Posterior-superior Glenoid Impingement of the Throwing Shoulder: Evaluation and Management

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abstract: *The throwing shoulder is subjected to extreme forces secondary to the complex motions that occur during the act of hurling a five-ounce spherical object through space. Numerous conditions can develop as a result of chronic microtrauma to the structures surrounding the glenohumeral joint. Posterior superior glenoid impingement (PSGI) involves impingement of the articular side of the rotator cuff against the posterior superior glenoid labrum. This occurs in conjunction with an underlying subtle instability of the glenohumeral joint. The mechanism is that of abduction, maximal external rotation and horizontal extension or that mechanism which is similar to the throwing motion. Because of the complex nature of the glenohumeral joint and the surrounding structures, the examiner must be knowledgeable regarding the functional anatomy of the shoulder girdle and how it relates to the mechanisms involved in the before mentioned conditions. The purpose of this paper is to describe clinical methodology, which may assist the examiner in the diagnosis and management of the throwing athlete with posterior superior glenoid impingement.*

key words: *Shoulder; Impingement syndrome; Baseball; Joint instability; Sports Medicine*

INTRODUCTION

The act of throwing a baseball requires a complex series of movement patterns from the foot to the hand (1-3). Excessive glenohumeral range of motion, especially in abduction-external rotation, is a common finding in the throwing population. This is associated with a compensatory loss of internal rotation (4-6). Underlying this extreme range of motion is subtle instability of the glenohumeral joint. It is the extremes of motion combined with subtle multi-directional or anterior instability that may result in impingement of the rotator cuff (RTC) at the posterior-superior aspect of the glenoid rim (7-10).

PSGI has been well documented as a source of posterior shoulder pain in the throwing shoulder (8,10-14). PSGI commonly results in articular side rotator cuff tears of the posterior supraspinatus and anterior infraspinatus.

Walch reported PSGI as a cause of articular side contact at the posterior superior glenoid during external rotation at 90 degrees of abduction of the glenohumeral joint (10). Walch also observed this contact in a population of patients without articular side lesions. It was his theory that "physiological contact" may be normal in this area of the glenoid and that symptoms only appear when the shoulder is exposed to excessive stresses, such as those that occur during the throwing motion. Mamanee and McFarland observed physiological contact of the RTC with the superior labrum during Neer's impingement sign (forward flexion) (15). Jobe also reported these two mechanisms (abduction, external rotation, extension and forward flexion) as a cause of superior glenoid impingement and implicated 5 structures as possible lesion sites (Table 1) (12,13). Jobe also discusses at length hyper-angulation that occurs between the articular surface of the humerus and the glenoid secondary to anterior instability. It is Jobe's opinion that a reduction of this hyper-angula-

Table 1
Common structures involved in PSGI

Structures Involved in PSGI

1. Articular surface of the rotator cuff
2. Posterior-superior labrum
3. Inferior glenohumeral ligament-labrum complex
4. Greater tuberosity
5. Osseous posterior-superior labrum

Adapted from Jobe CM. Ortho Clin N Am 1997;28:137-143

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tion may prevent the posterior-superior impingement from occurring (12-14).

The purpose of this paper is to briefly review functional anatomy and delineate historical and examination criteria for the clinical recognition of PSGI in the throwing population. A second purpose is to present management options, both surgical and conservative including treatment and rehabilitation.

DISCUSSION

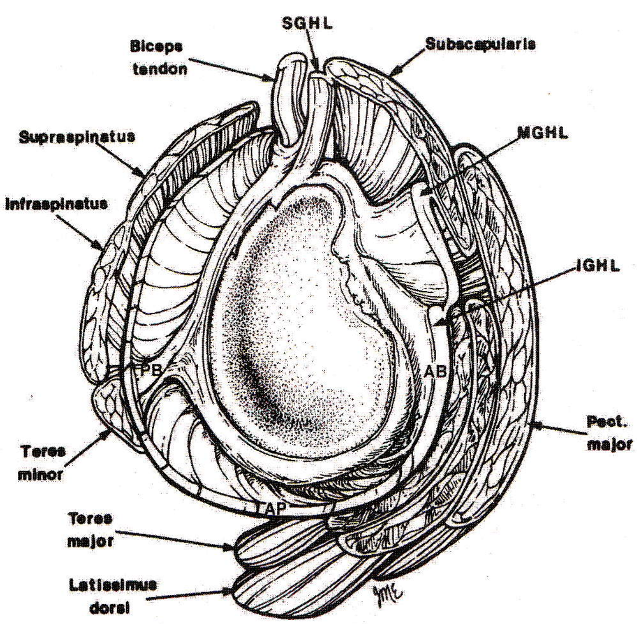
Functional Anatomy related to the Throwing Mechanism

