

# Predicting and Preventing Injury in Major League Baseball

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## Abstract

Major League Baseball (MLB) players are at significant risk for both chronic, repetitive overuse injuries as well as acute traumatic injuries. Pitchers have been shown to be at higher risk for sustaining injuries, especially upper extremity injuries, than position players. The past several MLB seasons have seen a dramatic rise in the number of ulnar collateral ligament reconstructions performed in MLB pitchers. Several recent prospective studies have identified risk factors for injuries to both the shoulder and elbow in MLB pitchers. These risk factors include a lack of external rotation, a lack of total rotation, and a lack of flexion in the throwing arm. Thus far, no study has demonstrated a correlation between cumulative work (number of games pitched, total pitches thrown, total innings pitched, innings pitched per game, and pitches thrown per game) and injuries in MLB pitchers, despite several studies showing this correlation in youth pitchers. Although many risk factors have been translated into guidelines for prevention, no study has been conducted to determine whether adherence to these guidelines effectively prevents injuries. Further studies are necessary to define exactly how injuries in MLB players can be prevented.

of all 30 MLB teams combined is estimated at \$36 billion; an increase of 48% from 1 year ago.<sup>2</sup> As the sport continues to grow in popularity and receives more social media coverage, several issues, specifically injuries to its players, have come to the forefront of the news. Injuries to MLB players, specifically pitchers, have become a significant concern in recent years. The active and extended rosters in MLB include 750 and 1200 athletes, respectively, with approximately 360 active spots taken up by pitchers.<sup>3</sup> Hence, MLB employs a large number of elite athletes within its organization. It is important to understand not only what injuries are occurring in these athletes, but also how these injuries may be prevented.

## Epidemiology

Injuries to MLB players, specifically pitchers, have increased over the past several years.<sup>4</sup> Between 2005 and 2008, there was an overall increase of 37% in total number of injuries, with more injuries occurring in pitchers than any other position.<sup>5</sup> While position players are more likely to sustain an injury to the lower extremity, pitchers are more likely to sustain an injury to the upper extremity.<sup>5</sup> The month with the most injuries to MLB players was April, while the fewest number of injuries occurred in September.<sup>5</sup> One injury that has been in the spotlight due to its dramatically increasing incidence is tear of the ulnar collateral ligament (UCL). Several studies have shown that the number of pitchers undergoing ulnar collateral ligament reconstruction (UCLR), commonly known as Tommy John surgery, has significantly increased over the past 20 years (**Figure 1**).<sup>4,6</sup> Between 25% to 33% of all MLB pitchers have undergone UCLR.

While the number of primary UCLR in MLB pitchers has become a significant concern, an even more pressing concern is the number of pitchers undergoing revision UCLR, as this number has

**M**ajor league baseball (MLB) is one of the most popular sports in the United States, with an average annual viewership of 11 million for the All-Star game and almost 14 million for the World Series.<sup>1</sup> MLB has an average annual revenue of almost \$10 billion, while the net worth

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increased over the past several years.<sup>7</sup> Currently, there is some debate as to how to best address the UCL during primary UCLR (graft type, exposure, treatment of the ulnar nerve, and graft fixation methods) because no study has shown one fixation method or graft type to be superior to others. Similarly, no study has definitively proven how to best manage the ulnar nerve (transpose in all patients, only transpose if preoperative symptoms of numbness/tingling, subluxation, etc. exist). Unfortunately, the results following revision UCLR are inferior to those following primary UCLR.<sup>4,78</sup> Hence, given this information, it is imperative to both determine and implement strategies aimed at minimizing the need for revision.

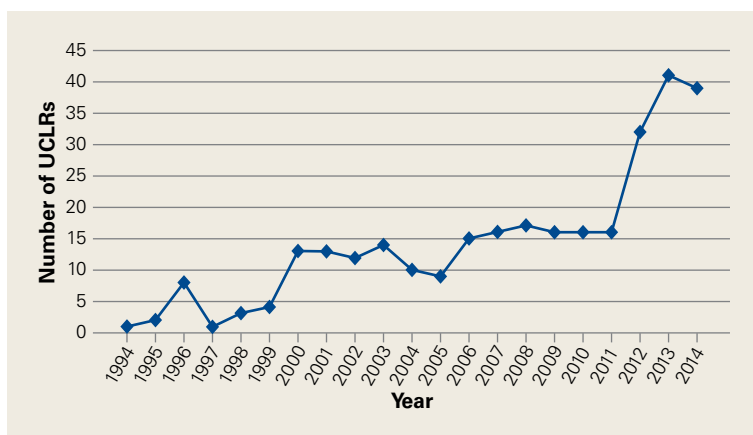
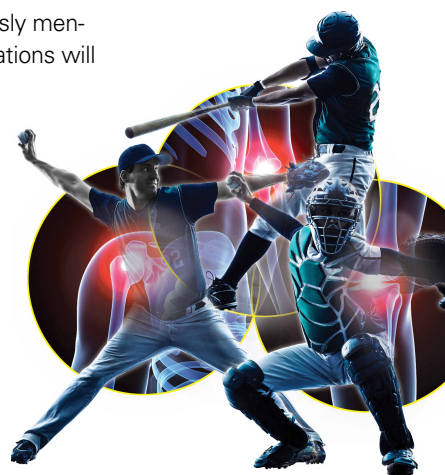
### Risk Factors for Injury

