[CLINICAL COMMENTARY]

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Shoulder Injuries in the Overhead Athlete

The overhead throwing motion is a highly skilled movement performed at extremely high velocity, which requires flexibility, muscular strength, coordination, synchronicity, and neuromuscular control. The throwing motion generates extraordinary demands on the shoulder joint. It is because of these high forces, which are repetitively applied, that the shoulder is the most commonly injured joint in professional baseball pitchers.[27]

During the throwing movement, tremendous forces are placed on the shoulder joint at extremely high angular velocities. The acceleration phase of the pitch is the fastest movement recorded and reaches a peak angular velocity of 7250°/s.[41,43] It has been estimated that the anterior translation forces generated when pitching are equal to one-half body weight (BW) during the late cocking phase, and there is a distraction force equal to BW during the deceleration phase.[43] Consequently, throwing requires a high level of muscle activation, as indicated by the electromyographic signal of the shoulder musculature, which can exceed 80% to 100% of the signal measured during a maximum voluntary isometric contraction (MVIC).[34] Lastly, the thrower's shoulder often exhibits excessive motion and laxity. Wilk et al[112] stated that the thrower's shoulder must be "loose enough to throw but stable enough to prevent symptoms." Whether the typical injury sustained to the thrower's shoulder is due to hyperlaxity or capsular tightness is currently a controversial topic of discussion. Shoulder pathology can manifest as pain, diminished performance (velocity and accuracy), or a decrease in strength or range of motion. The challenge for medical practitioners is to determine the accurate differential diagnosis, the cause of the injury, and the most effective treatment plan based on the identified pathology.

SUPPLEMENTAL VIDEO ONLINE

• **SYNOPSIS:** The overhead throwing motion is an extremely skillful and intricate movement. When pitching, the overhead throwing athlete places extraordinary demands on the shoulder complex subsequent to the tremendous forces that are generated. The thrower's shoulder must be lax enough to allow excessive external rotation but stable enough to prevent symptomatic humeral head subluxations, thus requiring a delicate balance between mobility and functional stability. We refer to this as the "thrower's paradox." This balance is frequently compromised and believed to lead to various types of injuries to the surrounding tissues. Frequently, injuries can be successfully treated with a well-structured and carefully implemented nonoperative rehabilitation program. The key to successful nonoperative treatment is a thorough clinical examination and accurate diagnosis. Rehabilitation follows a structured, multiphase approach, with emphasis on controlling inflammation, restoring muscles' balance, improving soft tissue flexibility, enhancing proprioception and neuromuscular control, and efficiently returning the athlete to competitive throwing. Athletes often exhibit numerous adaptive changes that develop from the repetitive microtraumatic stresses occurring during overhead throwing. Treatment should include the restoration of these adaptations.

• **LEVEL OF EVIDENCE:** Level 5. *J Orthop Sports Phys Ther 2009;39(2):38-54. doi:10.2519/jospt.2009.2929*

• **KEYWORDS:** *baseball, glenohumeral joint, labral lesions, pitching, rotator cuff*

In this manuscript, we will discuss the physical characteristic of the overhead athlete, common pathologies seen, and the nonoperative, surgical, and postoperative treatment.

PHYSICAL CHARACTERISTICS

It is important for the clinician to realize and appreciate the "typical" physical characteristics of the overhead thrower.

Range of Motion

Most throwers exhibit an obvious motion disparity, whereby shoulder external rotation (ER) is excessive and internal rotation (IR) is limited when measured at 90°

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of abduction.[11,18,20,54,112] This loss of IR of the throwing shoulder has been referred to as glenohumeral internal rotation deficit (GIRD). Several investigators have documented that pitchers exhibit greater ER of the shoulder than do position players.[11,54,111] Brown et al[18] reported that professional pitchers exhibited a mean ± SD of 141° ± 15° of shoulder ER measured at 90° abduction. This was approximately 9° more than for their nonthrowing shoulder and approximately 9° more than the throwing shoulder of position players. Recently, Bigliani et al[11] reported that dominant shoulder ER measured at 90° shoulder abduction averaged 118° (range, 95°-145°) in pitchers, whereas it averaged 108° (range, 80°-105°) for the dominant shoulder of positional players.

Wilk et al[105] reported on the glenohumeral joint range of motion (ROM) measured in 879 professional baseball pitchers from 2003 to 2008. Pitchers exhibited an average ± SD of 136.9° ± 14.7° of ER and 40.1° ± 9.6° of IR when passively assessed at 90° abduction. In pitchers, the ER is approximately 9° greater in the throwing shoulder when compared to the nonthrowing shoulder, while IR was 8.5° greater in the nonthrowing shoulder. In addition, the total motion (ER and IR added together) in the throwing shoulder was similar (within 7°) when compared to total motion of the nonthrowing shoulder, with the total rotational arc of motion being 176.3° ± 16.0° on the throwing shoulder and nonthrowing shoulder.[114] We refer to this as the "total motion concept" (**FIGURE 1**). Several authors have previously reported that total motion is equal comparing the throwing and nonthrowing shoulder.[4,6,40,77,114]

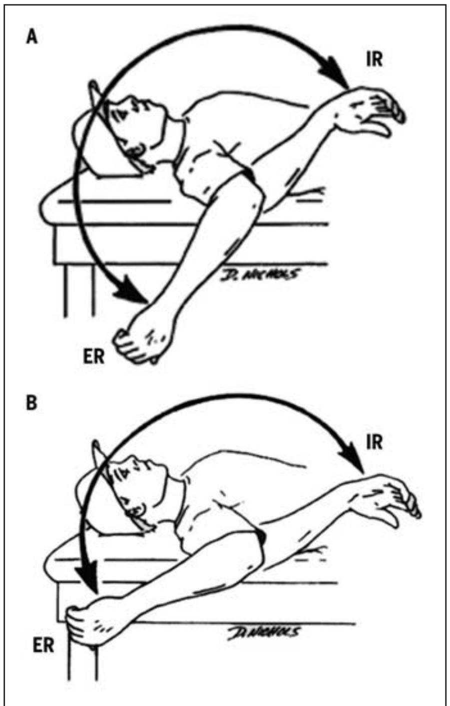

FIGURE 1. The total-rotational-motion concept. External rotation (ER) + internal rotation (IR) = total motion. Total rotational motion is equal bilaterally.

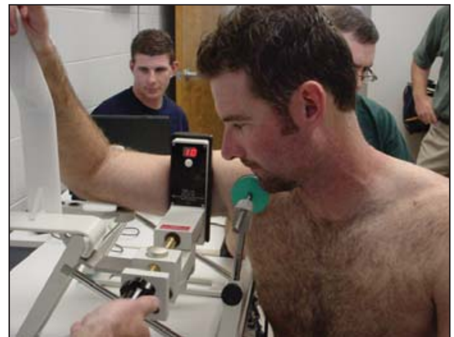

FIGURE 2. Glenohumeral laxity testing done on Telos device to objectively assess the amount of joint laxity.

