Preseason Shoulder Strength Measurements in Professional Baseball Pitchers: Identifying Players at Risk for Injury

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Preseason Shoulder Strength Measurements in Professional Baseball Pitchers

Identifying Players at Risk for Injury

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Background: The ability to identify pitchers at risk for injury could be valuable to a professional baseball organization. To our knowledge, there have been no prior studies examining the predictive value of preseason strength measurements.

Hypothesis: Preseason weakness of shoulder external rotators is associated with increased risk of in-season throwing-related injury in professional baseball pitchers.

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: Preseason shoulder strength was measured for all pitchers in a professional baseball organization over a 5-year period (2001-2005). Prone internal rotation (IR), prone external rotation (PER), seated external rotation (SER), and supraspinatus (SS) strength were tested during spring training before each season. The players were then prospectively followed throughout the season for incidence of throwing-related injury. Injuries were categorized on an ordinal scale, with no injury, injury treated conservatively, and injury resulting in surgery delineated 0, 1, and 2, respectively. Subset analyses of shoulder injuries and of players with prior surgery were also performed. The association between strength measurements and injury was analyzed using Spearman rank correlation.

Results: A statistically significant association was observed for PER strength ($P = .003$), SER strength ($P = .048$), and SS strength ($P = .006$) with throwing-related injury requiring surgical intervention. Supraspinatus strength was also significantly associated with incidence of any shoulder injury ($P = .031$). There was an association between the ratio of PER/IR strength and incidence of shoulder injury ($P = .037$) and some evidence for an association with overall incidence of throwing-related injury ($P = .051$). No associations were noted in the subgroup of players with prior surgery.

Conclusion: Preseason weakness of external rotation and SS strength is associated with in-season throwing-related injury resulting in surgical intervention in professional baseball pitchers. Thus, preseason strength data may help identify players at risk for injury and formulate strengthening plans for prevention.

Keywords: professional baseball; pitcher; strength measurements; shoulder injury

Injury to a professional athlete not only negatively affects the player/patient, but it can also have a significant effect on the team, its fan base, its profitability, and the outcome of an entire season. This effect is especially notable in the case of professional baseball pitchers, as these athletes can have a significant individual influence in an otherwise team-focused game. Investigators have shown that the throwing mechanism places considerable stresses on the glenohumeral and elbow joints.[6,9,13,14] When compared with other position players, professional baseball pitchers

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create significantly increased mean and peak torques during the pitching motion.[2] Compressive forces at the glenohumeral joint, internal rotation torque, horizontal abduction torque, and elbow varus torque have all been identified as possible sources of overuse injury to the shoulder and elbow.[9] Lower extremity strength and conditioning are also thought to be integral in the transfer of energy during pitching and thus may be involved in injury mechanisms as well.[15,23] Relative weakness of the shoulder external rotators as compared with the internal rotators in pitchers has been established in the literature, but none has shown a correlation of weakness to future injury.[**] Several studies have stressed the importance of strength and conditioning on injury prevention, however, theorizing that pitchers with more balanced rotator cuff musculature may be at lower risk for injury.[††] Given the high demands placed on the shoulder in throwing athletes, professional baseball pitchers may be at higher risk of injury without proper conditioning. The ability to identify players who are more likely to be injured during the course of the season would provide valuable information to players and trainers as they prepare for the upcoming season. The purpose of this study was to analyze the predictive value of preseason shoulder strength measurements in identifying players at risk for in-season throwing-related injury. Our hypothesis was that shoulders with weaker external rotation strength would be at higher risk for injury.

MATERIALS AND METHODS

Patients

Over a 5-year period (2001-2005), 144 Major and Minor League Baseball pitchers from a professional organization participated in the preseason strength testing protocol during the months of February and March of spring training. These players were then prospectively followed throughout each respective season for incidence of injury. Forty-four of the players remained with the organization for more than 1 year and were subsequently tested each year that they were active on the roster. One hundred players were tested for 1 season only, 31 were tested for 2 seasons, 7 were tested for 3 seasons, and 6 were tested for 4 seasons. The mean number of seasons that each player was tested was 1.4, with a median of 1 and range of 1 to 4 seasons. Players remaining with the organization for more than 1 year created separate unique data points for each season. A player/season data point constitutes a player's set of strength measurements for a given season and the associated injury outcome for that season. Over the course of 5 years, 207 total distinct player/season data points were collected from 144 players. Inclusion criteria included participating in preseason workouts as an active pitcher on the roster and having no restrictions on throwing activity. Players joining the organization after spring training were excluded, as no preseason data were collected for these players. Pitchers were not excluded for prior injury or surgery to the pitching arm. All players participated in standard preseason and intraseason strengthening programs per normal team protocols. One data point was retrospectively eliminated due to inaccurate transcription of strength measurements onto the data collection spreadsheet. The study was approved by the hospital institutional review board, and all measurements were deidentified before analysis.

