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Glenohumeral Findings on Magnetic Resonance Imaging Correlate With Innings Pitched in Asymptomatic Pitchers

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Background: In recent years, there has been a documented increase in the number of professional baseball players on the disabled list and the total number of days on the disabled list. Pitchers account for the largest number of disabled list reports.

Purpose: To examine the relationship between magnetic resonance imaging (MRI) findings in asymptomatic professional pitchers and subsequent time on the disabled list (DL).

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

Methods: A total of 21 asymptomatic professional pitchers from a single Major League Baseball (MLB) organization underwent preseason MRIs of their dominant shoulder from 2001 to 2010. Asymptomatic was defined as no related DL stays in the 2 seasons before the MRI. These studies were reevaluated by a fellowship-trained musculoskeletal radiologist who was blinded to patient name, injury history, and baseball history. A second investigator who was blinded to the MRI results collected demographic data, total career number of innings pitched, and any subsequent DL reports for each subject.

Results: The mean age at the time of MRI was 29.04 years (range, 20-39 years). Eleven of 21 pitchers had a rotator cuff tear (RCT): 9 had an articular surface tear (AST), and 2 had a full-thickness rotator cuff tear (FTT). Ten had superior labral anterior posterior (SLAP) tears, and 13 had either anterior or posterior labral tears. There was a statistically significant relationship between the number of innings pitched and presence of an RCT (AST + FTT). The mean number of career innings pitched by those with an RCT was 1014 compared with a mean of 729 innings pitched in pitchers without an RCT ($P < .01$). In addition, the number of career innings pitched was moderately correlated with presence of RCT ($r = 0.46$) and presence of superior and anterior/posterior labral tears ($r = 0.43$). There were no statistically significant findings between any single preseason MRI finding and subsequent time on the DL.

Conclusion: The MRI findings in asymptomatic MLB pitchers do not appear to be related to near future placement on the DL. However, there was a significant difference in numbers of innings pitched between pitchers who had an RCT and those who did not and a moderate correlation between innings pitched and the presence of RCT as well as the presence of labral lesions. This finding supports the notion that RCT and labral injury in pitchers may result from repetitive overhead motion with subsequent strain on the rotator cuff tendons and glenoid labrum. Asymptomatic shoulder lesions in professional baseball pitchers appear to be more frequent than previously thought.

Keywords: rotator cuff; pitcher; professional baseball; MRI

Baseball is America's "national pastime." Across all levels, no other major team sport has as many participants. There are 750 major league players, an estimated 2100 minor league players, 45,000 collegiate players, more than 400,000 high school players, and more than 2 million players in youth leagues across the United States. Baseball accounts for approximately 50,000 injuries per year across all age and ability levels. Rate of injury per 100 players per year is as low as 2 in Little League and as high as 58 in the major leagues.[3]

In 2001, Conte et al[3] documented an increase in the number of Major League Baseball (MLB) players on the disabled list (DL) as well as an increase in the total number of DL days over a 10-year span from 1989 to 1999. When evaluated by number of days per injury per player, the DL stays remained consistent during that time. This study further found that pitchers accounted for the largest number of DL stays at 48.4% and that the majority of these stays were related to a shoulder injury (27.8%).

At the professional level, a shoulder injury that requires being placed on the DL has a significant effect on the athlete and the athlete's contribution to the club's success. This is particularly true with pitchers, since they play such a prominent role in the game of baseball, similar to a quarterback in American football. Previous investigations have

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demonstrated the stress that repetitive overhead throwing imposes on the shoulder.[6] The forces of elite throwers approach the fatigue strength of the soft tissues of the shoulder. At ball velocities of 90 mph, the angular velocity of the shoulder approaches 7000 deg/s and the distractive force of the shoulder nears 950 N.[5] Because pitchers perform more repetitive high-velocity throws than any other players on the field, they are most susceptible to injuries common to throwing, such as rotator cuff and labral injuries.[3]

The ability to predict which pitchers are more likely to sustain an injury necessitating a DL stay would provide valuable information to the team medical staffs, players, and management. Magnetic resonance imaging (MRI) has been shown to be both sensitive and specific to rotator cuff and glenohumeral labral injury.[4,8,14] The purpose of this investigation is to analyze the relationship between the total innings pitched and any MRI findings of asymptomatic professional pitchers. A second purpose is to identify whether any of these preseason MRI findings predicted a subsequent throwing-related shoulder injury that required a stay on the DL. Our hypotheses were that (1) total number of innings pitched would correlate with the presence of rotator cuff tears (RCTs) and labral lesions, and (2) findings of RCTs and labral tears would be predictive of placement on the DL the following season for a throwing-related shoulder injury.