Laxity

Most throwers exhibit significant laxity of the glenohumeral joint, which permits excessive ROM. The hypermobility of the thrower's shoulder has been referred to as "thrower's laxity."[112] The laxity of the anterior and inferior glenohumeral joint capsule may be appreciated by the clinician during the stability assessment of the joint. Andrews et al[7] have reported that the excessive laxity exhibited by the thrower is the result of repetitive throwing, referring to this as "acquired laxity"; but others have documented that the overhead thrower exhibits congenital laxity.[11]

Borsa et al[14,15] reported no difference in the throwing shoulder compared to the nonthrowing shoulder when objective glenohumeral joint laxity testing was performed on the Telos device (**FIGURE 2**). Furthermore, they noted greater posterior laxity compared to anterior laxity and no association between measurements of joint laxity and ROM. In some cases, pitchers exhibited extremely diminished glenohumeral joint IR motion, while exhibiting significant posterior capsule laxity on Telos testing. Thus, the changes in glenohumeral joint motion seen in pitching may be due to factors other than glenohumeral joint capsular laxity.

Osseous Adaptations

Several investigators[23,29,85,88,89] have reported an osseous adaptation of the humeral head in the thrower's shoulder. Crockett et al[29] reported on 25 professional baseball pitchers who underwent computerized tomography (CT) scan to determine humeral head and glenoid fossa retroversion. The investigators noted that the humeral head on the throwing side exhibited a 17° increase in retroversion when compared to the nonthrowing shoulder. Furthermore, when comparing the pitchers to a group of nonthrowers, the nonoverhead athlete group exhibited no difference in their bilateral retroversion values. This could partially provide an explanation for the side-to-side differences noted in the throwers glenohumeral joint rotational ROM. An increase in humeral head retroversion would result in an increase in ER ROM and a decrease in IR. Lastly, Meister et al[77] documented in adolescent baseball players that the greatest change in glenohumeral joint ROM occurs between the ages of 12 and 13, when the growth plates are open.

Muscle Strength

Several investigators have examined muscle strength parameters in the overhead throwing athlete with varying results and conclusions.[1,9,18,28,30,48,107,108] Wilk et al[107,108] performed isokinetic testing on 83 professional baseball players as part of their physical examinations during spring training. The investigators demonstrated that the ER strength of the pitcher's throwing shoulder was significantly weaker ($P<.05$) than the nonthrowing shoulder by 6%. Conversely, IR of the throwing shoulder was significantly

TABLE 1 Glenohumeral Muscular Strength Values in Professional Baseball Players (n = 83)[103,104]

	180°/s	300°/s	450°/s
Bilateral comparisons (%)*			
External rotation	95-109	85-95	80-90
Internal rotation	105-120	100-115	100-110
Abduction	100-110	100-110	
Adduction	120-135	115-130	
Unilateral peak torque ratios (%)†			
External/internal rotation	63-70	65-72	62-70
Abduction/adduction	82-87	92-97	
External rotation/abduction	64-69	66-71	
Peak torque-body weight ratios‡			
External rotation	18-23	15-20	
Internal rotation	27-33	25-30	
Abduction	26-32	20-26	
Adduction	32-36	28-33	

** Strength ratio of the dominant to the nondominant side for each muscle group.*
† Data for the dominant (pitching) arm only.
‡ Peak torque measured in ft-lb and body weight in lb.

stronger ($P<.05$) than the nonthrowing shoulder by 3%. Additionally, adduction strength of the throwing shoulder was significantly stronger ($P<.05$) than that of the nonthrowing shoulder by approximately 9% to 10%. We believe that an important isokinetic value is the unilateral muscle ratio, which describes the antagonist-agonist muscle strength ratio of 1 shoulder. A proper balance between agonist and antagonist muscle groups is thought to provide dynamic stabilization to the shoulder joint. To provide proper muscle balance, the glenohumeral joint external rotator muscles should be at least 65% of the strength of the internal rotator muscles.[113] Optimally, the external-internal rotator muscles strength ratio should be 66% to 75%.[108 112,113] **TABLE 1** illustrates the optimal muscle strength values of professional baseball players. Furthermore, Magnusson et al,[72] using a handheld dynamometer, reported that professional pitchers exhibited significant weakness of the supraspinatus muscle on the throwing side compared to the nonthrowing side.

The scapulothoracic musculature plays a vital role during the overhead throwing motion.[34] Proper scapular movement and stability are imperative for asymptomatic shoulder function.[56,57] These muscles work in a synchronized fashion and act as force couples about the scapula, providing both movement and stabilization. Wilk et al[117] documented the isometric scapular muscle strength values of 112 professional baseball players. The results indicated that pitchers and catchers exhibited significantly higher strength of the protractor and elevator muscles of the scapula when compared to position players. All players (except infielders) exhibited significantly stronger depressor muscles of the scapula on the throwing side compared with the nonthrowing side. In addition, we believe that the agonist-antagonist muscle ratios are important values when considering how the scapula provides stability, mobility, and symptom-free function. **TABLES 2 AND 3** illustrate the scapular muscle strength values in the overhead-throwing athlete.

Posture and Scapular Position

As previously mentioned, the ability of the scapula to function as a cohesive unit with the upper body is essential for the overhead athlete. To be able to function properly, the scapula needs to be in the proper position to assist in the movement of the humerus. Kibler et al[57] defined alterations in motion of the scapula during coupled scapulohumeral movements as "scapular dyskinesis." Numerous authors have noted the role of scapular dyskinesis and the positive correlation to shoulder pathology.[56,57]

Oftentimes, the overhead athlete has changes in posture that result in a change of resting position of the scapula. Burkhart et al[19] has described these postural changes as the "SICK" scapula, which stands for scapular malpositions that include inferior medial border prominence, coracoid pain and malposition, and dyskinesis of scapular movement. This syndrome often presents clinically as an asymmetric "dropped" scapula. Bastan et al[10] reported the position of the scapula in the overhead athlete in 3 planes (rotation, tilt, elevation) for 4 different shoulder positions (rest, 90° abduction, 90° abduction with maximal ER, and 90° abduction with maximal IR). Their results indicated that the scapula of the dominant side, with the shoulder at rest, was significantly more protracted ($P = .006$) and tilted anteriorly ($P = .007$); with the shoulder at 90° of abduction, it was more rotated in the upward direction ($P = .039$); with both maximal ER and IR at 90° of abduction, it was more tilted anteriorly ($P<.001$).[10] Macrina et al[70] reported that once the scapular musculature gets fatigued, scapular position worsened, resulting in greater scapular protraction and anterior tilting. This anterior tilt position correlates with a loss of glenohumeral joint IR.[13,66] As previously mentioned, there have been numerous studies on the association between scapular positional change, scapular dyskinesis, and increased shoulder pathology. These studies further the belief that there is an increased rate of scapular position change that may lead to increased shoulder pathology in the overhead athlete.