When examining and treating the throwing or overhead athletic population the clinician must have a three dimensional knowledge of glenohumeral anatomy and avoid the pitfall of thinking two dimensionally. Especially important is having a working knowledge of recent anatomic studies, which illustrate the intricate relationship between not only the individual RTC muscles but the intersection of the RTC, long head biceps tendon, glenohumeral ligaments, capsule and labrum (Figure 1).

The dynamic role of the RTC muscles in providing stability to the glenohumeral joint is often under appreciated, despite the overwhelming evidence that it plays a significant role (5,7,16-23). Clark et al demonstrated a significant relationship between the supraspinatus, long head biceps tendon and the subscapularis (24). These three structures play a significant role in humeral head compression and depression during the throwing motion. In fact the static stabilizers contribute minimally to glenohumeral joint stability during the throwing motion. Their primary role is to provide support at the end ranges of motion. It is the RTC muscles that supply dynamic stability to the glenohumeral joint during the actual throwing motion (16,18,22,23,25,26).

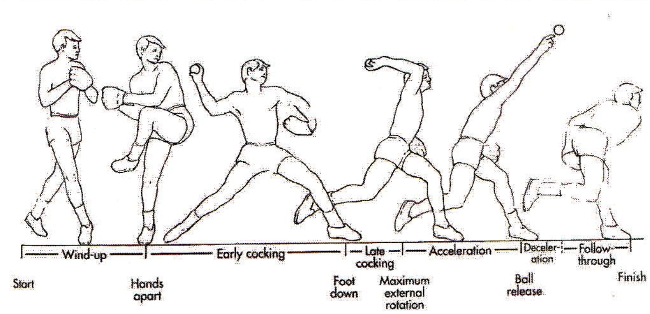
Surface contact of the humeral articular cartilage with the glenoid fossa is minimal. Jobe found that approximately 28% of the humeral head is in contact with the glenoid at any given time (12). This becomes an issue when the dynamic stabilizers become fatigued and transfer stabilizing forces to the static stabilizers. Dynamically the long head of the biceps tendon and subscapularis are essential to anterior glenohumeral joint stability at 90 degrees of abduction (27,28). The long head of the biceps tendon supplies a depressive and compressive mechanism to the humeral head, providing stability and decreasing coracoacromial impingement (5,29). The subscapularis contracts eccentrically providing pre-stretch for the early acceleration phase (Figure 2) of the throwing motion as well as dynamic stability through its compressive and depressive forces. Chronic repetitive eccentric contractions will cause fatigue of the dynamic stabilizers, transferring stabilizing forces to the static stabilizers. This will lead to attenuation of the static stabilizers over time and consequently result in anterior or multidirectional instability (12-14). Jobe has hypothesized that it is this instability which leads to hyper-angulation when the throwing arm is placed in a position of 90 degrees of abduction, 90 degrees of elbow flexion and maximal external rotation with horizontal extension. It is the hyper-angulation that allows for "over-rotation" resulting in the articular surface of the supraspinatus and/or infraspinatus being impinged between the

Figure 1.



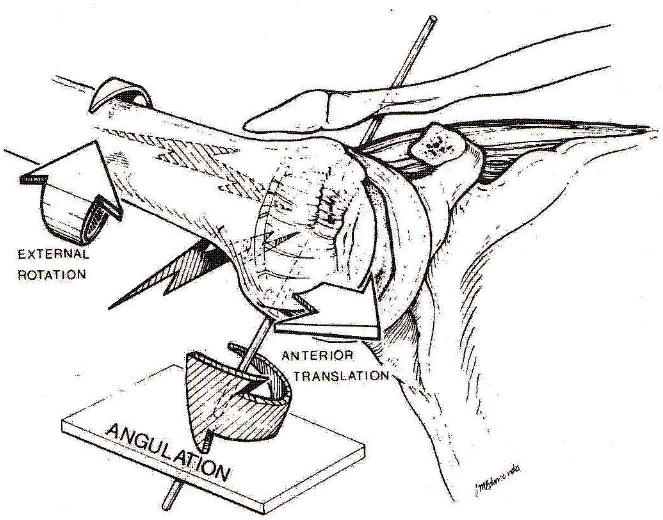
Sagittal view of the glenoid fossa (right shoulder) demonstrating the glenohumeral ligaments and surrounding soft tissues. SGHL, superior glenohumeral ligament; MGHL, middle glenohumeral ligament; IGHL, inferior glenohumeral ligament with components AB, anterior band; PB, posterior band; AP axillary pouch. (Reprinted with permission from DiGiovine et al. An electromyographic analysis of the upper extremity in pitching. J Shoulder Elbow Surg. 1992;1:15-25.)

