

## [ Orthopaedic Surgery ]



# Return to Sport Following Shoulder Surgery in the Elite Pitcher: A Systematic Review

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**Context:** The ability to return to elite pitching, performance, and clinical outcomes of shoulder surgery in elite baseball pitchers are not definitively established.

**Objective:** To determine (1) the rate of return to sport (RTS) in elite pitchers following shoulder surgery, (2) postoperative clinical outcomes upon RTS, and (3) performance upon RTS and to compare RTS rates in different types of shoulder surgery.

**Data Sources:** Using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and checklist, Medline, SciVerse Scopus, SportDiscus, and Cochrane Central Register of Controlled Trials were searched.

**Study Selection:** Levels I-IV evidence were eligible for inclusion if performance-based (eg, RTS) and/or clinical outcome-based reporting of outcomes were reported following surgical treatment of shoulder pathology in elite pitchers (major or minor league or collegiate).

**Data Extraction:** Subject, shoulder, and pre- and postoperative performance-based variables of interest were extracted. All shoulder surgery types were potentially inclusive (eg, open, arthroscopic, rotator cuff, labrum, biceps, acromioclavicular joint, fracture). Study methodological quality was analyzed using the Modified Coleman Methodology Score (MCMS).

**Results:** Six studies were analyzed (287 elite male pitchers [mean age, 27 years] who underwent shoulder surgery, with 99% on the dominant, throwing shoulder). MCMS was 38 (poor). Most pitchers were professional, with a mean career length of 6.58 years and postoperative clinical follow-up of 3.62 years. In 5 of 6 studies, multiple diagnoses were addressed concomitantly at surgery. Rate of RTS was 68% at mean 12 months following surgery. Twenty-two percent of Major League Baseball (MLB) pitchers never RTS in MLB. Overall performance did improve following surgery; however, this did not improve to pre-injury levels.

**Conclusion:** In this systematic review, the rate of return to elite baseball pitching following surgery was established. Performance tended to decrease prior to surgery and gradually improve postoperatively, though not reaching pre-injury levels of pitching.

**Level of Evidence:** IV (systematic review of studies level I-IV evidence), therapeutic.

**Keywords:** shoulder; surgery; arthroscopy; pitcher; Major League Baseball

The shoulder is an integral part of the kinetic chain in the throwing motion.<sup>22</sup> Elite pitchers throw a baseball in excess of 95 mph, with the generation of over 7250 degrees of motion in internal rotation per second.<sup>13</sup> The kinematics of the throwing motion progresses through several distinct phases, with potential functional and/or

pathologic adjustments occurring at each stage.<sup>23</sup> Although the entire throwing motion takes less than 2 seconds, repetitive microtrauma over the course of a career may lead to several osseous and/or soft tissue adaptations of the thrower's shoulder (Table 1).<sup>4,5,9,12,14,18,25,43,47,49-51</sup> The resultant changes demonstrate significant differences from the general population, baseball

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Table 1. Osseous and soft tissue adaptations of the thrower's shoulder

<ul style="list-style-type: none"> <li>• Internal impingement</li> <li>• Articular-sided rotator cuff tear</li> <li>• Posterosuperior labral tear</li> </ul>	<ul style="list-style-type: none"> <li>• Posterior humeral head impinges on posterosuperior labrum, with articular side of rotator cuff (posterior supraspinatus, anterior infraspinatus) pinched between, in abducted, externally rotated position; excessive “peel-back” mechanism, tensile stress to biceps/superior labrum (posterior SLAP tear)</li> </ul>
<ul style="list-style-type: none"> <li>• Rotator cuff tear</li> </ul>	<ul style="list-style-type: none"> <li>• A second theory for etiology of cuff tear: suprphysiological tensile stress on rotator cuff during deceleration phase</li> </ul>
<ul style="list-style-type: none"> <li>• Glenohumeral internal rotation deficit, anterior laxity, posterior capsule contracture</li> </ul>	<ul style="list-style-type: none"> <li>• Overrotation (external rotation) in late cocking/early acceleration, anterior capsule tensile stress (stretch) with subsequent anterior laxity; posterior capsule (PIGHL) tightening due to repetitive eccentric tensile stress during deceleration with subsequent thickening and contracture</li> </ul>
<ul style="list-style-type: none"> <li>• SICK scapula</li> </ul>	<ul style="list-style-type: none"> <li>• Scapular malpositioning, inferior medial border prominence, coracoid pain and malposition, dyskinesia of scapula</li> </ul>
<ul style="list-style-type: none"> <li>• Increased humeral retrotorsion and increased glenoid retroversion</li> </ul>	<ul style="list-style-type: none"> <li>• Morphologic adaptation during skeletal growth</li> </ul>
<ul style="list-style-type: none"> <li>• Acromioclavicular joint degeneration</li> </ul>	<ul style="list-style-type: none"> <li>• Radiographic findings in asymptomatic pitchers</li> </ul>
<ul style="list-style-type: none"> <li>• Bennett lesion</li> </ul>	<ul style="list-style-type: none"> <li>• Radiographic findings in symptomatic and asymptomatic pitchers</li> </ul>