TABLE 2	Strength of the Scapulothoracic Musculature*

	Dominant Arm	Nondominant Arm
Pitchers		
Protraction	32.2 ± 4.5	33.6 ± 5.9
Retraction	28.1 ± 3.6	27.2 ± 3.2
Elevation	37.6 ± 6.4	38.1 ± 6.8
Depression	10.0 ± 2.7	8.2 ± 2.3
Catchers		
Protraction	30.8 ± 4.5	33.1 ± 4.5
Retraction	28.6 ± 2.3	26.8 ± 3.2
Elevation	39.9 ± 6.8	38.6 ± 3.6
Depression	9.5 ± 1.8	7.3 ± 2.3
Position players		
Protraction	26.3 ± 4.5	26.3 ± 5.0
Retraction	25.9 ± 2.7	25.4 ± 2.7
Elevation	29.5 ± 5.4	29.9 ± 5.0
Depression	8.6 ± 2.3	8.2 ± 2.3

* *Values are mean ± SD kg.*

TABLE 3	Strength Ratios of the Scapulothoracic Musculature

	Dominant Arm	Nondominant Arm
Pitchers		
Protraction/retraction	87%	81%
Elevation/depression	27%	21%
Catchers		
Protraction/retraction	93%	81%
Elevation/depression	24%	19%
Position players		
Protraction/retraction	98%	94%
Elevation/depression	29%	27%

CLINICAL EXAMINATION

History

Although acute injuries to the shoulder do occur in the overhead-throwing athlete, it is much more common for injuries to be secondary to overuse and fatigue. General information about the patient, as well as specific information about symptoms and throwing history, is required to make a correct diagnosis (**APPENDIX A**).[45] Important information, such as onset of symptoms, changes in mechanics, development of a new pitch, training regimen, single-game and season pitch counts, as well as previous treatments, needs to be determined. It is equally important to see any imaging studies the patient had prior to evaluation. The imaging studies must be correlated to the physical examination to establish an accurate and differential diagnosis. Numerous imaging studies may be beneficial in establishing the diagnosis, such as plain radiographs, magnetic resonance arthrograms (MRA), or computerized tomography scans.

Physical Exam

After a thorough medical history has been obtained, the physical examination will focus the differential diagnosis down to a manageable list of possibilities. Each medical practitioner should have a consistent progression to follow for every physical exam (**APPENDIX B**). There are multiple tests or exam techniques to arrive at a diagnosis, and it is important that each medical practitioner use exam techniques that they are familiar with and are capable of duplicating with each patient.

Visual observation of the shoulder should be performed first, with special attention focused on any skin lesions or muscle atrophy. Next, the shoulder is palpated, feeling all bony prominences, with special attention on the bicipital groove, greater tuberosity, and acromioclavicular (AC) joint. Pain in these areas can indicate biceps tendon involvement, rotator cuff involvement, and AC joint arthrosis, respectively. ROM, both active (AROM) and passive (PROM), is observed, focusing on glenohumeral as well as scapulothoracic motion. Glenohumeral joint PROM is assessed for ER and IR at 90° abduction and for ER at 45° abduction in the scapular plane. When assessing IR, care is taken to palpate and stabilize the scapula. When assessing PROM, the clinician should assess both the quantity of motion and the end feel. Forward flexion, abduction, IR, and ER are important to assess, especially for any deficits that may be evident. Palpation of the shoulder during ROM can uncover crepitus, which may indicate certain pathologic lesions, such as bursa thickening, rotator cuff tears, and arthritis.

Muscle strength is the next component of the examination. To test the supraspinatus, the patient is asked to flex the shoulder to 90°, with the arm horizontally abducted to around 45° and the thumb pointing upward (full can). Resistance is applied in this position.[55,91] Weakness or pain may indicate a lesion of the supraspinatus muscle. With the arm at the side and the elbow flexed to 90°, the patient is asked to externally rotate against resistance (infraspinatus and teres minor) and internally rotate against resistance (sub-

FIGURE 3. Biceps load test performed to assess for possible SLAP lesion. The patient abducts the shoulder to 90°, fully externally rotates the shoulder, flexes the elbow to 90°, and fully supinates the forearm. The patient is asked to actively flex the elbow against resistance. Pain is positive indication for a SLAP lesion.

FIGURE 4. Pronated biceps load test to assess for possible SLAP lesion. The patient assumes the same position as the biceps load test but fully pronates the forearm. The patient is again asked to actively flex the elbow against resistance. Pain located in the superior glenohumeral joint (deep) is indicative of a SLAP lesion.

FIGURE 5. Resisted external rotation with supination performed to assess integrity of the superior labrum. The patient is asked to abduct the arm to 90°, and flex the elbow to 90°, keeping the shoulder in neutral rotation. The examiner resists the patient, while active external rotation of the arm and forearm supination is performed. Pain is considered a positive sign for a SLAP lesion.

scapularis). Again, weakness or pain may indicate a lesion. Resisted ER and IR are subsequently performed at 90° of abduction and neutral rotation, which is a more functional position to assess the overhead athlete. It may be beneficial to assess ER and IR strength at 90° of abduction, with the patients moving through an arc of motion concentrically and eccentrically against resistance.

At this point, the examiner can perform certain provocative maneuvers to assess other possible pathology (**APPENDIX B**). A few selected common tests performed in the clinic will be discussed below in more detail.

To assess subacromial impingement, the Hawkins-Kennedy test is often utilized. This subacromial impingement test has been reported to have 66% to 100% sensitivity and 25% to 66% specificity for the diagnosis of impingement, rotator cuff tears, and bursitis.[21,69,87] The patient's shoulder joint is forward flexed to 90° and the shoulder is forcibly internally rotated. This maneuver drives the greater tuberosity farther under the coracoacromial ligament, producing impingement. Pain with this maneuver may indicate subacromial impingement.[98] The test is performed at 90° of abduction in the scapular plane, sagittal plane, and with horizontal adduction beyond the sagittal plane, with the more horizontally adducted positions causing greater impingement and, therefore, being possibly more provocative for pain.