Figure 2.



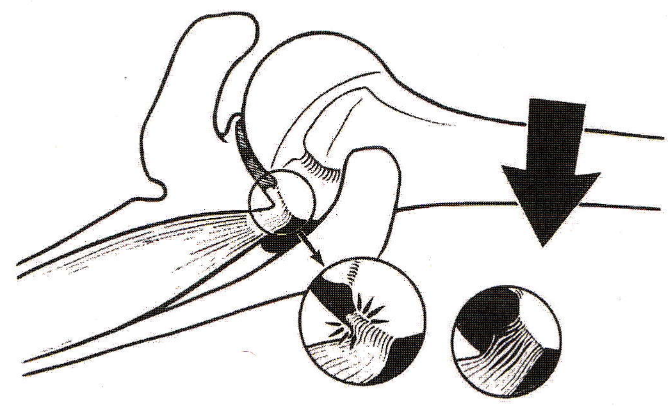
The stages of the overhead throwing motion. (Reprinted with permission from Jobe F. Operative Techniques in Upper Extremity Sports Injuries. St. Louis. MO: Mosby, 1996)

Figure 3.



Internal impingement as seen from anterior perspective. Three motions are depicted. Translation is along plane of glenoid. Rotation is about humeral axis. Angulation involves humeral extension about axis perpendicular to humeral shaft. (Reprinted with permission from Davidson PA, Elattrache NS, Jobe CM, Jobe FW. Rotator cuff and posterior-superior glenoid labrum injury associated with increased glenohumeral motion: A new site of impingement. J Shoulder Elbow Surg 1995;4:384-390.)

Figure 4.



Schematic representation of posterior-superior glenoid impingement. (Reprinted with permission from Riand et al. Results of derotational humeral osteotomy in posterior-superior glenoid impingement. Am J Sports Med 1998;26:454)

greater tuberosity insertion and the posterior-superior aspect of the glenoid. Over time repetitive impingement results in articular side tears of the RTC (Figures 3 and 4).

Clinical History

Most commonly the patient with PSGI experiences posterior shoulder pain in the dominant shoulder, during the cocking phase of the throwing motion. Pain during the cocking phase is an indication that the subscapularis is the deficient area of the cuff (19-21). It is of a slow insidious onset. The patient is usually a young athlete participating in overhead athletics or a patient whose occupation involves repetitive abduction/external rotation and horizontal extension. In the early stages, posterior shoulder pain is during overhead activities only (Table 2). As the condition becomes chronic the patient may experience pain at rest, eventually becoming bothersome during sleep especially if the patient rolls onto the affected shoulder. Signs of overt instability are rare in PSGI (8,11-14).

The first signs of PSGI may be as subtle as a reduction in performance such as reduced velocity and/or poor control. If this is the case a rotator cuff strength assessment should be performed to determine if early clinical weakness is responsible for the change in performance (Table 3).

Clinical Examination

Examination of the shoulder should begin with visual inspection. In an athlete with PSGI, deformity will be absent with the exception of compensatory changes. In the overhead throwing athlete there may be compensatory asymmetry do to hypertrophy of the throwing arm (1,7,17,30). Also common is hypertrophy of the acromioclavicular joint. Other defects to look for are deltoid atrophy in the form of a step-off defect and muscle wasting in the supraspinatus and infraspinatus fossa. These may be the result of axillary or suprascapular nerve entrapment respectively.

Superficial palpation should be performed to elicit gross tenderness and identify temperature change over the long biceps tendon, supraspinatus insertion, posterior capsule, coracoacromial ligament and the anterior and posterior joint lines.