Testing Protocol

A single certified athletic trainer collected all strength measurements in an isometric manner according to specific protocol. A PowerTrack II Commander hand-held dynamometer (J-Tech Medical, Salt Lake City, Utah) was employed to record quantitative strength measurements in kilograms. Intrarater validity and reliability of hand-held dynamometers have been established in the literature.[3,17,31,32] We have assumed intrarater reliability and validity of this testing apparatus based on previous studies and did not perform a pilot study to assess our own internal reliability. Strength was assessed in the throwing arm for prone internal rotation (IR), prone external rotation (PER), seated external rotation (SER), and supraspinatus (SS). Make tests were used rather than break tests, given their higher reliability coefficient when comparing the 2 methods using a hand-held dynamometer.[31] Three trials were performed for each strength measurement, and the median value of the 3 trials was recorded. The test sequence was the same for each player: PER, IR, SER, and SS.

Prone IR was measured with the patient lying face down on the examination table with the arm abducted in the coronal plane to 90° at the glenohumeral joint and the elbow flexed to 90°. With the humerus manually stabilized by the examiner and the arm at 0° of rotation, the dynamometer was placed on the volar aspect of the distal radius 5 cm proximal to the proximal wrist flexion crease. The patient was instructed to internally rotate the arm with maximum effort, avoiding additional shoulder abduction (Figure 1). Testing sequences were performed as make tests, as full effort was produced by the player until he felt that he had reached maximum force. Prone external rotation was measured in a similar fashion; however, the dynamometer was placed on the dorsal aspect of the forearm 5 cm proximal to the proximal wrist extension crease as the patient externally rotated the arm with maximum force.

Seated external rotation testing was performed with the patient sitting upright on a training room examination table with his back against the wall. The arm was stabilized by the examiner in an adducted position at the patient's side at 0° of rotation with a rolled towel in the axilla. The elbow was flexed to 90° with the forearm in neutral "thumbs-up" position. The dynamometer was then placed on the dorsal aspect of the forearm 5 cm proximal to the proximal wrist extension crease as the patient externally rotated the arm with maximum effort (Figure 2). Separate measurements for external rotation strength

**References 1, 2, 5, 8, 12, 21, 23, 24, 33, 35.

††References 7-9, 15, 18, 25, 26, 33, 34, 36.

Figure 1. Prone internal rotation strength testing.

were collected in the prone and seated positions to account for differences with the scapula free and the arm abducted (prone on an examining table) versus immobilized against the wall with the arm adducted (seated). With the back flush against the wall, prevention of scapular winging was reproducible among patients.

Supraspinatus strength was also measured with the patient seated on a training room examination table with his back against the wall. The arm was abducted in the coronal plane to 90° and then horizontally adducted to 45° with the forearm neutral. The dynamometer was placed 5 cm proximal to the proximal wrist extension crease as the patient raised the arm perpendicular to the floor with maximum effort (Figure 3).

Data Analysis

Patients were subsequently followed during the course of their respective seasons for the occurrence of any throwing-related injury. The type of injury and method of treatment were recorded. Using an established model,[18] each player's injury status for the season was categorized on an ordinal scale as either no injury (0), injury not requiring surgery (1), or injury requiring surgery (2). "Injury" was defined as any condition resulting in the athlete's placement onto the disabled list and/or missing at least 1 game because of the condition. "Throwing-related injury" was defined as any condition that could be linked to the kinetic chain of the throwing motion. Any injury that occurred from another mechanism (ie, fall, collision with another player, sprain/twist while running, hit by pitch, etc) was excluded. The associations between each strength measurement and the likelihood of injury requiring surgery were analyzed using Spearman rank correlation on the raw injury status variables. Each strength measurement was also analyzed for association with overall likelihood of injury, with injury status as a binary variable. A ratio of PER to IR was calculated for each player/season data point, and this ratio was also analyzed for association with likelihood of injury and injury requiring surgery.