There are a variety of tests described to assess for a possible superior labrum anterior posterior (SLAP) tear.[33] O'Brien's active compression test is frequently used.[83] The examiner asks the patient to forward flex the affected arm 90°, with the elbow in full extension. The patient then adducts the arm 10° to 15° medially. The arm is internally rotated so that the thumb is pointing downward. The examiner then applies a uniform downward force to the arm. The exact same technique is performed again, this time with the patient placing the palm up toward the ceiling. The test is considered positive if pain (located within the subacromial or superior glenohumeral joint) is elicited with the first maneuver and is reduced or eliminated with the second maneuver.[99] O'Brien et al[83] have reported 100% sensitivity and 97% to 99% specificity for this test in detecting glenoid labral or AC joint abnormality. The tests we perform to test the integrity of the glenoid labrum are the biceps load test, pronated biceps load test,[116] and resisted ER with supination test.[80] These tests, illustrated in **FIGURES 3 THROUGH 5** (**ONLINE VIDEO**), have been shown to be highly sensitive for SLAP tears/lesions in the overhead athlete.[80]

There exist numerous joint stability tests. For a complete and thorough description of these tests the reader is encouraged to review Wilk et al.[113,116] Those we routinely perform are the anterior drawer, fulcrum, relocation, and internal impingement signs and tests. The most important aspects of these tests are to determine the extent of laxity present, end point, and, in particular, the tissue elasticity at end range. To assess end point elasticity, the fulcrum test is performed at 90° of abduction. The posterior impingement sign is performed in the plane of the scapula at 90° of abduction, with the examiner passively rotating the arm into maximum ER (**ONLINE VIDEO**). A positive test is indicated by complaints of pain in the deep posterior shoulder. Meister et al[76] have reported 76% sensitivity and 85% specificity when performing this test for posterior rotator cuff and/or labrum tears.

Imaging

Imaging is the next important step in determining a diagnosis. Plain radiographs with multiple views of the involved glenohumeral joint are mandatory. Routine radiographic evaluation includes anterior-posterior (AP), Stryker notch, West Point, axillary, and acromial outlet views. These views allow visualization of the glenohumeral articulation as well as acromial morphology and the inferior glenoid.

The imaging modality of choice to assess soft tissue pathology of the shoulder is magnetic resonance imaging (MRI) with intra-articular contrast (MRA). This allows the best view of the rotator cuff tendons and muscles, glenoid labrum, biceps tendon, and other associated pathology, such as spinoglenoid cysts. Intra-articular contrast is especially useful to determine if there is a full-thickness versus partial-thickness tear of the rotator cuff. Furthermore, the MRA technique allows the physician to evaluate the glenoid labrum to determine if a detached labrum or frayed labrum exists. In the throwing athlete the most common lesions are partial-thickness rotator cuff tears and glenoid labrum pathology.

CLASSIFICATION OF LESIONS

There are numerous lesions that may occur in the overhead athlete (**APPENDIX C**).

Rotator Cuff Tendonitis/ Tendonosis/Bursitis

Tendonitis, tendonosis, and bursitis are 3 separate clinical entities for which the names are often incorrectly used interchangeably. Tendonitis is inflammation of the tendon. In many cases, it is actually the tendon sheath that is inflamed and not the tendon itself. Bursitis is inflammation of the subacromial bursa. Tendonosis implies intratendonous disease, such as intrasubstance degeneration or tearing.

The patient clinical presentation of tendonitis or tendonosis of the rotator cuff are pain with overhead activity and weakness secondary to pain. The symptoms in the thrower are pain during the late cocking phase of throwing, when the arm is in maximal ER, or pain after ball release, as the muscles of the rotator cuff slow the arm during the deceleration phase.[37] Weakness of the supraspinatus and infraspinatus are common findings in throwers with shoulder pathology; but asymmetric muscle weakness in the dominant shoulder is often seen in the healthy thrower. Differential diagnosis of tendonitis versus tendonosis is based on MRI and duration and frequency of symptoms. On MRI, the patient with tendonitis will exhibit inflammation of the tendon sheath (the paratenon); conversely, when tendonosis is present, there exists intrasubstance wear (signal) of the tendon.

Tendonitis/tendonosis is most frequently an overuse injury in the overhead athlete and does not usually represent an acute injury process. The symptoms frequently occur early in the season, when the athlete's arm is not conditioned properly.[114] These injuries may also occur at the end of the season, as the athlete begins to fatigue. If the athlete does not participate in an in-season strengthening program to continue proper muscular conditioning, tendonitis/tendonosis may also develop. Specific muscles (external rotator muscles and scapular muscles) may become weak and painful due to the stresses of throwing.[114]

Rotator Cuff Tears

Muscles of the rotator cuff are active during various phases of the throwing motion.[35,42,50] During the late cocking and early acceleration phases, the arm is maximally externally rotated, potentially placing the rotator cuff in position to impinge between the humeral head and the posterior-superior glenoid. Known as "internal impingement" or "posterior impingement," this may place the rotator cuff at risk for undersurface tearing (articular sided). Conversely, in the deceleration phase of throwing, the rotator cuff experiences extreme tensile loads during its eccentric action, which may lead to injury.[36] Rotator cuff tears in the overhead athlete may be of partial or full thickness. The history of shoulder pain either at the top of the wind-up (acceleration) or during the deceleration phase of throwing should alert the examiner to a rotator cuff source of pain or loss of function. Any history of trauma, changes in mechanics, loss of playing time, previous treatments, voluntary time off from throwing, and history of previous injury should be noted.

Rotator cuff tears may be caused by primary tensile cuff disease (PTCD), primary compressive cuff disease (PCCD), or internal impingement. PTCD results from the large, repetitive loads placed on the rotator cuff as it acts to decelerate the shoulder during the deceleration phase of throwing in the stable shoulder. The injury is seen as a partial undersurface tear of the supraspinatus or infraspinatus.[2,7] PCCD is found on the bursal surface of the rotator cuff in throwers with stable shoulders. This process occurs secondary to the inability of the rotator cuff to produce sufficient adduction torque and inferior force during the deceleration phase of throwing. Processes that decrease the subacromial space increase the risk for this type of pathology.[2] Partial-thickness rotator cuff tears can also occur from internal impingement.

Internal Impingement

Internal impingement was first described in 1992 by Walch and associates in tennis players.[104] They presented arthroscopic clinical evidence that partial, articular-sided rotator cuff tears were a direct consequence of what they termed "internal impingement." Internal impingement is characterized by contact of the articular surface of the rotator cuff and the greater tuberosity with the posterior and superior glenoid rim and labrum in extremes of combined shoulder abduction and ER.[49] In overhead throwing athletes, it appears that excessive anterior translation of the humeral head, coupled with excessive glenohumeral joint ER, predisposes the rotator cuff to impingement against the glenoid labrum.[63] Repeated internal impingement may be a cause of undersurface rotator cuff tearing and posterior labral tears. It is important that the underlying laxity of the glenohumeral joint be addressed at the time of treatment for an internal impingement lesion to prevent recurrence of the lesion.[7] Burkhart et al[20] have proposed that restricted posterior capsular mobility may result in IR deficits and may cause pathologic increases in internal rotator cuff contact and injury. The authors of this manuscript believe that the loss of IR is most often due to osseous adaptation[29,89] and muscular tightness, as opposed to capsular tightness.

Patients with internal impingement usually describe an insidious onset of pain in the shoulder.[5] Pain tends to increase as the season progresses. Symptoms may have been present over the past couple of seasons, worsening in intensity with each successive year. Pain is usually dull and aching, and is located over the posterior aspect of the shoulder. Late cocking phase seems to be most painful. Loss of control and velocity is often present secondary to the inability to fully externally rotate the arm without pain.