Neurovascular examination of the cervical spine is performed at this stage of the examination. This includes cervical spine ranges of motion, cervical compression testing in the most provocative position allowable by the patient's range of motion. Shoulder depression testing should be performed with the head rotated 45 degrees away from the side being tested. This may help rule out cervical disc or brachial plexus lesion as the etiology of the patient's shoulder complaint. Neuro-vascular assessment of the upper extremities includes palpation of the peripheral pulses, motor, reflex and sensory examination of cervical nerve roots C5-T1, auscultation for subclavian bruits, nail bed perfusion and Roos' elevated arm stress test.

Active and passive ranges of motion are performed in the planes established by the American Shoulder and Elbow Surgeons (31). They are forward elevation (maximum arm-trunk angle), neutral external rotation (arm at the side), external rotation/abduction, external rotation at 90 degrees abduction, internal rotation (highest posterior anatomy reached with

Table 2

Jobe's stages of PSGI

Stage	Symptom and Performance	Treatment
I	Stiffness Slow warm-up	2 week throwing program Strengthen cuff and scapular rotators
II	Posterior pain Positive relocation test	4-12 weeks throwing and rehabilitation program
III	Same as stage II plus failure of rehabilitation program	Anterior capsulolabral reconstruction (ACLR)

Modified from: Jobe CM. Ortho Clin N. Am 1997;28:137-143

Table 3

Suggested management of PSGI

Symptom and Performance	Treatment
No pain Reduced performance Clinical rotator cuff weakness	ART strengthen cuff and scapular rotators
Stiffness Slow warm-up	ART 2 week throwing program Strengthen cuff and scapular rotators
Posterior pain Positive relocation test	ART 4-12 weeks throwing and rehabilitation program
Same as stage III plus failure of rehabilitation program	Anterior capsulolabral reconstruction (ACLR) ART Applied Post-op

The author suggests adding an earlier phase to Jobe's classification.

thumb) and cross-body adduction (ante-cubital fossa to opposite acromion).

Passive range of motion should immediately follow the active range of motion of the plane tested. If pain is present the point during the range of motion that the pain presents should be recorded. Table 4 depicts conditions commonly associated with the planes of motion and the site of pain. Lateral scapular slide is tested during the range of motion examination. The three phases of lateral scapular slide should be examined and measured for the presence of asymmetry in the scapular-spinal distance (32). Increased scapular-spinal distance of greater than 1.5cm on the dominant side has been implicated in throwing related instability (32).

Specific manual muscle testing of the rotator cuff is performed based on recent electromyographic studies indicating the best positions for each muscle (33). The supraspinatus is tested in the "full can" (thumbs up in the scapular plane) position first. This is followed by the more provocative "empty can"

Table 4
Shoulder ranges of motion with common symptoms and possible diagnostic significance

Range of Motion	Significant other finding	Diagnosis
Forward elevation	Inability to perform Pain at end range	Rotator cuff tear Impingement
Neutral external rotation	Posterior pain Anterior pain	PSGI Anterior instability
External rotation/abduction	Pain at end range Shrug sign	Impingement Rotator cuff tear
External rotation at 90 degrees abduction	Posterior pain Anterior pain	PSGI Secondary Impingement/instability
Internal rotation	Posterior pain Posterior apprehension	RC tendonitis Posterior capsulitis Posterior instability
Cross-body adduction	Superior pain Anterior pain	AC joint lesion Secondary Impingement/instability Coracoid impingement

(thumbs down in the scapular plane) position (21,22,29,34). The infraspinatus and teres minor are tested in combination in the neutral position and -45 degrees of rotation. Strength and function of the subscapularis muscle is best assessed using Gerber's lift off and push tests (19,35).

There are many provocative orthopedic maneuvers available to test the glenohumeral joint today. Presented is a clinical examination format based on recent validation testing and positional testing based on the unique stresses placed on the shoulder of the overhead throwing athlete.

The history combined with the previous aspects of the examination should give the clinician a reasonable understanding of the athlete's injury to this point. Provocative examination should either confirm the current suspicion or point the examiner to suspect a subtle underlying cause, which may not be readily distinguishable.

Hawkin's impingement sign is performed in three positions. First the examiner abducts the shoulder to 90 degrees and forward flexes to the scapular plane while supporting the elbow with one hand the humerus is internally rotated by applying a downward force to the dorsal aspect of the wrist. This maneuver is then repeated at 45 degrees and finally 90 degrees of forward flexion. Hawkin's impingement sign is considered to be associated with coracoacromial impingement (36). Bak and Magnusson studied a group of elite swimmers and found Hawkin's impingement sign to be a more accurate test for impingement than Neer's impingement sign (37). This would make clinical sense, as secondary or coracoacromial type impingement is more common in the young athletic population that is prone to instability. Neer's impingement sign is typically more provocative in a patient with primary subacromial impingement (34).