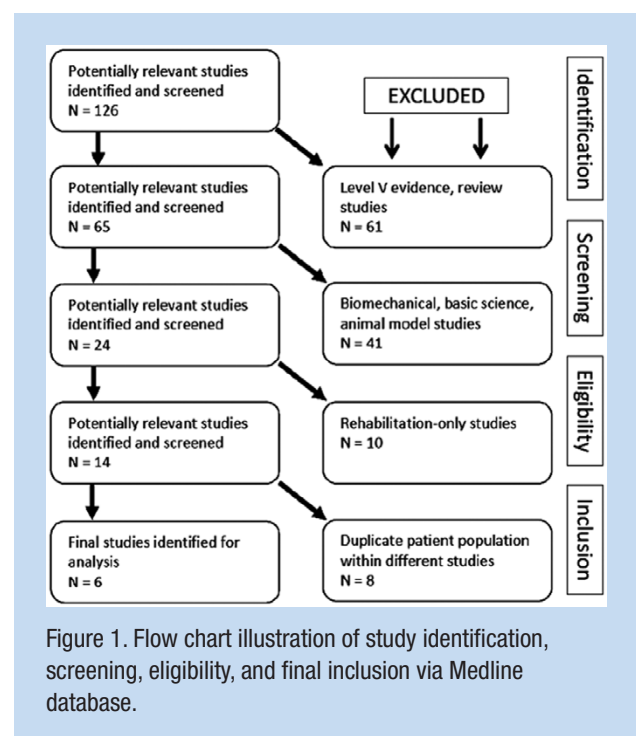
SICK, scapular malposition, inferior medial border prominence, coracoid pain and malposition, scapular dyskinesia; SLAP, superior labrum anterior to posterior; PIGHL, posterior inferior glenohumeral ligament.

position (nonpitcher) players,<sup>8,29</sup> and even the nonthrowing contralateral shoulder of pitchers.<sup>9,29,48,51</sup> The thrower's shoulder is a remarkable example of the balance of stability and motion to generate great velocity and control. Thus, any injury or surgery has the potential to disrupt this delicate and extraordinarily intricate equilibrium, altering the thrower's accuracy, velocity, and/or endurance.

Objective assessment by a physician may demonstrate excellent outcomes following shoulder surgery in pitchers.<sup>2,6,35</sup> However, even minor changes in accuracy, velocity, and endurance are often undetectable by physical examination, clinical outcome score, or imaging study and can dramatically affect the success of a pitcher's career. The primary purpose of this article is to systematically review the entire orthopaedic and sports medicine literature to determine the rate of return to sport (RTS) in elite pitchers following shoulder surgery. Secondary purposes include the determination of postoperative clinical outcomes upon RTS, performance upon RTS, and comparison of RTS rates in different types of shoulder surgery. The authors hypothesize that the rate of RTS following shoulder surgery is low (<75%). Further, the authors hypothesize that postoperative clinical outcomes are excellent, with decreased performance, and without a significant difference in outcome between different types of shoulder surgery.

## METHODS

A systematic review of the available literature was performed with use of PRISMA (Preferred Reporting Items for Systematic



Reviews and Meta-Analyses) guidelines and checklist (Figure 1).<sup>31</sup> Three physicians independently completed the search and agreed on the search criteria. The search was completed on October 1, 2012, using an explicit search algorithm,<sup>a</sup> in the