Although MLB has received more media attention than lower levels of baseball competition, there is relatively sparse evidence surrounding injury risk factors among MLB players. The majority of studies performed have evaluated risk factors for injury in younger baseball athletes (adolescent, high school, and college). The number of athletes at these lower levels sustaining injuries has increased over the past several years as well.<sup>9</sup> Several large prospective studies have evaluated risk factors for shoulder and elbow injuries in adolescent baseball players. The risk factors include pitching year-round, pitching more than 100 innings per year, high pitch counts, pitching for multiple teams, geography, pitching on consecutive days, pitching while fatigued, breaking pitches, higher elbow valgus torque, pitching with higher velocity, pitching with supraspinatus weakness, and pitching with a glenohumeral internal rotation deficit (GIRD).<sup>10-17</sup> The large majority of these risk factors are essentially part of a pitcher's cumulative work, which consists of number of games pitched, total pitches thrown, total innings pitched, innings pitched per game, and pitches thrown per game. One prior study has evaluated cumulative work as a predictor for injury in MLB pitchers.<sup>18</sup> While there were several issues with the study methodology, the authors found no correlation between a MLB pitcher's cumulative work and risk for injury.

Given our current understanding of repetitive microtrauma as the pathophysiology behind these injuries, it remains unclear why cumulative work would be predictive of injury in youth pitchers but not in MLB pitchers.<sup>16</sup> Several potential reasons exist as to why cumulative work may relate to risk of injury in youth pitchers and not MLB pitchers. Achieving MLB status may infer the element of natural selection

based on technique and talent that supersedes the effect of "cumulative trauma" in many players. In MLB pitchers, cumulative work is closely monitored. In addition, these players are only playing for a single team and are not pitching competitively year-round, while many youth players play for multiple teams and may pitch year-round. To combat youth injuries, MLB Pitch Smart has developed recommendations on pitch counts and days of rest for pitchers of all age groups (Table).<sup>19</sup> While data do not yet exist to clearly demonstrate the effectiveness of these guidelines, given the risk factors previously mentioned, it seems that these recommendations will show some reduction in youth injuries in years to come.

Some studies have evaluated anatomic variation among pitchers as a risk factor for injury. Polster and colleagues<sup>20</sup> performed computed tomography (CT) scans with 3-dimensional reconstructions on the humeri of both the throwing and non-throwing arms of 25 MLB pitchers to determine if humeral torsion was related to the incidence and severity of upper extremity injuries in these athletes. The authors defined a severe injury as those which kept the player out for >30 days. Overall, 11 pitchers were injured during the 2-year study period. There was a strong inverse relationship between torsion and injury severity such that lower degrees of dominant humeral torsion correlated with higher injury severity ( $P = .005$ ). However, neither throwing arm humeral torsion nor the difference in torsion between throwing and non-throwing humeri



**Figure 1.** Number of ulnar collateral ligament reconstructions (UCLRs) performed in Major League Baseball pitchers per year from 1994-2014.

were predictive of overall injury incidence. While this is a nonmodifiable risk factor, it is important to understand how the pitcher's anatomy plays a role in risk of injury.<sup>20</sup> Understanding nonmodifiable risk factors may be helpful in the future to risk stratify, prognosticate, and modulate modifiable risk factors such as cumulative work.