O'Brien's maneuver or active compression test is used in the throwing population because of its ability to detect multiple types of lesions with good reliability (38). The patient should be standing. The affected upper extremity is forward flexed to 90 degrees, fully internally rotated (thumb down) and adducted 10-15 degrees. The examiner then applies a downward force just distal to the elbow while the patient attempts to resist this force.

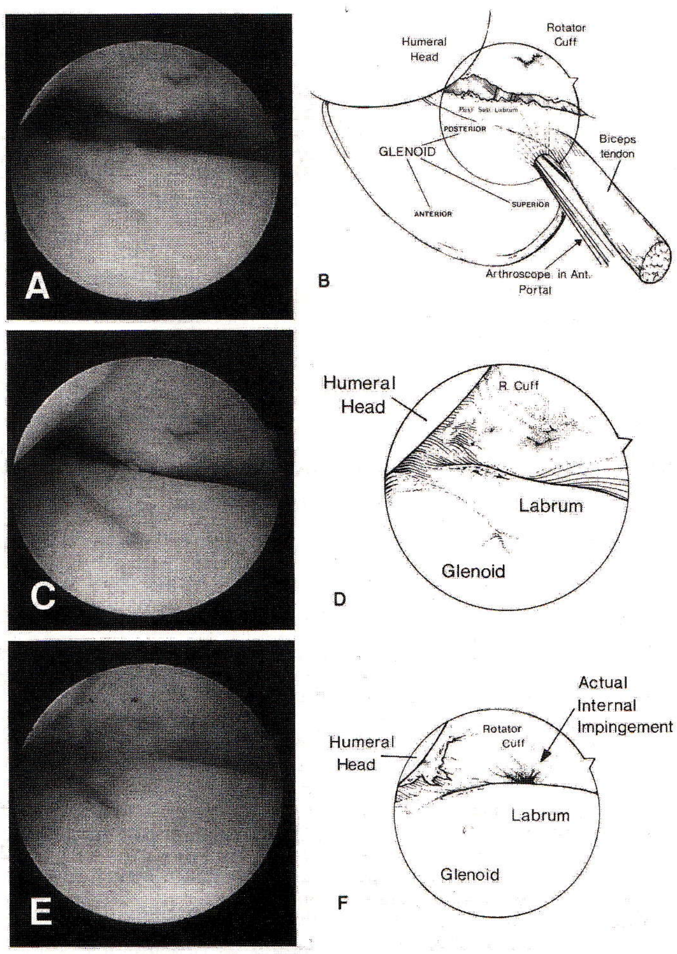
There are several possible positives for the active compression test. The test may be positive for an acromioclavicular joint lesion, SLAP tear, or posterior instability. Detection of acromioclavicular joint lesions and SLAP tears have been reported by O'Brien (38). These lesions are also commonly found in the

Table 5
Sulcus sign grading scale

Grade	Sulcus distance between acromion and humeral head
Grade I	<1cm
Grade II	1-2cm
Grade III	>2cm

Adapted from Silliman JF and Hawkins RJ. Clin Ortho 1993;291:7-19

Figure 5.



Arthroscopic sequence showing internal impingement during progressive external rotation of the humerus. Arthroscope is in anterior portal and is directed posteriorly. A, Beginning of sequence. C, Continued rotation. E, Direct contact between labrum and rotator cuff in maximum abduction and external rotation. Loose frayed tissue from both glenoid labrum and rotator cuff has been partially debrided to facilitate visualization. B, D, and F, Accompanying diagrams to arthroscopic photographs. (Reprinted with permission from Davidson PA, Elattrache NS, Jobe CM, Jobe FW. Rotator cuff and posterior-superior glenoid labruminjury associated with increased glenohumeral motion: A new site of impingement. J Shoulder Elbow Surg 1995;4:384-390.)

throwing or overhead population (1,2,7,16-18,38,39).

Using the active compression test during the clinical examination, I have observed that this test may also be helpful in the diagnosis of subtle posterior instability and/or posterior glenohumeral laxity (40). Via its mechanism of forward flexion, internal rotation and adduction, the active compression test becomes a provocative maneuver for posterior instability (40).