On physical examination, pain may be elicited over the infraspinatus muscle and tendon with palpation. Pain to palpation is more often posterior, in contrast to rotator cuff tendonitis, which usually elicits pain to palpation over the greater tuberosity.[5] With internal impingement, patients usually have full ROM. In both the normal and pathologic thrower's shoulder the dominant arm tends to have 10° to 15° more ER and 10° to 15° less IR with the arm abducted to 90°, compared with the nondominant arm.[29] The most common presentation is for the overhead athlete to have 1+ to 2+ anterior laxity and 2+ posterior laxity. Inferior laxity is often present. Most provocative tests are negative. The most frequent provocative exam to elicit pain is the internal impingement sign,[76] described earlier.

SLAP Lesions

SLAP lesions are a complex of injuries to the superior labrum and biceps anchor at the glenoid attachment. Andrews and associates[4] were the first to describe this lesion in 1985. They reported arthroscopic findings in a group of throwing athletes with shoulder dysfunction. Snyder and associates[94] later classified this injury complex as superior labrum anterior and posterior lesions, and coined the term *SLAP lesion*. The arthroscopic appearances of the lesions were originally classified into 4 distinct lesion types, with 3 variations later being added.[71] The pathophysiology of SLAP lesions is debated frequently, but the essentials of the lesion are agreed upon.

Patients who have SLAP lesions fall into 2 basic categories. The first consists of overhead athletes, most commonly baseball players, with a history of repetitive overhead activity and no history of trauma. The second category involves patients with a history of trauma.[49]

Burkhart et al[20] have described the peel-back lesion of the superior labrum, which frequently occurs in the overhead athlete (**FIGURE 6**). Peel-back lesions are considered a type II SLAP lesion. The athlete often presents to the practitioner with complaints of vague onset of shoulder pain and possibly problems with velocity, control, or other throwing complaints. The patient may complain of mechanical symptoms or pain in the late cocking phase, often poorly localized. The diagnosis of SLAP lesions can be very difficult, as symptoms can mimic rotator cuff pathology and glenohumeral joint instability. Definitive diagnosis can only be made by arthroscopy.[49]

Posterior Glenoid Exostosis (Bennett's Lesion)

Thrower's exostosis is an extracapsular ossification of the posteroinferior glenoid rarely seen except in older longtime throwers.[75] This condition is a result of secondary ossification involving the posterior capsule, probably due to repetitive trauma.[6] The osteophyte is thought to originate in the glenoid attachment of the posterior band of the inferior glenohumeral ligament, possibly from traction during deceleration. Patients often have a tight posterior capsule, with capsular contracture and asymmetric shoulder motion with an IR deficit.

This lesion can often mimic internal impingement. Pain is often found in the posterior part of the shoulder and is worse in late cocking. Patients often describe a pinching sensation during throwing. Pain usually is relieved by rest. Plain radiographs will assist in differentiating this lesion from internal impingement.

FIGURE 6. Arthroscopic view of peel-back lesion of the superior labrum.

SURGICAL INTERVENTIONS

Rotator Cuff Tendonosis/Tendonitis/Bursitis

Subacromial impingement pathologies can frequently be treated nonoperatively with or without a subacromial (extra-articular) injection, often consisting of a mixture of local anesthetic and a corticosteroid. The anesthetic and steroid are used to relieve pain and inflammation, allowing the patient to more effectively perform a therapy program. After the injection is performed, a period of rest and rehabilitation is used. It is common for the patient to be re-evaluated after 2 to 3 weeks. If no improvement is seen, a second injection may be indicated. If the patient fails this nonoperative course, shoulder arthroscopy with rotator cuff debridement may be indicated. At the time of surgery, the shoulder can be assessed for other lesions and any identified pathology addressed. Often, instability and hyperlaxity are underlying causes for rotator cuff lesions.

Rotator Cuff Tear

Surgical intervention is only considered with a full-thickness rotator cuff tear or with partial-thickness tears, after the patient has failed at least 1, but usually 2, courses of rehabilitation, followed by an interval throwing program. Prior to physical therapy for partial-thickness rotator cuff tears, either a subacromial corticosteroid injection or a glenohumeral injection is frequently performed. If the patient fails this course of treatment, arthroscopy is indicated.

The first step in the operative intervention is an examination under anesthesia. After the examination under anesthesia has been performed, diagnostic arthroscopy of the shoulder begins by establishing a posterior viewing portal to visualize the glenohumeral joint. Care is taken to look at the labrum, with special attention to the superior labrum, biceps anchor, and articular surface of the rotator cuff. The glenoid and humeral articular surfaces are also visualized for lesions. Other structures visualized include the biceps tendon, superior border of the subscapularis tendon, the middle glenohumeral ligament, rotator interval, and axillary pouch. An anterior working portal is then created through the rotator interval. A probe is brought into the joint to assess integrity of the superior labrum and biceps anchor, the rotator cuff, and any other structures in question. The arthroscope is then placed in the anterior portal to visualize the posterior structures.

Once any intra-articular pathology has been identified, a full-radius shaver is brought in through the anterior portal. Any fraying of the labrum or undersurface of the rotator cuff can be debrided back to a stable base. Undersurface rotator cuff tears are evaluated for the percent thickness of the tendon that is torn. The normal rotator cuff attaches to the articular margin of the humerus, and the footprint spans approximately 14 mm from medial to lateral. Partial articular-sided tears can be measured from the articular margin to assess the percentage of injury (7 mm exposed surface from the articular margin, 50% tear). Tears of less than 50% thickness are debrided, while tears of greater than 50% thickness may also be debrided or repaired to the footprint.[37] Significant partial-thickness tears or full-thickness tears may be repaired arthroscopically or through a standard mini-open technique. Arthroscopic repair involves placing the arthroscope into the subacromial space (in most cases), performing a subacromial decompression, and repairing the involved rotator cuff tendon or tendons with side-to-side repair or suture anchors. More recently, double-row rotator cuff repairs have become increasingly popular. The postoperative outcomes of rotator cuff repairs in the overhead athlete have been reported to be less than optimal, with approximately less than 15% of athletes returning to play.[73]

Internal Impingement

As mentioned earlier, internal impingement is a common pathology seen in the overhead athlete. The best treatment for this lesion is a thorough and well-developed nonoperative treatment program. If nonoperative measures fail, surgery is indicated. As with other shoulder injuries, an examination under anesthesia, followed by diagnostic arthroscopy, is performed. Simple arthroscopic debridement of rotator cuff tears and labral fraying was originally described to treat internal impingement.[3] Results were mixed with simple debridement, and it became evident that some sort of anterior stabilization was also required to help stabilize the shoulder. Therefore, in conjunction with debridement of the rotator cuff or labral lesions, capsulolabral reconstruction[51] or thermal capsuloraphy[63] has been recommended. Generally, subacromial decompression does not have a role in the treatment of internal impingement.