Figure 2. Seated external rotation strength testing.

Figure 3. Supraspinatus strength testing.

A subset analysis of shoulder injuries was also performed, with shoulder injuries classified on the same ordinal 0, 1, and 2 scale. The associations between strength measurements and overall shoulder injury as well as shoulder injury requiring surgery were also analyzed using Spearman rank correlation. The data of pitchers with a history of shoulder or elbow surgery prior to preseason strength testing (n = 26) were also analyzed separately from the group. Analyses

TABLE 1
Distribution of Injuries[a]

	Nonoperative	Operative	Combined
Shoulder injuries			
Rotator cuff strain or tendinitis	12	1	13
Biceps tendinitis	8	0	8
SLAP lesion	2	6	8
Impingement syndrome	4	1	5
Rotator cuff tear	0	3	3
Posterior labral tear	0	1	1
Pectoralis major strain	1	0	1
Latissimus dorsi strain	1	0	1
Scapular stress fracture	1	0	1
Shoulder injury total	29	12	41
Elbow injuries			
Ulnar collateral ligament injury	3	9	12
Flexor/pronator strain or tendinitis	5	0	5
Synovitis/inflammation	1	3	4
Loose bodies	0	3	3
Ulnar neuritis	2	0	2
Olecranon bursitis	1	0	1
Olecranon stress fracture	0	1	1
Elbow injury total	12	16	28
Other injuries			
Lower extremity sports hernia	1	0	1

[a]SLAP, superior labrum anterior to posterior.

were performed using free open source R version 2.8.1 (www.r-project.org).[28] The relationship between the strength variable and likelihood of injury was estimated using the loess nonparametric smoother, creating a graphical depiction of the data.[4] Statistical significance was defined a priori as $P \leq .05$.

RESULTS

The median preseason shoulder strength measurements (with 25th and 75th percentiles) in kilograms were 35.0 (30.0, 40.0) for IR, 36.0 (32.0, 43.0) for PER, 26.0 (22.0, 31.0) for SER, and 28.0 (24.25, 32.0) for SS. Redundancy analysis showed each of the 4 preseason strength measurements to represent unique, nonoverlapping variables. Of the 5 strength measures, the 2 most closely correlated were SS and IR (Spearman $\rho = .6$). The median ratio of PER to IR strength was 1.05, with 25th and 75th percentiles of 0.91 and 1.19, respectively. There were a total of 70 injuries in 50 players, with 10 players having suffered injuries in multiple seasons. As demonstrated in Table 1, there were 41 shoulder injuries and 28 elbow injuries, with 12 shoulders and 16 elbows treated operatively. There was one lower extremity sports hernia that was treated nonoperatively. Overall, 42 injuries were treated nonoperatively, and 28 were treated surgically. Shoulder injuries included rotator cuff strain/tendinitis, biceps tendinitis, superior labrum anterior to posterior (SLAP) lesion, shoulder impingement syndrome, rotator cuff tear, posterior labral tear, pectoralis major strain, latissimus strain, and scapular stress fracture. Elbow injuries included ulnar collateral ligament injury, flexor/pronator strain or tendinitis, synovitis/inflammation, loose bodies, ulnar neuritis, olecranon bursitis, and olecranon stress fracture (Table 1).

Associations between strength variables and the ordinal outcome scale were generally weaker than with a binary outcome scale. Thus, we analyzed the association between each strength variable and no injury versus injury requiring surgery, as well as each strength variable and no injury versus injury. As seen in the graphical depiction, there was strong evidence for an association between PER strength ($P = .003$), SER strength ($P = .048$), and SS strength ($P = .006$) and throwing-related injury requiring surgical intervention (Figure 4). There was also some evidence of an association between the ratio of PER/IR and likelihood of any throwing-related injury, that is, those categorized as either 1 or 2 on the ordinal scale ($P = .051$). As seen in Table 2, the estimated likelihood of injury requiring surgery decreased significantly between those players at the 5th and 95th percentiles for PER, SER, and SS strength. Similarly, those players with a PER/IR ratio at the 5th percentile had an estimated 39% likelihood of injury as compared with 17.5% in those at the 95th percentile. No significant association existed between preseason IR strength and injury requiring surgical intervention. Likewise, no significant association was noted between any of the preseason strength measurements individually and overall likelihood of injury.