The sulcus sign is used as a measure of generalized joint laxity as well as a component of multidirectional instability. Multidirectional instability is a common trait amongst the overhead athletic population. The patient should be seated. While stabilizing the scapula the examiner applies an axial force to the humerus in an inferior direction. When the sign is present there will be a visible tenting of the skin over the acromion with a resultant sulcus between the acromion and humeral head (2,7,9,30). Table 5 displays a grading scale commonly used for the sulcus sign (9).

The classic apprehension test is perhaps the best test for assessing subtle and occult anterior instability (2,7,9,16,18). This is performed with the patient in a supine position. The elbow is flexed to 90 degrees while the shoulder is abducted to 90 degrees with maximal external rotation. Reproduction of the patient's anterior shoulder pain is indicative of subtle glenohumeral joint instability. This assumption is confirmed by the relocation test (41,42). If application of a posteriorly directed force on the proximal humerus in the apprehension position relieves the patient symptoms, instability is implied. If during the apprehension test, the patient experiences posterior shoulder pain that is relieved by a posteriorly directed force on the proximal humerus this would indicate posterior-superior glenoid impingement (42).

Riand and colleagues have recently described a maneuver that reproduced posterior shoulder symptoms in a population with arthroscopically confirmed articular side rotator cuff lesions and posterior-superior glenoid impingement (10,11) (Figure 5). The patient is supine with the arm in full external rotation and extension. The arm is then abducted while external rotation and extension are maintained. Onset of symptoms occurred between 90 degrees and 150 degrees of abduction. The relocation test performed at the initiation of symptoms was positive in 19 of 20 cases. This implies that anterior instability is the underlying etiology in this group of patients with PSGI (10). The author refers to this test as the "dynamic impingement test."

Standard plain film radiographs may show changes such as sclerosis on the greater tuberosity or the posterior lip of the glenoid secondary to chronic impact as the greater tuberosity contacts the posterior-superior region of the bony glenoid

Table 6

Radiographic series for impingement

View	Possible lesions
Anterior-posterior glenohumeral joint	Glenohumeral degenerative changes Calcific tendonitis
Acromioclavicular joint spot (15 degree cephalad tube tilt)	Acromioclavicular joint degenerative changes Acromioclavicular separation Distal clavicular osteolysis
Axillary lateral	glenohumeral joint dislocation Bony Bankart lesion (glenoid rim) Os acromiale Hill Sachs (posterior humeral head)
Supraspinatus outlet (Y-view)	Acromial morphology Degenerative changes anterior acromion

Table 7

Position continuum for shoulder rehabilitation

	Position Continuum
Start	Neutral position (no abduction)
Scapular plane	30-40 degrees of abduction and forward flexion
Last phase	90 degrees abduction and 90 degrees elbow flexion

(8,11-13). Otherwise, plain films are generally normal. Radiographs appear to be more helpful for what they rule out. Table 6 lists the appropriate radiographic views that make up the "impingement series" and the suspected lesions for each view. MRI may show signal changes consistent with articular side rotator cuff tearing, SLAP lesion or long head biceps tendon injury. Because of the subtle nature of throwing related lesions as well as the potential for confusing anatomical anomalies MRI of the shoulder should be ordered with contrast in the throwing or overhead athlete. Ordering a shoulder MRI without contrast may lead to an inaccurate or misleading diagnosis (43,44).

Non-Surgical Management

Accurate diagnosis is the key to beginning the management plan for the athlete with PSGI. If the underlying etiology is glenohumeral instability and the posterior shoulder symptoms are treated as tendonitis this patient is destined to fail to respond to conservative management. In this case the underlying instability requires treatment and rehabilitation. Although cases of PSGI have been reported without instability (11), it has been the author's experience that the throwing athlete with PSGI commonly experiences underlying instability. This concept has been supported in the literature (2,7,12-14,16,45). Therefore the management plan presented will address treatment and rehabilitation of PSGI with underlying instability.