SLAP Lesions

Once the diagnosis has been established, treatment options are considered. The nonsurgical treatment of SLAP lesions depends upon the type of lesion. Most lesions in the overhead athlete are type II and may not respond well to nonsurgical management.

When pain and dysfunction persist after a period of rest and rehabilitation, surgical intervention is indicated. As with other shoulder injuries, a physical examination under anesthesia is done, followed by diagnostic arthroscopy. All of the intra-articular structures are visualized and evaluated. Close attention to the superior labrum and biceps anchor is warranted.

If a true superior labral detachment is noted, arthroscopic repair is the procedure of choice. SLAP lesions occurring in the overhead athlete are almost always type II.[49] These tears must be repaired. Initially, the lesion must be identified and the surgeon determines if there is a primarily posterior or anterior component. The location of the predominant pathology dictates arthroscopic portal placement and repair techniques. Prior to repair of the lesion, a shaver must be used to debride the glenoid neck and prepare a bony bed to which the labrum is reattached. Lesions with anterior extension may or may not need an additional accessory lateral portal. Suture anchors are placed along the glenoid rim, and the labrum and biceps complex are secured back to the glenoid with arthroscopic knots. If the lesion is predominantly located posterior to the biceps anchor, an accessory posterior portal will likely need to be created. Subacromial decompression is generally not indicated after SLAP repair.

Posterior Glenoid Exostosis (Bennett's Lesion)

Treatment of athletes with this lesion is controversial. The senior author (J.R.A.) believes that the presence of posterior glenoid exostosis is highly predictive of an undersurface rotator cuff tear caused by internal impingement and injury to the posterior labrum.[6] Initially, these patients are treated with a period of active rest and supervised rehabilitation. Throwers with posterior glenoid exostosis can be conservatively managed for some time; however, long-term success is limited and surgical intervention may become necessary.[114]

As with other shoulder lesions, when nonsurgical measures fail to relieve symptoms, operative intervention is undertaken. Initially, examination under anesthesia is performed, followed by diagnostic arthroscopy. Any concurrent intra-articular pathology is addressed at the time of arthroscopy. A 70° arthroscope is placed in the anterior portal to improve visualization over the posterior glenoid rim. The posterior glenoid exostosis is uncovered through a small capsulotomy at the medial edge of the posteroinferior capsule by penetrating the capsule with a shaver just off the posterior labral attachment. A small round burr is then employed to debride the exostosis back to the normal contour of the posterior glenoid rim.[7] Underlying glenohumeral joint instability is also addressed during the surgical procedure. The posterior capsule is generally not repaired, resulting in an effective posterior capsular release.

NONOPERATIVE REHABILITATION PROGRAM

Most shoulder injuries in the overhead thrower can be successfully treated nonoperatively. The rehabilitation program involves a multiphased approach that is progressive and sequential, and is based on the physical examination, the specifically involved structures, and the primary cause. The key to successful rehabilitation is the identification of the underlying factors and structures causing the lesion. The specific goals of each of the 4 phases of the program are outlined in **APPENDIX D**. Each phase represents a progression, the exercises becoming more aggressive and demanding, and the stresses applied to the shoulder joint gradually greater.

Phase 1: Acute Phase

One of the goals, to diminish the athlete's pain and inflammation, is accomplished through the use of local therapeutic modalities such as ice, iontophoresis, nonsteroidal anti-inflammatory drugs (NSAIDs), and/or injections. We prefer the use of iontophoresis for soft tissue inflammation about the shoulder. In addition, the athlete's activities (such as throwing and exercises) must be modified to a pain-free level. The thrower is often instructed to abstain from throwing until advised by the physician or rehabilitation specialist. Additionally, stretching exercises have been shown to assist in reducing the athlete's pain.[81]

FIGURE 7. Sleeper stretch performed to increase internal rotation. The patient is asked to lay on the involved side with arm flexed to 90°. The patient grabs the wrist/forearm of the involved extremity and pushes the extremity into internal rotation. Care is given to assume the proper position to lock down the scapula. (B) Sleeper stretch with lift. The examiner lifts the patient's scapula and repositions it laterally, stabilization of the scapula may be necessary.

Another essential goal during the first phase of rehabilitation is to normalize shoulder motion, particularly shoulder IR and horizontal adduction. It is common for the overhead thrower to exhibit loss of IR of 20° or more, referred to as "GIRD." This loss of IR has been suggested to be a cause of specific shoulder injuries.[19]

We believe that the loss of IR is most often due to osseous adaptations of the humerus and posterior muscle tightness.[15] We do not believe that the loss of IR is routinely due to posterior capsular tightness. It appears that most throwers exhibit significant posterior laxity when evaluated.[15] Thus, to improve IR motion and flexibility, we prefer the stretches illustrated in **FIGURES 7 AND 8.** These stretches include the sleeper's stretch (**ONLINE VIDEO**) and supine horizontal adduction with IR. These stretches are performed to improve the flexibility of the posterior musculature, which may become tight because of the muscle contraction during the deceleration phase of throwing. We do not recommend performing stretches for the posterior capsule unless the capsule has been shown on clinical examination to be excessively hypomobile. If the posterior glenohumeral joint capsule is hypomobile, then a posterior-lateral joint mobilization glide technique is performed to effectively mobilize the posterior capsule.

FIGURE 8. Horizontal adduction with internal rotation stretch. The patient flexes the arm to 90°. The rehabilitation specialist applies a stabilizing force to the lateral border of the scapula while the arm is horizontally adducted and then applies a gentle force into internal rotation.

The rehabilitation specialist, in addition to helping restore glenohumeral motion, should assess the resting position and mobility of the scapula. Frequently, we see overhead throwers who exhibit a posture of rounded shoulders and a forward head. This posture appears associated with muscle weakness of the scapular retractor muscles due to prolonged elongation or sustained stretches. In addition, the scapula may often appear protracted and anteriorly tilted. An anteriorly tilted scapula has been shown to contribute to a loss of glenohumeral joint IR.[13,70] In overhead throwers, it is our experience that this scapular position abnormality is associated with pectoralis minor muscle tightness and lower trapezius muscle weakness, and a forward head posture. Tightness of the pectoralis minor muscle can lead to axillary artery occlusion and neurovascular symptoms, such as arm fatigue, pain, tenderness, and cyanosis.[8,82,93,95] The lower trapezius muscle is an important muscle in arm deceleration in that it controls scapular elevation and protraction.[34] Weakness of the lower trapezius muscle may result in improper mechanics or shoulder symptoms. Thus, the rehabilitation specialist should carefully assess the position, mobility, and strength of the overhead thrower's scapula. We routinely have throwers stretch their pectoralis minor muscle and strengthen the lower trapezius muscle in addition to the scapular retractors. Furthermore, a scapular brace may be utilized to assist in postural correction.