The subset analysis of shoulder injuries revealed significant associations between PER strength ($P = .05$) and SS strength ($P = .038$) and shoulder injury requiring surgical intervention. There were also significant associations between SS strength ($P = .031$) as well as the ratio of PER/IR ($P = .037$) and the likelihood of any shoulder injury. There was no significant association between SER or IR strength and shoulder injury requiring surgical intervention. Likewise, there were no significant associations between individual measurements of PER, IR, or SER strength and the likelihood of any shoulder injury.

The strength data of those who had previously undergone surgery (n = 26) were also analyzed. When looked at separately, there were no significant associations between any strength measurements and overall injury, injury requiring surgery, shoulder injury, or shoulder injury requiring surgery. When these players' data were removed from the overall group, however, the associations between PER, SER, and SS strength and likelihood of injury requiring surgery remained significant.

DISCUSSION

Injury to a professional athlete can result in loss of income and decreased career length. Baseball pitchers are particularly susceptible to injuries due to the repetitive, demanding nature of the overhead throwing motion. Injuries to the shoulder and elbow of these athletes are common, as tremendous energy is transferred from the lower extremities and trunk to the upper extremity during the throwing

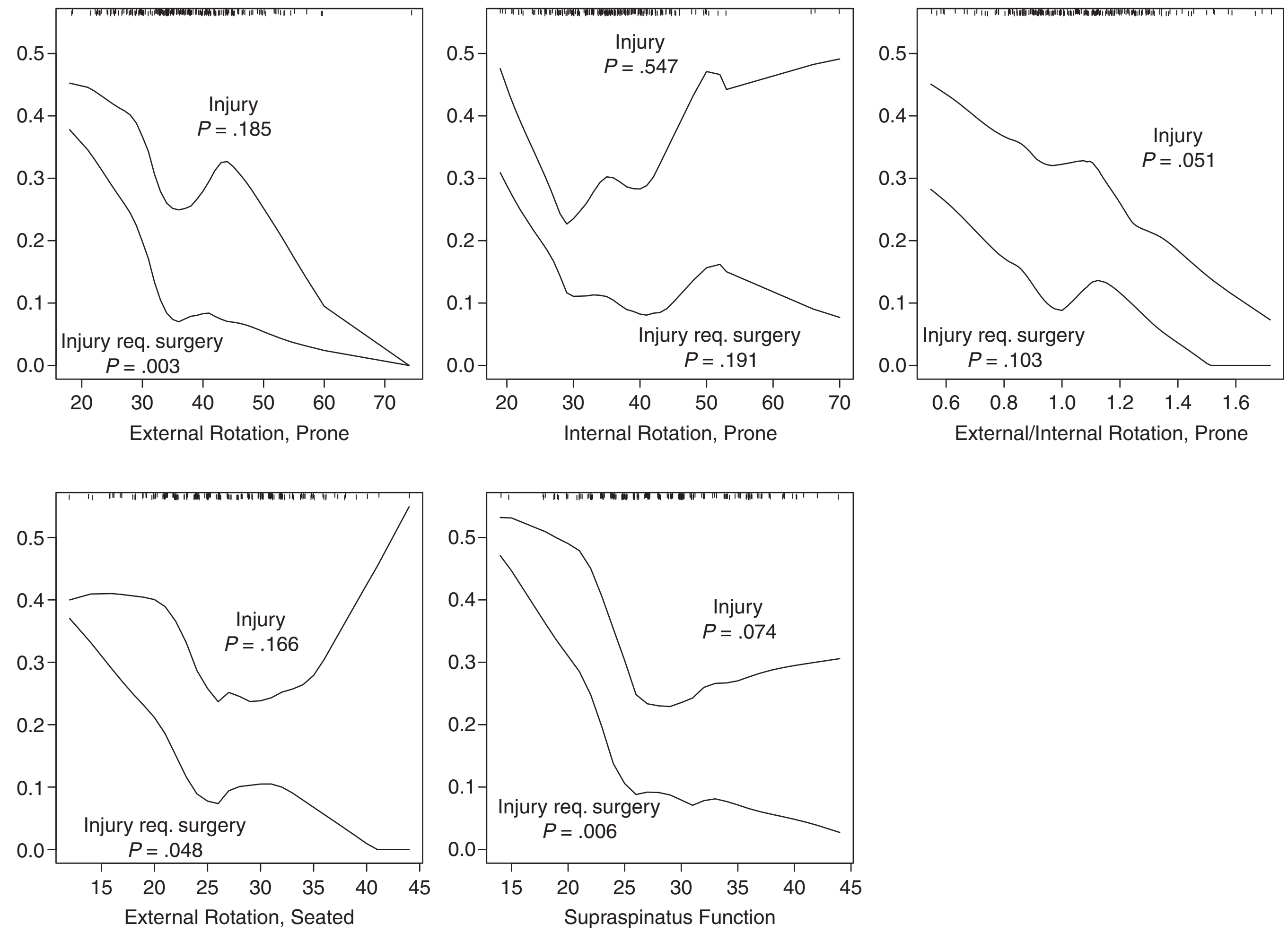

Figure 4. Y-axis = likelihood of injury or injury requiring surgery; X-axis = strength measurement in kilograms (prone external rotation [PER]/internal rotation [IR] ratio in graph 3). Tick marks above each graph represent the distribution of raw values of the x-axis variable in the sample.

TABLE 2
Association Between Strength and Injury Variables[a]

	Strength Variable		Estimated Likelihood of Injury		Estimated Likelihood of Injury Requiring Surgery	
	5th Percentile	95th Percentile	5th Percentile	95th Percentile	5th Percentile	95th Percentile
PER	23.3 kg	52 kg	.432	.221	.313[b]	.046[b]
SER	18 kg	36 kg	.406	.305	.249[b]	.056[b]
IR	24 kg	48 kg	.344	.433	.217	.136
SS	19.25 kg	38.75 kg	.497	.291	.328[b]	.053[b]
PER/IR	.724	1.42	.390	.175	.205	.029

[a]PER, prone external rotation; SER, seated external rotation; IR, internal rotation; SS, supraspinatus.
[b]Association statistically significant at $P \leq .05$.

motion.[9,15,20,27,33] Inherently unstable due to the large size of the humeral head and relatively small glenoid fossa, the glenohumeral joint relies on the dynamic stabilization provided by the rotator cuff and surrounding shoulder musculature.[30] Critical points of maximal stress to the shoulder joint during throwing motion have been identified as late cocking and arm deceleration.[9,15,20] Electromyography analysis of the throwing arm has shown deceleration to be the most vigorous phase of rotator cuff muscle activation, and such forces place significant stress on the surrounding soft tissues of the shoulder.