MATERIALS AND METHODS

Before initiation of the investigation, approval was obtained from the institutional review board. From 2001 to 2010, 21 professional pitchers from a single professional baseball organization had an MRI of their throwing shoulders in the off-season. The MRIs were performed on an asymptomatic shoulder at the time of a contract signing or a trade as a condition of the trade or signing. For the purposes of this investigation, asymptomatic was defined as no stay on the DL for the dominant shoulder in the prior 2 years and no shoulder complaints at the time of the MRI. The MRIs were performed at 4 different centers, and all were performed with a closed 1.5-T magnet. One of the 21 MRIs was an MR arthrogram (1.5-T) and was performed with a contrast agent. All 21 MRIs were reviewed by a fellowship-trained musculoskeletal radiologist who was blinded to the original MRI interpretation and the subject's identity, injury status, and innings pitched. Particular attention was paid to the rotator cuff and the glenoid labrum. Specifically for the labral tears, each MRI was evaluated for the presence of a superior labral tear (10 o'clock to 2 o'clock), anterior labral tear (2 o'clock to 6 o'clock in a right shoulder), and posterior labral tear (10 o'clock to 6 o'clock). Each labral tear was documented separately, meaning that if a patient had a superior labral tear and an anterior labral tear, it was documented as 2 distinct tears. Each MRI was analyzed and the results were recorded. Each MLB pitcher's pitching history was then recorded for his total professional and collegiate career up to and including the season following the MRI. The total number of innings pitched was calculated, combining all collegiate, minor league, and major league innings. Any shoulder injury that required a stay on the DL throughout the season following the MRI was recorded from the subjects' records. Statistical analysis was performed with SPSS version 20 (SPSS Inc, Chicago, Illinois). To examine any difference between total career innings pitched and the presence of a particular MRI finding as well as between MRI findings and subsequent DL stay, the Mann-Whitney U test was used with statistical significance set at $P < .05$. Pearson correlation coefficient was used to determine any correlation between innings pitched and glenohumeral lesions, with statistical significance set at $P < .05$.

RESULTS

Twenty-one MRIs were examined that fit the inclusion criteria of being obtained on an asymptomatic shoulder at the time of the MRI for a player who had not been on the DL in the 2 years before the MRI. At the time of the MRI, the average age was 29.04 years (range, 20-39 years). There were 17 right-handed pitchers and 4 left-handed. The mean total number of innings pitched at the time of the MRI was 760.6 (range, 169-3083 innings). Of the 21 pitchers, 18 were at the major league level and 3 were in related minor league teams (2 pitchers in triple-A and 1 in single-A). Five of 21 pitchers sustained an injury that required a stay on the DL in the season following the MRI. Of those 5 pitchers, 4 spent 15 days on the DL and 1 spent 60 days on the DL for "shoulder inflammation." None had a surgical procedure performed resultant from the injury. The pitcher who was placed on the 60-day DL had a repeat MRI. His initial MRI demonstrated a superior labral anterior posterior (SLAP) tear and cuff tendinosis, and his repeat image showed an interval increase in tendinosis and an articular surface rotator cuff tear. He elected to be treated nonoperatively.

Twenty of 21 pitchers had rotator cuff tendinosis. Among the 20 pitchers with tendinosis, 11 had evidence of an RCT, 2 full-thickness rotator cuff tears (FTTs), and 9 articular surface rotator cuff tears (ASTs). There were 10 SLAP tears, and 13 pitchers had either anterior or

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TABLE 1
Age and Total Innings by Disabled List (DL) Status

		Age[a]		Total Innings[a]	
DL Status	Subjects	Median	Range	Median	Range
No	16	32	20-39	871.5	169-3083
Yes	5	27	23-34	990.0	412-1180

[a]$P > .05$; Mann-Whitney U test.