Additional primary goals of this first phase are to restore muscle strength, re-establish baseline dynamic stability, and restore proprioception. In the early phase of rehabilitation, the goal is to re-establish muscle balance.[112,113] Therefore, the focus is on improving the strength of the weak muscles such as the external rotator muscles, the scapular muscles, and those of the lumbopelvic region and lower extremities.[112,113] If the injured athlete is extremely sore or in pain, submaximal isometric exercises should be employed; conversely, if the athlete exhibits minimal soreness, then lightweight isotonic exercises may be safely initiated. Additionally, during this phase, we use rehabilitation exercise drills designed to restore the neurosensory properties of the shoulder capsule that has experienced microtrauma and to enhance the sensitivity of the afferent mechanoreceptors.[60,62]

Specific drills that restore neuromuscular control during this initial phase are rhythmic stabilization exercises for the internal/external rotator muscles of the shoulders. Additionally, proprioceptive neuromuscular facilitation patterns are used with rhythmic stabilization and slow reversal hold to re-establish proprioception and dynamic stabilization.[58,60,62,96,111,112] The purpose of these exercises is to facilitate agonist/antagonist muscle coactivation. Efficient coactivation assists in restoring the balance in the force couples of the shoulder joint, thus enhancing joint congruency and compression.[46] Padua et al[84] used proprioceptive neuromuscular facilitation patterns for 5 weeks and significantly improved their subjects' shoulder function and enhanced functional throwing performance test scores. Uhl et al[101] reported improved proprioception after specific neuromuscular training that challenged the glenohumeral musculature.

Other exercises commonly used during this first rehabilitation phase include joint repositioning tasks[60-62] and axial loading exercises (upper extremity weight-bearing exercises). Active joint compression stimulates the articular receptors.[26,59] Thus, axial loading exercises, such as weight shifts, weight shifting on a ball, wall push-ups, and quadruped positioning drills, are beneficial in restoring proprioception.[106,112,109]

Phase 2: Intermediate Phase

In phase 2 of the rehabilitation program, the primary goals are to progress the strengthening program, continue to improve flexibility, and facilitate neuromuscular control. During this phase, the rehabilitation program is progressed to more aggressive isotonic strengthening activities, with emphasis on restoration of muscle balance. Selective muscle activation is also used to restore muscle balance and symmetry. In the overhead thrower, the shoulder external rotator muscles and scapular retractor, protractor and depressor muscles are frequently isolated because of weakness. We have established a fundamental exercise program for the overhead thrower that specifically addresses the vital muscles involved in the throwing motion.[106,118] This exercise program was developed based on the collective[12,31,47,53,64,74,78,86,91,100] information derived from electromyographic research of numerous investigators and is referred to as the "Thrower's Ten" program.[115] Frequently, the patient exhibits ER muscular weakness. The specific exercises we prefer are side-lying ER (**ONLINE VIDEO**) and prone rowing into ER. Both have been shown to elicit the highest amount of muscular activity of the posterior cuff muscles.[91]

FIGURE 9. Scapular neuromuscular control drills. The athlete lies on his side with the hand placed on the table and the clinician applies manual resistance to resist scapular movements (such as protraction and retraction). The athlete is instructed to perform slow and controlled movements.

The scapula provides proximal stability to the shoulder joint, enabling distal segment mobility. Scapular stability is vital for normal asymptomatic arm function. Several authors have emphasized the importance of scapular muscle strength and neuromuscular control in contributing to normal shoulder function.[31,56,57,85] Isotonic exercises are used to strengthen the scapular muscles. Furthermore, Wilk et al[111] developed specific exercise drills to enhance neuromuscular control of the scapulothoracic joint. These exercise drills are designed to maximally challenge the scapulothoracic muscle force couples and to stimulate the proprioceptive and kinesthetic awareness of the scapula. These scapular neuromuscular control drills are illustrated in **FIGURE 9** (**ONLINE VIDEO**).

Another popular exercise used by athletes is the "empty can" exercise. With this exercise movement, the arm is placed in the scapular plane with the hand placed in full IR (thumb down). Originally Jobe and Moynes[52] reported high levels of activation of the supraspinatus muscles during this exercise. Recently, Reinold et al[90,91] reported that the best exercise for supraspinatus muscle was instead the "full can" exercise. Blackburn et al[12] noted that the position with the patient lying prone and with the arm abducted to 100° and full ER produced the highest

FIGURE 10. Ball throw into wall. The patient throws a 2-pound (0.9 kg) Plyoball (Functional Integrated Technologies, Watsonville, CA) against the wall at end range of external rotation (late cocking).

FIGURE 11. Neuromuscular dynamic stabilization exercise: exercise tubing resisting shoulder external rotation with manual resistance at end range.

EMG signal in the supraspinatus muscles compared to the empty can position.

Also during this second rehabilitation phase, the overhead throwing athlete is instructed to perform strengthening exercises for the lumbopelvic region, including the abdomen and lower back musculature. Plus, the athlete should perform lower extremity strengthening and participate in a running program, including jogging and sprinting. Upper extremity stretching exercises are continued as needed to maintain soft tissue flexibility.

Phase 3: Advanced Strengthening Phase

In phase 3, the advanced strengthening phase, the goals are to initiate aggressive strengthening drills, enhance power and endurance, perform functional drills, and gradually initiate throwing activities. During this phase, the athlete performs the Thrower's Ten exercise program, continues manual resistance stabilization drills, and initiates plyometric drills. Dynamic stabilization drills are also performed to enhance proprioception and neuromuscular control. These drills include specific stabilization techniques that employ the concept of perturbations and range stability. These drills include rhythmic stabilization exercise drills by throwing a ball against the wall (**FIGURE 10**), push-ups onto a ball, and tubing ER with end range manual resistance (**FIGURE 11, ONLINE VIDEO**). Many of the stabilization exercises may be performed on a physioball. The authors believe that performing these exercises improves dynamic stabilization and increases muscular demands (**FIGURES 12 AND 13**). Plyometric training may be used to enhance dynamic stability, enhance proprioception, and gradually increase the functional stresses placed on the shoulder joint.

Plyometric exercises employ 3 phases, all intended to use the elastic reactive properties of muscle to generate maximal force production.[16,22,25] The first phase is the eccentric phase, where a rapid prestretch is applied to the musculotendinous unit, stimulating the muscle spindle. The second phase is the amortization phase, representing the time between eccentric and concentric phases. This time should be as short as possible so that the beneficial neurologic effects of prestretch are not lost. The final phase is the resultant concentric action. Wilk et al[111-112,114] established a plyometric exercise program for the overhead thrower. The initial plyometric program consists of 2-handed exercise drills such as chest passes, overhead soccer throws, side-to-side throws, and side-throws. The goal of the plyometric drills is to transfer energy from the lower extremities and trunk to the upper extremity. Once these 2-handed exercise drills are mastered, the athlete is progressed to 1-handed drills. These drills include standing 1-handed throws in a functional throwing position, wall dribbling, and plyometric step-and-throws. Swanik et al[97] reported that a 6-week plyometric training program resulted in enhanced joint position sense, enhanced

FIGURE 12. Seated external rotation on a physioball with single-leg support. Resisted external rotation is performed with exercise tubing. To enhance the demands on the shoulder stabilizers, a rhythmic stabilization technique may be performed.