Table 2. Variables extracted from studies

<i>Thrower</i>	<i>Performance Variables</i>
• Age	• Number of seasons played
• Level of elite pitching	• Innings pitched/season
• Pitching position (eg, starter, reliever)	• Earned run average (ERA)
• Dominant shoulder	• Strikeouts per 9 innings played (K/9)
• Shoulder side (left vs right)	• Walks and hits per innings pitched (WHIP)
• Preoperative duration of symptoms	
• Preoperative duration of nonoperative treatment	
<i>Shoulder Injury</i>	<i>Clinical Outcome Scores</i>
• Rotator cuff	• Kerlan Jobe Orthopaedic Clinic (KJOC) score
• Biceps/labrum	• American Shoulder and Elbow Surgeons (ASES) score
• Instability	• Athletic Shoulder Outcome Rating Score (ASORS)
• Internal impingement	• Short-Form-12; 36 (SF-12, SF-36)
• Pain, undiagnosed	

following databases: Medline (1950-October 1, 2012), SciVerse Scopus (1960-October 1, 2012), SportDiscus (1975-October 1, 2012), and Cochrane Central Register of Controlled Trials (1994-second quarter, 2012). Levels I, II, III, and IV evidence (according to the Oxford Centre for Evidence-Based Medicine used by the American version of the *Journal of Bone and Joint Surgery*<sup>37</sup>) English-language studies were eligible for inclusion in this review. Both print journal and electronically published articles were eligible for inclusion. Medical conference abstracts were not eligible for inclusion. All references within included studies were cross-reference assessed for potential inclusion if missed by the initial search. Duplicate subject publications within separate unique studies were not reported twice. The study with longer duration follow-up, higher level of evidence, or greater number of subjects was retained for inclusion in this event.

The primary outcome measure of interest determining inclusion in this review was a pitcher's rate of RTS (pitching) at the same level as pre-injury. Additionally, rates of RTS (regardless of level), performance upon RTS, and clinical outcome scores were secondary outcomes of interest. Study inclusion criteria were: clinical outcome study reporting results of shoulder surgery in elite pitchers. "Elite" was defined as throwing in at least one Major League Baseball (MLB), minor league (A, AA, or AAA), or collegiate (all divisions, Divisions I, II, and III, NAIA) game. Only English-language studies with a performance-based (eg, return to pitching) and/or clinical outcome-based reporting of outcomes were included.

Subject, shoulder, and pre- and postoperative performance-based variables of interest were extracted from all included studies (Table 2). All shoulder surgery types were potentially inclusive (eg, open, arthroscopic, rotator cuff, labrum, biceps, acromioclavicular joint, fracture). Exclusion criteria were: non-English-language studies, basic science, biomechanical, surgical technique (surgical technique description without clinical outcomes reported), letters to the editor, conference abstract/proceedings, and other systematic reviews/meta-analyses.

Study methodological quality and bias were evaluated using the Modified Coleman Methodology Score (MCMS)<sup>7</sup>. Two separate authors independently reviewed the studies using MCMS. Disagreements were settled via discussion and resolution with the senior author. This study quality checklist has been used in prior orthopaedic and sports medicine research and is applicable to both randomized and nonrandomized controlled trials.<sup>15,16</sup> The MCMS is a 15-item instrument with a scaled potential score ranging from 0 to 100, with scores 85 to 100 (excellent), 70 to 84 (good), 55 to 69 (fair), and less than 55 (poor). Descriptive statistics were calculated for each parameter/variable. Continuous variable data were reported as mean  $\pm$  standard deviation (weighted means where applicable). Categorical data were reported as frequencies with percentages. For all statistical analyses,  $P < 0.05$  was deemed statistically significant. All statistical analyses reported were extracted directly from the studies included and analyzed. Heterogeneity within different outcome measures utilized precluded assimilation of the data and performance of meta-analysis.

## RESULTS

Six studies were analyzed (Table 3).<sup>26,28,34,35,39,40</sup> The MCMS was  $38.2 \pm 3.9$  (poor). There were 287 elite male pitchers (mean age, 27 years) who underwent shoulder surgery, with 99% on the dominant, throwing shoulder. Most pitchers were professional, with a mean career length of 6.58 years, and postoperative clinical follow-up within these studies was 3.62 years. Only 1 study<sup>28</sup> reported the duration of prior symptoms (35 months), duration of prior nonoperative treatment (17 months), and previous surgeries (superior labrum anterior to posterior [SLAP], rotator cuff, thermal capsulorrhaphy, subacromial decompression, lysis of adhesions). Overlapping concomitant diagnoses were frequent among the subjects analyzed (Table 4). However, surgical treatment of rotator cuff tears (43%), internal impingement (30%), and labral tears (27%) were the most common primary diagnoses indicating operative intervention. The most common surgeries performed were for labral tears (46%; 61% debridement and 39% repair), rotator cuff tears (35%; 85% debridement and 15% repair), and thermal capsulorrhaphy (11%).