[14] By eccentrically contracting during arm deceleration, the primary role of the external rotators in the pitching motion is to dissipate the kinetic energy created by the concentric contraction of the internal rotators during late cocking and acceleration.[6,9,14,26,35] Investigators have proposed that it is during this eccentric overload that the posterior shoulder muscles are at risk for injury, as they work to resist glenohumeral distraction and horizontal adduction of the arm.[7,9,33] It has been postulated that repetitive eccentric overloading may result in a cycle of intramuscular connective tissue tearing, inflammation, and weakness.[12,20,30] Weakness or poor coordination of the external rotators can also lead to a lack of muscular control during late cocking and deceleration, which may in turn predispose pitchers to shoulder injury.[11,18] Poor coordination between internal and external rotator cuff muscle activation has been linked to pain during the throwing motion.[11] On the basis of these assumptions, we hypothesized that pitchers with weaker external rotators would be the most at risk for injury due to loss of control during the deceleration phase of the throwing motion.

Given the role of external rotators in arm deceleration, an examination of their strength in relation to the internal rotators of the arm is essential in understanding the stresses incurred on the posterior musculature during pitching. It has been theorized that an imbalance between overstrengthened internal rotators and weakened external rotators causes damage to shoulder muscle and connective tissues.[26,33,34] Strength testing has shown that internal rotators of the shoulder are subjected to high performance demand during the pitching motion.[10,23] Unlike the eccentrically acting external rotators, the internal rotators of the humerus undergo plyometric strengthening during the throwing motion—stretching during late cocking and concentrically contracting during acceleration.[12,34] Without a concurrent increase in external rotation strength, this relative increase in internal rotation strength creates an imbalance of the rotator cuff in pitchers.[8,26] Many investigators have studied the ratios of external rotation to internal rotation forces generated by pitchers at multiple levels of competition.[‡‡] When comparing external rotator to internal rotator strength among throwers, many have shown internal rotator strength to be significantly greater. External to internal rotation strength ratios in the pitching arm have varied among studies, but the majority have found the ratio to range from approximately 0.60 to 0.80.[§§] This ratio has been attributed to the relatively large size of the latissimus dorsi and pectoralis major, as well as the adaptive plyometric strengthening of the internal rotators seen in overhead athletes.[2,12,34]