## Elbow

Injuries to the elbow have become more common in recent years amongst MLB players, although the literature regarding risk factors for elbow injuries is sparse.<sup>4,6</sup> Wilk and colleagues<sup>21</sup> performed a prospective study to determine if deficits in glenohumeral passive range of motion (ROM) increased the risk of elbow injury in MLB pitchers. Between 2005-2012, the authors measured passive shoulder ROM of both the throwing and non-throwing shoulder of 296 major and minor league pitchers and followed them for a median of 53.4 months. In total, 38 players suffered 49 elbow injuries and required 8 surgeries, accounting for a total of 2551 days spent on the disabled list (DL). GIRD and external rotation insufficiency were not correlated with elbow injuries. However, pitchers with deficits of  $>5^\circ$  in total rotation between the throwing and non-throwing shoulders had a 2.6 times greater risk for injury ( $P = .007$ ) and pitchers with deficits of  $\geq 5^\circ$  in flexion of the throwing shoulder compared to the non-throwing shoulder had a 2.8 times greater risk for injury ( $P = .008$ ).<sup>21</sup> Prior studies have demonstrated trends towards increased elbow injury in professional baseball pitchers with an increase in both elbow valgus torque as well as shoulder external rotation torque; maximum pitch velocity was also shown to be an independent risk factor for elbow injury in professional baseball pitchers.<sup>10,11</sup> These injuries typically occur during the late cocking/early

acceleration phase of the pitching cycle, when the shoulder and elbow experience the most significant force of any point in time during a pitch (**Figure 2**).<sup>17</sup> At our institution, there are several ongoing studies to determine the relative contributions of pitch velocity, number, and type to elbow injury rates. Prospective studies are also ongoing at other institutions.

## Shoulder

Shoulder injuries are one of the most common injuries seen in MLB players, specifically pitchers. Similar to the prior study, Wilk and colleagues<sup>22</sup> recently performed a prospective study to determine if passive ROM of the glenohumeral joint in MLB pitchers was predictive of shoulder injury or shoulder surgery. As in the previous study, the authors' measured passive shoulder ROM of the throwing and non-throwing shoulder of 296 major and minor league pitchers during spring training between 2005-2012 and obtained an average follow-up of 48.4 months. The authors found a total of 75 shoulder injuries and 20 surgeries among 51 pitchers (17%) that resulted in 5570 days on the DL. While total rotation deficit, GIRD, and flexion deficit had no relation to shoulder injury or surgery, pitchers with  $<5^\circ$  greater external rotation in the throwing shoulder compared to the non-throwing shoulder were more than 2 times more likely to be placed on the DL for a shoulder injury ( $P = .014$ ) and were 4 times more likely to require shoulder surgery ( $P = .009$ ).<sup>22</sup> The authors concluded that an insufficient side-to-side difference in external rotation of the throwing shoulder increased a pitcher's likelihood of shoulder injury as well as surgery.

## Other

One area that has not received as much attention as repetitive use injuries of the shoulder and elbow is acute collision injuries. Collision injuries include concussions, hyperextension injuries to the knees, shoulder dislocations, fractures of the foot and ankle, and others.<sup>23</sup> Catchers and base runners during scoring plays are at a high risk for collision injury. Recent evidence has shown that catchers average approximately 2.75 collision injuries per 1000 athletic exposures (AE), accounting for an average of 39.1 days on the DL per collision injury.<sup>23</sup> However, despite these collision injuries, catchers spend more time on the DL from non-collision injuries (specifically shoulder injuries requiring surgical intervention), as studies have shown 19 different non-collision injuries that accounted for  $>100$  days on the DL for catchers compared to no

Table. **Current Protocol from Major League Baseball Pitch Smart for Recommended Days of Rest Following a Pitching Outing Based on Player Age**

| Age, y | Daily Max (Pitches In Game) | Required Rest (Pitches) |       |        |        |        |
|--------|-----------------------------|-------------------------|-------|--------|--------|--------|
|        |                             | 0 Days                  | 1 Day | 2 Days | 3 Days | 4 Days |
| 7-8    | 50                          | 1-20                    | 21-35 | 36-50  | N/A    | N/A    |
| 9-10   | 75                          | 1-20                    | 21-35 | 36-50  | 51-65  | 66+    |
| 11-12  | 85                          | 1-20                    | 21-35 | 36-50  | 51-65  | 66+    |
| 13-14  | 95                          | 1-20                    | 21-35 | 36-50  | 51-65  | 66+    |
| 15-16  | 95                          | 1-30                    | 31-45 | 46-60  | 61-75  | 76+    |
| 17-18  | 105                         | 1-30                    | 31-45 | 46-60  | 61-75  | 76+    |
| 19-22  | 120                         | 1-30                    | 31-45 | 46-60  | 61-75  | 76+    |

collision injuries that caused a catcher to be on the DL for >100 days.<sup>23</sup> The position of catcher is not an independent risk factor for sustaining an injury in MLB players.<sup>5</sup>

