonly injured among Hiroshima Toyo Carp injuries and the shoulder, thigh, and hand being more commonly injured among Los Angeles Angels injuries; however, there was no difference in the proportion of shoulder or elbow injuries ($P < .001$) (Tables 2–4). While there was too much diversity in specific diagnoses to allow a statistical comparison, the most common injury types of both systems were tabulated and are shown in Table 5.

DISCUSSION

The findings from this 2-team study are novel for baseball medical personnel affiliated with both leagues in which no research, to date, has compared injury statistics between NPB and MLB players. Our hypothesis was supported in that differences were noted between the leagues in velocity and pitch type usage, incidence divided by the total games played by the club, repeat injuries, injury severity, and mechanism of injury. The MLB team demonstrated higher average fastball velocity and breaking ball usage (slider and curveball); greater incidence of injuries per game; less injury severity as determined by the number of days missed; more athletes with repeat injuries; more throwing-related, contact, and acute injuries; and more noncompetitive injuries compared with the NPB team.

In addition to physical size, our competitive metrics for fastball velocity as well as curveball and slider usage suggests potential differences in biomechanical loading profiles among MLB and NPB pitchers. MLB starting pitchers threw >1 mph faster than did NPB starting pitchers, with a similar trend observed among MLB relief pitchers. MLBMi pitchers, on average, threw nearly 2 mph faster than did NPBMi pitchers. MLBMi starting and relief pitchers threw more curveballs, while MLBMi relief pitchers threw more sliders than did NPBMi relief pitchers. MLB players were approximately 3 cm taller and 3 kg heavier than were NPB players. Fleisig et al[5] evaluated pitchers across different levels and showed that increased mass, arm length, and angular velocity led to higher joint forces and velocities in larger pitchers. The MLB team's larger sized athletes throwing more sliders and curveballs may point to greater overall throwing-arm loads.[6,7] Changeup use, which is the only pitch type known to reduce kinetic loads, did not differ between teams.[6,7] Research comparing biomechanics between American and Japanese pitchers has previously shown that Americans were larger, threw faster, and had higher elbow loads.[13]

The MLB team had a much greater incidence of injuries per game. Even when players with repeat injuries were removed, the MLB team still had more than double the injury incidence of the NPB team. In the MLB team, many injured players sustained large numbers of subsequent injuries, which fits with previous studies that have shown that a previous injury is a strong predictor of future injuries.[3,8,9-11,15] While the specific cause of these differences is unclear, the ratio of player to medical staff may play a role, as we identified ratios as high as 10.6 in NPB and NPBMi, 25 in MLBMi, and 6.25 in MLB. Although less injury prone, the NPB team had a greater number of days missed per injury, and its age of injury onset was older compared with the MLB team, potentially signifying a decline in recovery from aging.

The mechanisms of injury differed between teams. The NPB team had more injuries from pitching, while the MLB team had more injuries related to throwing. A higher percentage of throwing injuries relative to the total in the current study suggests that MLB teams should closely examine their practice plans and appropriately prescribe workload schedules in preparation for games, as practices tend to show a higher injury risk in other research.[4] Running-based training is another

practice event that poses a risk to athletes. Greater running volumes were prescribed for the NPB team and were likely related to the higher percentages of general overuse injuries and conditioning-based injuries in Japanese players comparatively. Hamstring spasms and hamstring strains were among the top 10 injuries reported in this study and are frequently related to running-based activities in baseball, for which pitchers have the greatest vulnerability and injury rates.[27] Performance specialists from both leagues should be aware of the current trends and focus attention on periodization and undulation in running-based training, particularly for pitchers who require endurance, speed, and agility.

For all anatomic regions of the body, the proportion of spinal injuries was 2-fold greater for the NPB team than MLB team. Previous research has reported that back and core injuries in MLB generally account for 12% of all reported injuries per year.[2] In this specific MLB team, between 2015 and 2019, a better rate of 5% was observed.[2] Injuries can include, but are not limited to, disc degeneration, stenosis, stress fractures, and facet joint pain.[2] Baseball players require multidirectional pelvis and trunk stabilization programming, but movements in pitching and hitting that involve the activation of lumbar paraspinal muscles to coordinate lumbar extension and rotation can expose the athlete to disc injuries as well as back spasms and strains.[2] For the most part, these actions are nonmodifiable biomechanically, as extension and rotation occur with every swing and throw. Thus, workload management becomes most critical for these actions. Conducting future research into motion-sensing technology and having dedicated sports science personnel evaluate swinging and throwing intensity, density, frequency, and volume may be helpful in this regard.