### Return to Sport

The rate of RTS at pre-injury level of pitching following shoulder surgery in elite pitchers was 68% (Table 5). The mean time to return to competition (game situation) was 12 months (range, 9-17 months). Twenty-two percent of MLB pitchers never pitched again in MLB. Only 1 study examined isolated shoulder diagnoses: Ricchetti et al<sup>40</sup> reported outcomes following labral repair without concurrent rotator cuff or other shoulder pathologies. Thus, no comparison was able to be made regarding rate of RTS between different types of shoulder surgery. Fifty-nine pitchers (22%) never returned to pitching competitively and retired from their sport. Return to competitive pitching seldom occurred during the same season as labral surgery (7/51; 14%).<sup>40</sup> Return to competitive pitching never occurred during the same season following rotator cuff surgery (0/33; 0%).<sup>34</sup> Duration of competitive pitching following RTS was only reported in 2 studies.<sup>28,39</sup> Reynolds et al<sup>39</sup> reported a median of 2 seasons of pitching (range, 0-4) following debridement of partial-thickness rotator cuff tears. Mazoue and Andrews<sup>28</sup> reported a mean of 0.7 seasons of pitching (range, 3 innings-3 seasons) following mini-open cuff repair. In the latter study, of the 5 patients who were able to return to any competition at all (5/12; 42%), only 1 was able to pitch for more than half of a season.

### Performance: Innings Pitched

Innings pitched prior to surgery declined to a nadir the season of surgery in the report by Namdari et al.<sup>34</sup> Postoperatively, innings pitched steadily increased for 3 consecutive years. Despite the improvement, pitchers still pitched significantly fewer innings in comparison with their numbers of innings

Table 3. Study, subject, and surgical demographics

Parameter	n (%)
Number of studies analyzed	6
Levels of evidence	
III	4
IV	2
Financial conflict of interest	
No	3
Yes	0
Not reported	3
Dates of subject enrollment	1976 to 2007
Mean Modified Coleman Methodology Score	$38.2 \pm 3.9$ (poor)
Number of subjects	287
Number of shoulders	287
Dominant/throwing	203 (99)
Nondominant	2 (1)
Right	124 (75)
Left	42 (25)
Major/minor league or collegiate pitchers	276 (96)
Number of years playing professionally	$6.58 \pm 2.11$
Other position players	11 (4)
Mean subject age, y	$27.1 \pm 2.89$
Mean clinical follow-up, y	$3.62 \pm 1.10$
Number of surgical cases	287
Primary diagnoses treated	
Rotator cuff tear	120 (43)
Internal impingement	82 (30)
Labral tear	74 (27)
Surgical procedures performed <sup>a</sup>	
Labrum	
Repair	157
Debridement	99
Rotator cuff	
Repair	29
Debridement	162
Thermal capsulorrhaphy	63
Subacromial decompression	42

<sup>a</sup>Many subjects had more than 1 surgical technique performed concurrently.

Table 4. Individual study demographics

Study	Study Design	Primary Outcome Variables	Injury	Subject Groups
Namdari et al <sup>34</sup>	Case-control	Performance	Rotator cuff tear	<ul style="list-style-type: none"> <li>MLB pitchers undergoing surgery for tear versus pitchers without tear</li> <li>Pitchers requiring surgery had performance decline preoperatively</li> <li>Pitchers requiring surgery were older, starters, all-stars, with lower ERA, more seasons</li> </ul>
Neri et al <sup>35</sup>	Case-control	Self-reported subjective scores (KJOC, ASES); performance	Type II SLAP tear	<ul style="list-style-type: none"> <li>MLB and college pitchers undergoing surgery versus healthy athletic cohort</li> </ul>
Ricchetti et al <sup>40</sup>	Case-control	Performance	Labral tear	<ul style="list-style-type: none"> <li>MLB pitchers undergoing surgery for tear versus pitchers without tear</li> <li>Starters had higher rates of injury requiring labral repair (vs relievers)</li> </ul>
Reynolds et al <sup>39</sup>	Retrospective case series	General health (SF-12) and subjective (ASORS); performance	Partial-thickness rotator cuff tear	<ul style="list-style-type: none"> <li>MLB, MiLB pitchers</li> <li>48 and 27 concomitant labral repair and thermal capsulorrhaphy, respectively</li> <li>Only 3 patients had isolated partial-thickness rotator cuff tear</li> </ul>
Mazoue and Andrews <sup>28</sup>	Retrospective case series	Subjective (ASORS); performance	Full-thickness rotator cuff tear	<ul style="list-style-type: none"> <li>MLB, MiLB, collegiate pitchers</li> <li>66% of patients had concurrent procedures (SLAP, SAD, thermal capsulorrhaphy, LOA)</li> </ul>
Levitz et al <sup>26</sup>	Retrospective comparative	Performance	Internal impingement	<ul style="list-style-type: none"> <li>MLB, MiLB, collegiate pitchers</li> <li>Concurrent procedures: labrum and cuff (debridement, repair)</li> </ul>