### Preventative Measures

Given that recent evidence has identified certain modifiable risk factors, largely regarding shoulder ROM, for injuries to MLB pitchers, it stands to reason that by modifying these risk factors, the number of injuries to MLB pitchers can be decreased.<sup>21,22</sup> However, to the authors' knowledge, there have been no studies in the current literature that have clearly demonstrated the ability to prevent injuries in MLB players. Based on the prior studies, it seems logical that lowering peak pitch velocity and ensuring proper shoulder ROM would help prevent injuries in MLB players, but this remains speculative. Stretching techniques that have been shown to increase posterior shoulder soft tissue flexibility, including sleeper stretches and modified cross-body stretches, as well as closely monitoring ROM may be helpful in modifying these risk factors.<sup>24-26</sup>

Although the number of collision injuries is significantly lower than non-collision repetitive use injuries, MLB has implemented rule changes in recent years to prevent injuries to catchers and base runners alike.<sup>23,27</sup> The rule change, which went into effect in 2014, prohibits catchers from blocking home plate unless they are actively fielding the ball or are in possession of the ball. Similarly, base runners are not allowed to deviate from their path to collide with the catcher while attempting to score.<sup>27</sup> However, no study has analyzed whether this rule change has decreased the number of collision injuries sustained by MLB catchers, so it is unclear if this rule change has accomplished its goal.

### Outcomes Following Injuries

One of the driving forces behind injury prevention in MLB players is to allow players to reach and maintain their full potential while minimizing time missed because of injury. Furthermore, as with any sport, the clinical outcomes and return to sport (RTS) rates for MLB players following injuries, especially injuries requiring surgical intervention, can be improved.<sup>4,28,29</sup> Several studies have evaluated MLB pitchers following UCLR and have shown that over 80% of pitchers are able to RTS following surgery.<sup>4,30</sup> When critically evaluated in multiple statistical parameters upon RTS, these players perform better in some areas and worse in others.<sup>4,30</sup> However, the results following revision UCLR are not as encouraging as those following primary UCLR in MLB pitchers.<sup>7</sup> Following

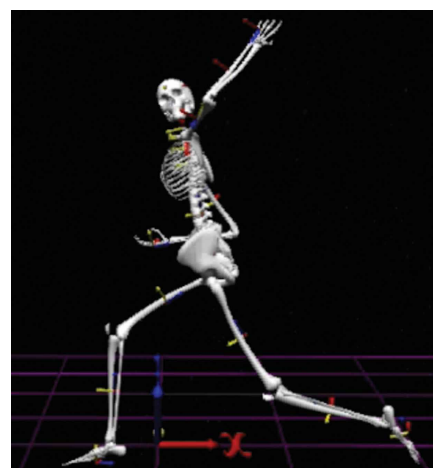
revision UCLR, only 65% of pitchers were able to RTS, and those who were able to RTS pitched, on average, almost 1 year less than matched controls.<sup>7</sup> Unfortunately, results following surgeries about the shoulder in MLB players have been worse than those about the elbow. Cohen and colleagues<sup>28</sup> reported on 22 MLB players who underwent labral repair of the shoulder and found that only 32% were able to return to the same or higher level following surgery, while over 45% retired from baseball following surgery. Hence, it is imperative these injuries are prevented, as the RTS rate following treatment is less than ideal.

### Future Directions

Although a concerted effort has been made over the past several years to mitigate the number of injuries sustained by MLB players, there is still significant room for improvement. New products are in development/early stages of use that attempt to determine when a pitcher begins to show signs of fatigue to allow the coach to remove him from the game. The mTHROW sleeve (Motus Global), currently used by several MLB teams, is an elastic sleeve that is worn by pitchers on their dominant arm. The sleeve approximates torque, velocity, and workload based upon an accelerometer positioned at the medial elbow and sends this information to a smart phone in real time. This technology theoretically allows players to be intensively monitored and thus may prevent injuries to the UCL by preventing pitchers from throwing while fatigued. However, elbow kinematic parameters may not change significantly as pitchers fatigue, which suggests that this strategy may be suboptimal. Trunk mechanics do change as pitchers become fatigued, opening up the possibility for shoulder and elbow injury.<sup>17,31,32</sup> Further products that track hip-to-shoulder separation and trunk fatigue may be necessary to truly lower injury rates. However, no study has proven modifying either parameter leads to a decrease in injury rates.

### Conclusion

Injuries to MLB pitchers and position players have become a significant concern over the past several years. Several risk factors for injury



**Figure 2.** Animation created by a pitcher throwing in the motion analysis lab demonstrating the position of the arm at the transition point from the late cocking to the early acceleration phase of the pitching cycle.

have been identified, including loss of shoulder ROM and pitch velocity. Further studies are necessary to determine the effectiveness of modifying these parameters on injury prevention.

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