TABLE 2
Presence of MRI Findings by DL Status[a]

DL Status	Rotator Cuff Tear (n = 11)	SLAP Tear (n = 10)	Labral Tear (n = 13)
No	9	7	11
Yes	2	3	2

[a]MRI, magnetic resonance imaging; DL, disabled list; SLAP, superior labral anterior posterior.

posterior labral tears; additionally, 5 pitchers had both superior and anterior or posterior labral lesions.

The median age of the subjects who required a DL stay after the MRI was 27 years, compared with 32 years for those who did not. The median number of innings pitched was 990 for those who had a DL stay compared with 871.5 for those who did not. Neither of these were statistically significant (Table 1). Nine of the 11 subjects who had RCTs, 7 of 10 with SLAP tears, and 11 of 13 with labral (non-SLAP) tears did not require a stay on the DL. There was no statistically significant relationship between the presence of any findings on MRI and a subsequent stay on the DL (Table 2).

When the relationship between total innings pitched and findings on MRI was evaluated, there was a statistically significant difference between the total career innings pitched between the subjects who had a rotator cuff tear (1014 innings) and those who did not have a cuff tear (729) ($P = .043$). However, there was no statistical difference in the median number of innings pitched between pitchers who had SLAP tears (996 innings) and those without SLAP tears (840 innings) ($P = .55$). Similarly, the presence of labral tears (anterior or posterior) was not related to the total number of innings pitched (884 innings with and 874 innings without injury) ($P = .37$) (Table 3).

Pearson correlation coefficient between the presence of a rotator cuff tear and the total number of career innings pitched was $r = 0.46$ ($P = .02$). Similarly, the correlation coefficient for pitchers with both a SLAP tear and a tear of either the posterior or anterior labrum was $r = 0.43$ ($P = .03$). The correlation coefficient between the presence of a SLAP tear and innings pitched was $r = 0.21$ ($P = .19$) and between the presence of an anterior or posterior labral tear was $r = 0.31$ ($P = .09$). Finally, the correlation coefficient between innings pitched and any labral lesion (superior or anterior or posterior) was $r = 0.22$ ($P = .17$) (Table 4).

TABLE 3
MRI Findings by Total Innings Pitched[a]

	Innings Pitched, Median (Range)
Rotator Cuff Tear[b]	
Yes	1014 (412-1180)
No	729 (169-3083)
SLAP Tear[c]	
Yes	996 (169-3083)
No	840 (412-2984)
Labral Tear[c]	
Yes	884 (412-3083)
No	874 (169-2984)

[a]MRI, magnetic resonance imaging; SLAP, superior labral anterior posterior.
[b]$P < .05$; Mann-Whitney U test.
[c]$P > .05$; Mann-Whitney U test.

TABLE 4
Correlation of Total Innings Pitched to MRI Findings[a]

	Correlation With Innings Pitched[b]	
MRI Findings	r	P Value
Rotator cuff tear	0.46	.02
SLAP tear	0.21	.19
Labral tear	0.31	.09
SLAP *and* labral tear	0.43	.03
SLAP *or* labral tear	0.22	.17

[a]MRI, magnetic resonance imaging; SLAP, superior labral anterior posterior.
[b]Pearson correlation coefficient.

DISCUSSION

Injury to an MLB pitcher can result in significant loss of income to the athlete and can cause a cascade of events for his baseball organization. Baseball pitchers, because they perform repetitive high-velocity throwing motions, are particularly susceptible to shoulder injuries. Shoulder injuries in MLB pitchers have been demonstrated to be the most common cause of DL days during the baseball season.[3] The glenohumeral joint, unlike the hip joint, does not rely heavily on the related bony structure for stability.[15,19] Rather, the stability of the shoulder is derived from the dynamic stabilization afforded by surrounding soft tissue structures, including the rotator cuff, periscapular musculature, the glenoid labrum, and the glenohumeral ligaments.[1,11,12,19,20,22]

Tears of the rotator cuff associated with throwing are most likely caused by a tensile overload and repetitive traction injury. The adaptive increased external rotation of the pitcher's throwing shoulder allows for hyperexternal rotation of the glenohumeral joint. This results in repetitive twisting and internal impingement of the rotator cuff fibers. In the maximally abducted and externally rotated position seen in the late cocking phase of throwing, the

greatest stress is located at the articular insertion of the cuff tendons on the humeral head. Following ball release, the deceleration phase of throwing is the most violent phase of pitching.[6,13,15] During deceleration, the rotator cuff, specifically the external rotators, fires eccentrically to dissipate the kinetic energy created by the internal rotators during acceleration.[9,10,18,23] It is the repetitive, eccentric loading of the rotator cuff that is postulated to put the rotator cuff at risk for injury, because the cuff prevents glenohumeral distraction.[6,7,15]