MLB, Major League Baseball; ERA, earned run average; KJOC, Kerlan-Jobe Orthopaedic Clinic; ASES, American Shoulder and Elbow Surgeons; SLAP, superior labrum anterior to posterior; SF-12, Short Form-12; ASORS, Athletic Shoulder Outcome Rating Score; MiLB, minor league baseball; SAD, subacromial decompression; LOA, lysis of adhesions.

pitched 3 years prior to surgery (pre-injury). Ricchetti et al<sup>40</sup> demonstrated no significant difference in number of innings pitched between case (labral repair) and control (no labral repair) MLB pitchers over a 3-year follow-up following surgery. In the latter, successful return to play (RTP) was significantly associated with a greater number of innings pitched (IP) in the seasons prior to surgery.<sup>40</sup>

#### Performance: Earned Run Average

Major League Baseball pitchers who underwent surgery for rotator cuff tears had better baseline earned run average (ERA) than control (no rotator cuff tear) pitchers in the report by Namdari et al.<sup>34</sup> Following surgery, the ERA continued to gradually improve for the ensuing 3 postoperative years

versus no observed trend in the control group.<sup>34</sup> ERA gradually increased for the 3 preoperative years leading up to glenoid labral repair in MLB pitchers and then gradually decreased (improved) for the first 3 postoperative years in the report by Ricchetti et al.<sup>40</sup> Other than the year of surgery, there were no differences in ERA for the 3 years before or after surgery between case (labral repair) and control (no labral tear) groups.<sup>40</sup> In the latter, there was no significant association between successful RTP and better ERA.

#### Performance: Strikeouts and Walks and Hits per Inning Pitched

In the report by Namdari et al.,<sup>34</sup> walks and hits per inning pitched (WHIP) and strikeouts per 9 innings (K/9) were

Table 5. Individual study outcomes

	Injury	Length of Follow-up	Outcomes
Namdari et al <sup>34</sup>	Rotator cuff tear	3 seasons	<ul style="list-style-type: none"> <li>• 73% RTP (24/33) pitchers at mean 17 months postoperatively</li> <li>• 27% MLB pitchers never pitched again in MLB</li> <li>• No pitcher returned during same season</li> <li>• Surgery improved performance, but not back to baseline preoperative status</li> <li>• After surgery, fewer IP, higher WHIP and ERA, lower K/9</li> <li>• No difference in attrition rate from MLB between groups</li> </ul>
Neri et al <sup>35</sup>	Type II SLAP tear	38 months	<ul style="list-style-type: none"> <li>• 57% (13/23) RTP at pre-injury level at mean 9 months postoperatively</li> <li>• 26% (6/23) RTP with pain</li> <li>• 17% (4/23) never pitched again competitively</li> <li>• 52% (12/23) good/excellent KJOC score</li> <li>• 96% (22/23) good/excellent ASES score</li> <li>• Inability to RTP correlated (<math>P = 0.00</math>) with presence of partial-thickness rotator cuff tear</li> </ul>
Ricchetti et al <sup>40</sup>	Labral tear	3 seasons	<ul style="list-style-type: none"> <li>• 73% RTP (37/51) pitchers at mean 13 months postoperatively</li> <li>• Pitchers that RTP averaged more (<math>P &lt; 0.05</math>) IP prior to surgery than those that did not RTP</li> <li>• 14% (7/51) returned during same season</li> <li>• No significant difference (<math>P &gt; 0.05</math>) in performance between pre- and postoperative</li> <li>• No difference in attrition rate from MLB or performance between groups</li> </ul>
Reynolds et al <sup>39</sup>	Partial-thickness rotator cuff tear	39 months	<ul style="list-style-type: none"> <li>• 55% RTP (37/67) at pre-injury level at mean 11 months</li> <li>• 76% RTP (51/67) in MLB/MiLB; 24% (16/67) never pitched again in MLB/MiLB</li> <li>• No significant relationship between concomitant procedures and RTP</li> <li>• Of those RTP, 71% and 65% did not have same velocity or control, respectively</li> <li>• Median number of seasons played postoperatively: 2 (range, 0-4)</li> <li>• ASORS good/excellent in 76.5% pitchers</li> <li>• 5 patients had repeat shoulder surgery due to continued dysfunction</li> </ul>
Mazoue and Andrews <sup>28</sup>	Full-thickness rotator cuff tear	67 months	<ul style="list-style-type: none"> <li>• 8% RTP (1/12) in MLB/MiLB</li> <li>• 66% of patients had concurrent procedures (SLAP, SAD, thermal capsulorrhaphy, LOA)</li> <li>• 1 player had ASORS 90 (excellent); the remaining 11 had ASORS 36 (16-40; poor)</li> </ul>
Levitz et al <sup>26</sup>	Internal impingement	30 months	<ul style="list-style-type: none"> <li>• 87% RTP (71/82) at mean 7.8 months</li> <li>• 71% RTP at final follow-up at pre-injury level of play</li> <li>• Concurrent procedures: labrum and cuff (debridement, repair)</li> </ul>