When the athlete presents with a painful shoulder, the first stage in any plan is to reduce pain while restoring range of motion (46,47). This is accomplished using several evidence-based approaches. The patient is instructed on the home use of ice applications at least four times per day for 20 minutes each time to reduce rotator cuff and capsular inflammation. Active Release Techniques Soft Tissue Management System for the Upper Extremities (ART) is applied to the rotator cuff muscles (48,49). Recently it has been published that the subscapularis is an issue in the unstable athletic shoulder (19-21,34,50,51) as well as the asymptomatic throwing shoulder (19). Therefore manual treatment with ART and rehabilitation should be applied not only to the posterior cuff but additionally to the subscapularis muscle as a dynamic anterior stabilizer of the glenohumeral joint (13,14,21-23,37,46,47,50-53).

Because of anterior or multi-directional instability, it is common in the throwing population to see the posterior capsule tighten. This will cause an increased scapular-spinal distance on the dominant side (32,46). Flexibility should be restored to the posterior capsule prior to commencing a strengthening program. Manual or assisted stretching by the clinician is performed initially. As flexibility and pain-free range of motion returns the patient is instructed on a home flexibility program aimed at stretching the posterior capsule, restoring lost internal rotation and maintaining the previous level of external rotation necessary for throwing. Once pain-free range of motion is restored a strengthening program begins (6,25,26,37,46, 47,50,51).

There are many thoughts and methods for strengthening the rotator cuff. The program for strengthening the rotator cuff and scapular stabilizers is based on the principles of restoring strength and function while avoiding mechanisms that recreate impingement (20,21,50,53). Positions are used that stimulate the rotator cuff muscles while producing minimal shear and impingement at the glenohumeral joint (5,21,53,54).

Since the scapula is the root of the shoulder via its muscular attachment to the spine and thorax, the scapular rotators should be strengthened early and often. Patients can usually perform these exercises even with a painful shoulder and without exacerbation of their symptoms. The scapular clock exercises can be performed manually with assistance of the examiner as well as in a closed chain fashion at home using a wall (32,46,47).

A position continuum is followed throughout the program (Table 7). Exercises performed in a short-lever and neutral position are introduced initially. As the patient responds, short-lever exercises are introduced in the scapular plane at 30-40 degrees of elevation. This is followed by short-lever exercises at 90 degrees of abduction. The last phase is the introduction of long-lever exercises in multiple positions and exercises that emphasize coordinated scapular and glenohumeral movements (21,52-54).

Surgical Management

Surgical treatment, when indicated, is aimed at correction of the underlying instability with repair or debridement of damaged tissues. The procedure of choice is the anterior capsulolabral reconstruction (ACLR) as described by Jobe (16). In brief summary, this procedure involves splitting of the subscapularis muscle at the junction of the upper two-thirds and lower one-third so that the insertion is not disrupted. A capsular shift is then performed on the glenoid side of the joint. This will tighten the attenuated or redundant joint capsule. The ACLR addresses the underlying cause of PSGI by reestablishing the proper anatomical relationship of the joint capsule while preserving the necessary range of motion to perform the throwing motion (16).

The ACLR is followed by an early onset, usually the first post-operative day, range of motion and rehabilitation program to ensure timely return to competition. Although range of motion is started early, the arm is placed in a post-operative splint that maintains the arm in 90 degrees of humeral abduction, 45 degrees of external rotation and 30 degrees of forward flexion. This allows for healing in a functional position and facilitates the rehabilitative process. The splint is removed for rehabilitation but is otherwise worn full time until the patient can actively abduct and forward flex the glenohumeral joint to 90 degrees, which occurs typically in two weeks (16).

CONCLUSION

Posterior-superior glenoid impingement is a condition that commonly presents in the throwing and overhead athlete. The arthroscope has made the detection and visualization of this lesion unquestionable (11,13-15,42,45). Based on clinical experience and advances published in the literature, it is my opinion that the majority of these cases could be identified with a thorough history and physical examination (11,13,14,42,45). A recent study points the way for identification of predisposing factors such as rotator cuff weakness, range of motion deficit and scapular asymmetry prior to symptom onset (19).

Based on the information provided, it is recommended that the described examination format be performed on throwing athletes a minimum of two times per year as a preventive measure. Examination of this type at the end of the season will allow the athlete and medical staff time to design and implement a corrective program, which can be followed during the off season. A pre-spring training examination will allow for follow-up of players undergoing a corrective off season program and detection of deficits in players who did not display deficits at the end of the previous season.

Identifying the etiology of PSGI, in this case instability, is the key to prescription of the appropriate treatment and training regimens. Early detection is the most important factor. The longer the condition is present prior to diagnosis the poorer the prognosis for resolution with conservative management.

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