The theory of repetitive loading of the rotator cuff leading to injury was the basis of our hypothesis that the total number of innings pitched would be related to the presence of glenohumeral, and more specifically rotator cuff, injury in asymptomatic shoulders. This hypothesis was supported by the data in this investigation, as it appears that pitchers who had at least a partial rotator cuff tear pitched more than 800 innings, whereas pitchers who did not have rotator cuff lesions pitched fewer than 800. Further, a moderate correlation of 0.46 was determined between innings pitched and rotator cuff tears. This allows us to conclude there is a relationship between innings pitched and the presence of rotator cuff injury. In addition, the presence of both a SLAP tear and either an anterior or a posterior labral tear demonstrated a moderate correlation to total innings pitched (0.43). This also supports the notion that repetitive overhead throwing puts intra-articular structures at risk. Although there was no statistical difference between the 2 groups (pitchers who had SLAP and either anterior or posterior labral tears) in terms of total innings pitched, the Pearson correlation demonstrated a moderately positive relationship between innings pitched and the presence of a SLAP and anterior or posterior labral tear. This supports the notion that repetitive pitching places glenohumeral structures at risk. Furthermore, the presence of superior labral tears alone did not correlate with innings pitched in this investigation, but a combined labral injury did. This is perhaps due to a progressive tearing of the labrum over time after an initial superior labral tear.

Our second hypothesis, which was that these MRI findings would be predictive of shoulder injury that required a stay on the DL, was not supported by our data. There was no MRI finding in this sample population that was predictive of a DL stay. An interesting trend, albeit not statistically significant, is that the pitchers who had a DL stay were younger (27 years) than those who did not (32 years). Conversely, innings pitched for those who went on the DL was higher (990) than for those who did not (871.5). This may further demonstrate that injuries requiring a DL stay are more a reflection of repetitive throwing rather than purely age-related wear of the rotator cuff in this population.

Applying these data as a whole, one can conclude that a short-term contract for an asymptomatic professional baseball pitcher is reasonable as MRI findings do not indicate an immediate future risk. However, this study does not allow for conclusions to be made about contracts beyond 1 year in the asymptomatic pitcher with rotator cuff or labral findings on an MRI.

Previous MRI studies of asymptomatic shoulders have demonstrated rotator cuff injury, including partial- and full-thickness tears.[21] Sher et al[21] found that 34% of the 96 MRIs they obtained in a normal population had rotator cuff partial or full-thickness tears. When the group was broken down by age, however, the investigators noted that in the group aged 19 to 39 years, only 1 of 25 MRIs revealed a significant finding. This is significantly lower than the current study's finding of 11 of 21 MRIs with a cuff tear in a similar age group. This suggests that professional baseball pitchers are at higher risk for asymptomatic cuff findings on MRI than is the average population. Miniaci et al[16] evaluated healthy volunteers (average age 29 years) by MRI of the shoulder and found that 36% had partial-thickness tears and none had full-thickness tears. Of the 20 volunteers, 14 were recreational athletes and none were professional. That study demonstrated a lower percentage of rotator cuff tears in comparison with our group of professional overhead pitchers, of whom 52% demonstrated a rotator cuff tear.

Miniaci et al[17] also examined asymptomatic professional pitchers with an MRI of the throwing and nonthrowing shoulders. The average age of the subjects was 20.1 years. The authors found that 3 of 14 throwing shoulders (21%) had a partial tear of either the supraspinatus or the infraspinatus tendon. They further found that 45% of the throwing shoulders had labral tears and 36% had posterior humeral head cysts. The current study found superior labral tears in 48% of the shoulders and anterior or posterior labral tears in 62%. Similarly, the current study found a higher percentage of humeral head cysts on MRI: 16 of 21 shoulders (76%). A clear difference in the 2 patient populations exists between the 2 studies. The average age of our subjects is 8 years older, so they likely had more pitching experience. Miniaci et al did not quantify the years of professional pitching or total innings pitched to make a direct comparison. However, given the average age difference, it is reasonable to assume that the number of throws or innings would be less than in our group. However, when we look at both studies, it is reasonable to conclude that MRI changes occur earlier in pitchers than in the general population and can progress throughout a pitcher's professional career. Further, the current study found a significant difference between the median number of innings pitched in those who had a cuff tear and those who did not as well as a moderate correlation between innings pitched and rotator cuff and labral lesion, supporting the theory that repetitive overhead throwing places the rotator cuff at risk.