RTP, return to play; MLB, Major League Baseball; IP, innings pitched; WHIP, walks and hits per innings pitched; ERA, earned run average; K/9, strikeouts per 9 innings; SLAP, superior labrum anterior to posterior; KJOC, Kerlan-Jobe Orthopaedic Clinic; ASES, American Shoulder and Elbow Surgeons; MiLB, minor league baseball (A, AA, AAA); ASORS, Athletic Shoulder Outcome Rating Score; SAD, subacromial decompression; LOA, lysis of adhesions.

significantly worse at the second postoperative season (following rotator cuff surgery) versus the season 3 years prior to surgery. Otherwise, there were no significant differences in WHIP or K/9 pre- or postoperatively in the case (rotator cuff surgery) or control (no rotator cuff tear) groups.<sup>34</sup> Although there was a gradual increase in WHIP before surgery and gradual improvement after surgery in the study by Ricchetti et al,<sup>40</sup> there was no significant difference between mean pre- and postoperative (labral repair) WHIP. Further, there was no significant difference between case (labral repair) and control (no labral tear) groups.<sup>40</sup> WHIP was not significantly associated with successful RTP.<sup>40</sup>

### Performance: Velocity and Control

In the report by Reynolds et al<sup>39</sup> (debridement of partial-thickness rotator cuff tears), maximum pitching velocity was 94.2 mph ( $\pm 2.3$  mph) before surgery.<sup>39</sup> The maximum velocity following surgery had declined to 90.1 mph  $\pm$  4.1 mph.<sup>39</sup> Further, in the latter study, nearly two-thirds (65%) of pitchers did report a subjective loss of pitch control.<sup>39</sup> Although not formally measured, Mazoue and Andrews reported that the primary complaint following repair of full-thickness rotator cuff tear (in the small proportion of subjects able to RTP) was early fatigue, despite good velocity and control.<sup>28</sup>

### Clinical Outcomes

Three studies reported shoulder-specific clinical outcomes following shoulder surgery.<sup>28,35,39</sup> Neri et al<sup>35</sup> reported results following type II SLAP repair with or without partial-thickness rotator cuff tear debridement. In the latter, American Shoulder and Elbow Surgeons (ASES) score was good or excellent in 96% of patients (22/23). However, utilization of the Kerlan-Jobe Orthopaedic Clinic (KJOC) score revealed only 52% good or excellent outcomes (12/23). No patient in that study had a poor ASES score, while 7 patients had a poor KJOC score. Mazoue and Andrews<sup>28</sup> reported results using the Athletic Shoulder Outcome Rating Score (ASORS). They demonstrated only 8% excellent outcomes (1/12) following rotator cuff repair for full-thickness tears.<sup>28</sup> Reynolds et al<sup>39</sup> also utilized the ASORS following debridement of small partial-thickness rotator cuff tears, demonstrating 76.5% of pitchers with a good or excellent outcome. Only 1 study reported complications or re-operations following shoulder surgery in elite pitchers: Reynolds et al<sup>39</sup> following debridement of partial-thickness rotator cuff tears, in which there was a 15% rate of re-operation due to continued shoulder dysfunction.