Similar to our data, however, other investigators have found higher ratios of external to internal rotation strength.[7,18,26,29,30] Donatelli et al[7] reported external to internal rotation strength ratios of 0.83 to 0.99 in professional baseball pitchers with the arm at 90° of glenohumeral abduction. While Magnusson et al[18] did not report a ratio, examination of their mean data reveals an external to internal rotation strength ratio of approximately 0.92 in professional baseball pitchers. Sirota et al[30] found concentric strength ratios to be 0.85 to 0.98 in professional pitchers, attributing the higher ratio to the increased age and experience of their cohort. Both Scoville et al[29] and Noffal[26] also reported higher ratios (1.08 and 1.17, respectively), measuring eccentric external rotation strength in comparison with concentric internal rotation strength. In our analysis, we found the median ratio of PER to IR strength to be 1.05, with 25th and 75th percentiles of 0.91 and 1.19, respectively. These findings are comparable with those of Magnusson et al,[18] whose similar data collection protocol also employed the hand-held dynamometer. It has been shown that eccentric muscle strength is greater than concentric muscle strength in the rotator cuff.[21,26,29,30] However, studies have also demonstrated no difference in eccentric and concentric fatigue resistance in the shoulder.[22] In addition, others have shown higher test-retest reliability of isometric and concentric muscle testing in the shoulder as compared to eccentric muscle testing in the shoulder.[19,31] Therefore, despite the fact that external rotators function primarily in an eccentric manner during the deceleration phase of pitching, we believe that the isometric strength measurements are still valuable data for assessing external rotator strength.

Conflicting data also exist in the literature comparing external to internal rotation strength ratios in dominant versus nondominant arms. Such a comparison allows for an internal control with each athlete providing valuable information regarding adaptive changes in the pitching arm. Several authors have reported no difference between the ratio of PER/IR strength in dominant and nondominant arms of throwers.[1,2,21,24,30] Among those analyzing strength ratios in professional baseball pitchers, only Brown et al[2] and Sirota et al[30] found no difference between dominant and nondominant arms. On the contrary, the majority of investigators have demonstrated a significantly lower external to internal rotation strength ratios in the dominant arm compared with the nondominant arm of pitchers at multiple skill levels.[5,7,8,12,23,26,33,35] These data seem to point toward an adaptive mechanism, resulting in weaker dominant arm external rotation strength in pitchers. These results make our findings clinically relevant, as those with weaker external rotators had a higher incidence of injury requiring surgery.

Supraspinatus weakness has also been described in the professional baseball pitcher. Both Magnusson et al[18] and Mullaney et al[23] reported significantly weaker supraspinatus on the dominant side as compared with the nondominant arm of professional pitchers. Magnusson et al[18] also demonstrated weaker supraspinatus strength in professional pitchers as compared with age-matched controls. Despite reporting that injury history had no effect on shoulder strength, their analysis did show relative dominant-sided supraspinatus weakness in those pitchers who reported a prior injury requiring surgical intervention.[18] While multiple authors have examined risk factors for injury in baseball pitchers, to our knowledge, only Magnusson et al[18] have attempted to show a relationship between shoulder weakness and injury in the professional baseball pitcher.[27,33]

‡‡References 1, 2, 5, 7, 8, 12, 21, 23, 24, 26, 29, 30, 33, 35.

§§References 1, 2, 5, 8, 12, 21, 23, 24, 33, 35.

In our study, we did not collect strength data from the nondominant arm of pitchers; thus, we are unable to comment on side-to-side differences in strength ratios. However, we have shown a statistically significant association between preseason external rotation weakness and throwing-related injury requiring surgical intervention. This association was significant for both PER, with the scapula free ($P = .003$), and SER, with the scapula fixed against the wall ($P = .048$). Given the magnitude of data in the literature describing relative external rotation weakness in pitchers, this association with injury requiring surgery is clinically significant. We also noted a statistically significant association between preseason SS weakness and incidence of throwing-related injury requiring surgical intervention ($P = .006$), shoulder injury requiring surgical intervention ($P = .038$), and overall shoulder injury ($P = .031$). Again, while previous investigators have shown supraspinatus weakness in pitchers, its association with injury has significant implications for preseason strength training.[18,23] In addition, some evidence was seen for an association between the ratio of external to internal rotation strength and the overall likelihood of throwing-related injury in a given season ($P = .051$). When looking at shoulder injuries separately, a stronger association existed between the PER/IR strength ratio and overall shoulder injury ($P = .037$). The ratio allows for an internal control for each pitcher rather than relying on absolute values of external rotation strength as a guide for preseason weight training. Trakis et al[33] have shown that relative supraspinatus weakness and internal rotation overstrengthening is associated with pain in adolescent pitchers, but our data allow for application of these principles to the professional baseball pitcher.