Contact and noncontact injuries differed proportionally between teams, with contact injuries being more prevalent in MLB players. All elbow injuries in NPB players stemmed from noncontact incidents, whereas 79% of elbow injuries in MLB players occurred from noncontact events. A greater proportion of forearm injuries were noncontact for the MLB team, but a greater proportion of shoulder injuries (89%) were noncontact for the NPB team. Biomechanical differences between teams may have accounted for these disparities.[13] Other than contact with the ball, the highest incidence mechanisms were contact with the ground and barriers, such as stadium walls. There were no injuries stemming from contact with a boundary for the NPB team for the time frame of this study. Ground contact injuries are typically a result of falls or miscues in diving plays. Fatigue potentially amplifies these issues, as inadequate sleep could reduce contraction, proprioception, and cognitive responses.[1] Even on a short-term basis of 24 hours, sleep deprivation can reduce muscle strength as well as vestibular and mechanoreceptor sensitivities, and if it occurs over the course of a week, it could affect postural control, increasing the chance of falls during high-speed sprinting.[1,14] Sleep disturbance occurs from coast-to-coast travel, so MLB teams may reduce the financial cost of ground and barrier contact injuries by improved schedules. This may include more off days in the MLB season to improve travel acclimation. As an example, Sunday night games may not be in the best interest of recovery and sleep quality for MLB athletes, as teams have to travel through the night to prepare for the first game of a series on the following Monday. In such instances, MLB teams could consider scheduling an off day on the following Monday to allow athletes to catch up on missed sleep and prepare for the start of the next series on a Tuesday night. This change has already been made in NPB, which always has Mondays as off days. In combination with shorter travel times, Japanese professional baseball players may thus be better able to recover.

Infectious illnesses were listed in the top 10 diagnoses, with upper respiratory infections and internal illnesses being in the top 2 ranks for both teams. The COVID-19 pandemic may improve the occurrence of infectious diseases for both MLB and NPB teams, as players and staff must go through a daily symptom check and temperature screen, wear personal protective gear, and be diligent with sanitization and personal hygiene. If current preventive practices are maintained, it is likely that the percentage of bacterial and viral infections will decrease and thereby improve health statistics between both leagues.

Limitations

The study had a few limitations; if improved, greater injury surveillance can be achieved for both NPB and MLB teams. Our data represent a 2-team comparison, and results may not be generalizable to their overall leagues. Another limitation is that NPB does not have a central data repository similar to the MLB HITS. As a result, diagnoses within the NPB data set did not follow HITS criteria, and thus, a retrospective effort was necessary to align the data sets. The MLB HITS database is subject to data entry errors, and positional data were not available for all players. Cultural differences between leagues could affect the frequency of communication with medical personnel and thereby inflate or reduce reports for minor injuries or ailments. When evaluating environmental attributes, the term "workout" may be used differently by different athletic trainers; for example, different portions of a baseball practice can be labeled as a "workout." In the future, it may be in the best interest of the HITS database to consider including the metadata term "strength training" so that such information can benefit professional strength coaches in understanding injury data relevant to their scope of practice. Because of inconsistencies in competitive schedules between the MLB and NPB teams, exposures may be construed as unequal between leagues. To offset discrepancies in game schedules, injury exposures were normalized to player-games. This normalization is imperfect, as playing time is not evenly distributed and per-player exposure data were not available. Last, reporting standards appeared to differ between teams; it is possible that the MLB HITS reported more injuries that were less severe, potentially giving rise to a higher injury incidence but fewer days missed per injury for the MLB team.

CONCLUSION

This is the first empirical study to examine injury trends between MLB and NPB athletes. MLB players were larger than were NPB players; were more susceptible to injuries; were younger with fewer days missed per injury; predominantly pitched with greater velocity and reliance on breaking pitches; and differed in the percentage of injuries related to type, activity, timing, and mechanism.

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