## DISCUSSION

The primary purpose of this systematic review was to determine the rate of RTS in elite pitchers following shoulder surgery. The authors hypothesized that the rate of RTS following shoulder surgery was low (<75%). This hypothesis was confirmed, as the rate of RTS was 68% with

a postoperative mean clinical follow-up of 3.6 years. RTS occurred at a mean of 12 months following surgery. Secondary purposes include the determination of postoperative clinical outcomes upon RTS, performance upon RTS, and comparison of RTS rates in different types of shoulder surgery. The authors hypothesized that postoperative clinical outcomes were excellent, with decreased performance, and without a significant difference in outcome between different types of shoulder surgery. Heterogeneity in clinical outcome measurement tools (KJOC, ASES, ASORS) precluded a definitive answer regarding success. Performance (IP, ERA, WHIP, K/9, velocity, and control) tended to decrease prior to surgery and gradually improve postoperatively, though not reaching pre-injury levels of pitching.<sup>34,39</sup> Only 1 study reported on subjects with an isolated shoulder diagnosis (labral tear).<sup>40</sup> Thus, no comparison was able to be made regarding rate of RTS between different types of shoulder surgery.

Baseball pitching demands a balance between mobility and stability. It is not surprising that generation of greater amounts of torque during cocking and early acceleration leads to greater velocity and angular rotation during acceleration and ball release. The ability to pitch at an elite level requires several years of training. The repetitive microtrauma induced from throwing over a career (~3000 to 5000 innings pitched in competition<sup>11</sup>) may lead to several osseous and soft tissue adaptations, both functional and pathologic. This has led to a reduction in allowed pitch counts in both MLB<sup>1,30</sup> and youth baseball<sup>27,30</sup> in attempts to reduce injury<sup>30,38</sup> and improve performance.<sup>1</sup> The inability to throw, in context of the sudden loss of ability to pitch (“the dead arm”), “is nothing short of an athletic tragedy.”<sup>32,41</sup> The latter may occur in as little as 1 pitch to as much as several years. Accordingly, treatment often takes place over several months to years, with many different nonoperative and operative options utilized. This was true in the current systematic review, with subjects symptomatic for nearly 3 years and having undergone treatment over 1½ years. Surgical treatment has the potential to dramatically affect the kinematics of throwing and the ability to RTS, the performance upon RTS, and the postoperative clinical outcome. Many pitchers have even undergone more than 1 shoulder surgery in attempts to return to pitching. This was also true in the current systematic review, with 1 study reporting 92% of subjects having a previous surgery on the index shoulder (rotator cuff, labrum, and capsule) prior to repair of a full-thickness rotator cuff tear.<sup>28</sup>

There were 3 primary diagnoses treated within this systematic review (rotator cuff tear, glenoid labral tear, and internal impingement). Despite the primary diagnosis being the indication for surgery, many subjects had greater than 1 source of pathology within the shoulder consistent with the thrower’s shoulder. In fact, only 1 study analyzed in this review reported outcomes following surgical intervention for an isolated diagnosis.<sup>40</sup> However, the latter study did not report the type of labral tear or the type of repair performed. Given this constellation of pathology, it is believed that

repetitive throwing leads to tensile stretching of the anterior capsuloligamentous complex, a so-called pseudolaxity.<sup>5,19</sup> Thus, a diagnosis of “microinstability” may be applied with an instability-type surgery performed as a treatment and omission of treatment of the most common cause of the dead arm syndrome, SLAP tear.<sup>3,5,32</sup> The reason subjects did not RTP in this review was generally not reported. However, if a diagnosis of microinstability was made (and subsequent surgical treatment such as thermal capsulorrhaphy and anterior capsulolabroligamentous tightening), then this may fail to address the true underlying cause of symptoms leading to surgery, the SLAP lesion (although no high-level evidence studies exist to support this theory and the studies did not mention other comorbid patient factors such as tissue quality, physical deficits, etc). Further, if RTP was attempted, then performance is expected to be inferior, which was also confirmed in this review in all but 1 study in at least 1 performance variable per study.<sup>26,28,34,35,39</sup> In addition to the anterior structural changes, the posteroinferior capsule has been shown to become pathologically tight. Although varying degrees of internal impingement occur in all shoulders, repetitive throwing may lead to tightening of the posteroinferior capsule, posterosuperior migration of humeral head on glenoid, and subsequent impingement of the humerus on the articular side of the rotator cuff and posterosuperior labrum in the abducted and externally rotated position.<sup>46</sup> There has been disagreement and controversy on whether anterior laxity contributed to worsening<sup>17</sup> or lessening<sup>14</sup> of internal impingement.