Because of the role of the external rotators of the shoulder in arm deceleration, evaluation of their strength in relation to internal rotators is essential for injury prevention and rehabilitation.[13,14,26,36] An appropriate balance between the agonist internal rotators and antagonist external rotators helps provide stabilization to the shoulder; thus, investigators have proposed training programs focused on strengthening the relatively weak external rotators and supraspinatus.[25,35,36] Wilk et al[36] have established the "Thrower's Ten Program" to maximize activation of the posterior shoulder musculature. For pitchers with posterior rotator cuff tendinitis, they have suggested a minimum appropriate external to internal rotator strength ratio of 64% before return to pitching. Other investigators have also seen success in restoring rotator cuff imbalance via specialized preseason strength training focused on posterior shoulder musculature.[25]

While our data have shown an association between external rotation weakness, supraspinatus weakness, and cuff imbalance and injuries, there are limitations to this study. Overuse injuries to the pitcher have been associated with a number of factors, including pitch count, higher velocity, glenohumeral internal rotation deficit (GIRD), and frequency of pitching activity.[27] In our analysis, we did not classify injuries as traumatic or subacute in onset. This subclassification would be helpful, as strength may influence the subacute injuries more than acute, traumatic injuries. Investigators have also associated pitching mechanics and pitch type with risk of shoulder and elbow injury in adolescent baseball pitchers.[16] Quite a bit of variability exists among the number of pitches thrown by professional baseball pitchers, and this variability has not been accounted for in the present study. Our method of collecting external rotation strength in an isometric manner is also a limitation of the testing protocol. Shoulder external rotators function primarily in an eccentric manner during the deceleration phase of the throwing motion.[6,9,14,26,35] Therefore, it may have been more clinically relevant to measure the strength of these muscles in an eccentric manner.

Another limitation of the current study is the ordinal scale used to identify throwing-related injury. Based on the model created by Magnusson et al,[18] we placed injury incidence into 1 of 3 categories based on the treatment modality. This scale may not be clinically precise, however, as injuries treated conservatively may be equally as deleterious as those treated surgically. Grouping different anatomical injuries may also cloud the association between strength measurements and injury by introducing more possible confounding factors. However, by performing a subset analysis of shoulder injuries, we have attempted to minimize the limitations of this injury scale. Previous studies examining shoulder strength in pitchers were conducted with healthy pitchers. In our data set, we did not eliminate those with prior injury from analysis. Instead, we chose to simply create a new data point for each player/season regardless of prior injury. When those players with prior shoulder injury were removed from the analysis, however, the associations between weakness and injury requiring surgery remained. As seen by the lack of association between weakness and injury in players who had previously undergone surgery, however, prior surgery precludes predictive value of these strength measurements. Several players had multiple player/season data points if they continued to play for the same professional baseball club. Using multiple data points from certain players could allow for increased effect of outliers. Finally, lower extremity and core strength plays a role in generating force in the throwing motion as well as decelerating the upper body during pitching.[15,23] We did not assess lower body strength in the current study, potentially missing another risk factor for injury in pitchers.

The shoulder and elbow are subjected to significant stresses during the pitching motion, resulting in a number of injuries to professional baseball pitchers. Investigators have postulated that relative external rotation weakness and supraspinatus weakness may be associated with injury; however, to our knowledge, none has shown such a relationship. We have demonstrated a significant association between shoulder external rotator and supraspinatus weakness and injury requiring surgical intervention. We also noted that the ratio of external to internal rotator strength was associated with any shoulder injury and trended toward association with overall incidence of injury. When analyzed separately, these associations were not present in players who had previously undergone shoulder or elbow surgery. Given the high prevalence of throwing-related injuries among professional pitchers, we believe that this association is clinically significant. These findings may be helpful in preventing future injuries by focusing preseason and intraseason strength training on the posterior rotator cuff and supraspinatus, especially in players found to be weaker in these areas.

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