Connor et al[2] studied the MRIs of 20 overhead collegiate athletes, including 12 pitchers, and then conducted a follow-up survey 5 years after the MRIs were performed. The average age at survey was 26.4 years. This study found that 8 of 20 athletes (40%) had partial or full-thickness tear of the rotator cuff on the dominant side compared with 0 of 20 on the nondominant side. At the 5-year follow-up, no athletes reported any shoulder symptoms or sought care with regard to their shoulders over the 5-year period. Although the investigation by Connor et al supports our findings that rotator cuff pathologic changes are common in the overhead athlete, it is difficult to compare this study directly with the current study because

the results were not broken down to pitchers specifically. However, both studies found no relationship between MRI findings and future shoulder complaints.

To the authors' knowledge, only 1 study has examined the number of innings pitched in relation to radiographic findings. Wright et al[24] evaluated plain radiographic findings of the shoulder and elbow of 57 asymptomatic professional pitchers and correlated the findings with the total number of innings pitched. There was a positive correlation between radiographic findings and innings pitched, with a Pearson correlation coefficient of 0.46. Similar to the current study's results, there was no significant association between radiographic findings and future placement on the DL.

There are some limitations to this study. First, this is a retrospective study and therefore has the limitations that are inherent to a retrospective review. The MRIs used in this investigation were not done with a standardized protocol because the imaging studies were performed at multiple locations. The imaging studies consisted of 1 arthrogram and 20 MRIs without contrast. As the literature shows, arthrograms are more sensitive and specific than plain MRIs to identify rotator cuff and labral injury. However, we thought that the arthrogram should be included so we could completely discuss the sample group.

In addition, we used DL stays as an indicator for shoulder injury in our subjects. However, injuries or maladies can occur that do not necessitate a 15-day rest but do require a missed start or missed outing by a pitcher. Thus, it is likely that the total number of injuries or amount of missed work for these subjects is underreported in our data. A prospective study that evaluates every pitcher and maintains a database of any subsequent shoulder complaint and missed game in addition to a DL list stay is warranted to further evaluate the relationship between MRI findings and future injury. In addition, our data only included injuries that occurred in the season following the MRI. A long-term follow-up of the pitchers with and without rotator cuff tears may provide further information regarding injury risk.

This investigation found that there was a difference in rotator cuff lesions based on innings pitched and suggested a landmark of 800 innings. However, this could be overstated given our small sample size of 21 pitchers. It should be noted that no other MRI finding had a similar innings cut-off. In addition, with a larger sample size, the trend of innings pitched rather than pitcher age may prove to be statistically significant. Further, we did not examine any of the pitchers' performances after the MRI to evaluate whether their ability to be a productive player was affected. However, this is the first study to demonstrate a relationship between rotator cuff or labral pathologic abnormalities and the number of innings pitched at an elite level.

The major league baseball pitcher's shoulder is subjected to significant repetitive stress. The current literature and the results of this study indicate that attritional changes to the rotator cuff and other glenohumeral structures, as detected by MRI, occur more frequently in professional throwers than in the general population. In addition, these imaging abnormalities can remain asymptomatic despite the continual violent overhead throwing motion. The current study has found a correlation between the total number of innings pitched and rotator cuff lesions, where 800 total innings is an apparent threshold, which has not been previously demonstrated. Further, there was a moderate positive correlation between the total innings pitched and rotator cuff and labral tears that involve both the superior labrum and either the anterior or posterior labrum. The current study also demonstrated that the rate of labral tears and rotator cuff tears is higher than previously reported in major league baseball pitchers. However, despite the presence of specific rotator cuff, labral, or osseous abnormalities on MRI, there is no relationship to future disability severe enough to require a stay on the DL in the year following the MRI. It is important to recognize the high rate of asymptomatic findings on MRI in this patient population when evaluating an elite pitcher with a shoulder complaint. Clinical correlation and a meticulous physical examination are essential in this population to avoid proceeding with treatment of an injury based on a false-positive MRI result.

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