The primary process that likely occurs during the pathologic throwing shoulder is the loss of internal rotation in the abducted arm (glenohumeral internal rotation deficit [GIRD]).<sup>5,33</sup> The loss of internal rotation often exceeds the gain in external rotation with a reduction in the total arc of motion.<sup>45,48</sup> This reduced total arc in combination with GIRD has been associated with twice the risk of shoulder injury.<sup>48</sup> The lack of internal rotation is caused by a contracted posteroinferior capsule with subsequent increase in external rotation (or hyperexternal rotation) in abduction,<sup>33</sup> bony retrotorsion,<sup>51</sup> and posterior muscle tightness.<sup>33</sup> A tight posteroinferior capsule (posterior inferior glenohumeral ligament) creates an obligatory posterosuperior translation of the humeral head in the cocked position and further stresses the “peel-back” mechanism on the superior labrum.<sup>24</sup> Several studies have identified significant relationships between GIRD and development of type II SLAP tears.<sup>21,45</sup> Further, scapular dyskinesia may worsen internal impingement secondary to scapular internal rotation and glenoid antetilting.<sup>22</sup> Most pitchers can be successfully managed nonsurgically with posteroinferior capsular stretching, preventing symptomatic type II SLAP tears and the incidence of surgical labral treatment.<sup>5,20</sup> However, a small proportion of throwers fail nonoperative treatment, with a long duration of symptoms and nonoperative treatment course. These pitchers may undergo surgical treatment of the SLAP tear and the contracted posteroinferior capsule. However, following type II

SLAP repair in this patient group, the rate of RTP at pre-injury level is significantly worse than that of nonoverhead throwing athletes.<sup>42</sup>

### Limitations

The potential sources of bias limiting the conclusions of this systematic review are related to the studies it analyzes. The authors intended to minimize selection bias by inclusion of only a very exclusive subject group: elite pitchers. However, most pitchers had greater than 1 source of pathology within the surgically treated shoulder. Further selection bias was unavoidable due to the retrospective nature of all studies analyzed. Performance bias was present in that the subjects were extracted from publically available sources without detailed descriptions of diagnoses, operative findings, and surgical techniques performed. For example, terms such as *labral tear* and *rotator cuff tear* were applied to the primary diagnosis indicating surgery, and *labral treatment (debridement or repair)* and *rotator cuff surgery* were applied to the techniques utilized. Transfer bias was present secondary to the different lengths of clinical and professional (MLB pitching) follow-up.

Detection bias was present due to the different methods of postoperative evaluation (precludes meta-analysis) and lack of consistent use of the same validated, reliable, and responsive measures. Self-reported outcome scores are important in the postoperative evaluation of shoulder surgery. However, the psychometric properties of athletic-based outcome scores are limited. Further, most shoulder scores are intended to evaluate subjective and objective results relative to activities of daily living and are limited in scope in the evaluation of high-level sports. The subtle differences of shoulder function that are exhibited by a slight decrease in fastball velocity, pitch accuracy, or innings pitched per game are difficult to assess with traditional shoulder outcome scores. These scores are just not sensitive enough to elucidate these changes and therefore may show falsely elevated scores. The ASORS was the first athlete-specific shoulder outcome score with both objective (10%) and subjective (90%) components intended to address these limitations.<sup>44</sup> The subjective portion evaluated pain, power, intensity, stability, and endurance. Despite the intent to evaluate the athlete’s shoulder, its psychometric properties were not formally evaluated in the assessment of this unique patient population. The KJOC score was recently developed to address similar parameters, evaluating the function and performance of overhead throwing athletes’ shoulders and elbows.<sup>35</sup> Although it has been validated (comparison with Disabilities of Arm, Shoulder, and Hand score) for use in evaluation of overhead position athletes, the validation was for elite athletes undergoing elbow collateral ligament reconstruction, not shoulder pathology.<sup>10</sup> Further, proper development, reliability, responsiveness, and allocation of the weighting of items on the KJOC score have not been formally evaluated and were arbitrarily chosen without justification.





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