FIGURE 13. Scapular horizontal abduction performed on a physioball. This exercise is performed to enhance scapular muscle activity and core stability.

kinesthesia, and decreased time to peak torque generation during isokinetic testing. Fortun et al[44] noted improved shoulder IR power and throwing distances after 8 weeks of plyometric training in comparison with conventional isotonic training.

Additionally, muscular endurance exercises should be emphasized for the overhead thrower. Lyman et al[68] documented that the overhead athlete is at greater risk for shoulder or elbow injuries when pitching when fatigued. Recently, Murray et al[79] documented the effects of fatigue on the entire body during pitching using kinematic and kinetic motion analysis. Once the thrower was fatigued, shoulder ER decreased and ball velocity diminished, as did lead lower extremity knee flexion and shoulder adduction torque. Voight et al[103] documented a relationship between muscle fatigue and diminished proprioception. Chen et al[24] demonstrated that once the rotator cuff muscles are fatigued, the humeral head migrates superiorly when arm elevation is initiated. Furthermore, Lyman et al[67] reported that the predisposing factor that correlated to the highest percentage of shoulder injuries in Little League pitchers was complaints of muscle fatigue while pitching. Thus the endurance drills described here appear critical for the overhead thrower.

Specific endurance exercise drills we use include wall dribbling with a Plyoball (Functional Integrated Technologies, Watsonville, CA), wall arm circles, upper body cycle, or isotonic exercises using lower weights with higher repetitions. Other techniques that may be beneficial to enhance endurance include throwing an underweighted or overweighted ball (that is, a ball that is either less than or more than the weight of an official baseball).[17,25,32,39,65,102] These techniques are designed to enhance training, coordination, and the transfer of kinetic energy. Fortun et al[44] noted an increase in shoulder IR strength and power after an 8-week plyometric training program using a weighted ball. Most commonly, the underweighted ball is used to improve the transfer of energy and angular momentum.[32,39,102] Conversely, the overweighted ball is generally used to enhance shoulder strength and power.[32,39,102]

During this third rehabilitation phase, an interval throwing program may be initiated. Before initiating such a program, we occasionally suggest that the athlete perform "shadow" or mirror throwing, which is the action of mimicking throwing mechanics into a mirror, but not actively throwing. This is designed to allow the athlete to work on proper throwing mechanics before throwing a baseball. The interval throwing program[92] is initiated once the athlete can fulfill these specific criteria: (1) satisfactory clinical examination, (2) nonpainful ROM, (3) satisfactory isokinetic test results, and (4) appropriate rehabilitation progress. The interval throwing program is designed to gradually increase the quantity, distance, intensity, and type of throws needed to facilitate the gradual restoration of normal biomechanics.

Interval throwing is organized into 2 phases: phase 1 is a long-toss program (45-180 ft [15-60 m]) and phase 2 is an off-the-mound program for pitchers. During this third rehabilitation phase, we usually initiate phase 1 of the interval throwing program at 45 ft (15 m) and progress to throwing from 60 ft (20 m). The athlete is instructed to use a crow-hop type of throwing mechanism and lob the ball with an arc for the prescribed distance. Flat-ground, long-toss throwing is used before throwing off the mound to allow the athlete to gradually increase the applied loads to the shoulder while using proper throwing mechanics. In addition, during this phase of rehabilitation, we routinely allow the position player to initiate a progressive batting program that progresses the athlete from swinging a light bat, to hitting a ball off a tee, to soft-toss hitting, to batting practice.

Phase 4: Return-to-Throwing Phase

Phase 4 of the rehabilitation program, the return-to-throwing phase, usually involves the progression of the interval throwing program. For pitchers, we progress the long-toss program to 120 ft (40 m), whereas position players would progress to throwing from 180 ft (60 m). Once the pitcher has successfully completed throwing from 120 ft, the athlete is instructed to throw 60 ft from the windup on level ground. Once this step is successfully completed, phase II (throwing from the mound) is performed.[92] Position players continue to progress the long-toss program to 180 ft, then perform fielding drills from their specific position. While the athlete is performing the interval throwing program, the clinician should carefully monitor the thrower's mechanics and throwing intensity. In a study conducted at our biomechanics laboratory, we objectively measured the throwing intensity of healthy pitchers. When pitchers were asked to throw at 50% effort, radar gun analysis indicated that actual effort was approximately 83% of their maximum speed. When asked to throw at 75% effort, they threw at 90% of their maximum effort. This indicates that these athletes threw at greater intensities than were suggested, which may imply difficulty of controlling velocity at lower throwing intensities.

In addition, during this fourth phase, the thrower is instructed to continue all the exercises previously described to improve upper extremity strength, power, and endurance. The athlete is also instructed to continue the Thrower's Ten program, stretching program, core stabilization exercise training, and lower extremity strengthening activities. Lastly, the athlete is counseled on a year-round conditioning program based on the principles of periodization.[38] Thus, the athlete is instructed when to begin such things as strength training and throwing.[112] To prevent the effects of overtraining or throwing when poorly conditioned, it is critical to instruct the athlete specifically on what to do through specific exercises throughout the year. This is especially critical in preparing the athlete for the following season. Wooden et al[119] demonstrated that performing a dynamic variable resistance exercise program significantly increased throwing velocity.

SUMMARY

Overhead-throwing athletes typically present with a unique musculoskeletal profile. The overhead thrower exhibits ROM, postural, and strength changes, which appear to be from adaptations from imposed demands. This unique client exhibits unique lesions, and the recognition and treatment of these lesions may present a significant challenge to the clinician. Based on the accurate recognition of the lesion and underlying cause of the pathology, a successful nonoperative or in some cases operative treatment plan can be implemented. In this manuscript, we have attempted to provide the reader with information regarding the evaluation and treatment of the overhead throwing athlete.

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APPENDIX A

BASELINE FOR ESTABLISHING A THROWING HISTORY IN OVERHEAD ATHLETES

- General information
  - Age
  - Gender
  - Dominant-handedness
  - Position
  - Years throwing
  - Level of competition
- Injury pattern
  - Onset of symptoms: acute, chronic
  - History of trauma or sudden injury
- Symptom characteristics
  - Location of symptoms: anterior, lateral, posterior
  - Quality of symptoms: sharp, dull, burning
  - Presence of mechanical symptoms
  - Presence of weakness or instability
  - Severity of symptoms
  - Duration of symptoms
  - Activities that worsen symptoms
  - Activities that relieve symptoms
  - Presence of neurosensory changes
  - Phases of throwing that produce symptoms
  - Innings pitched per season/year
  - Frequency of starts/relief appearances
  - Changes in velocity of pitches
  - Loss of control/location of pitches
- Treatment/rehabilitation
  - Amount of rest from throwing
  - Type and duration of rehabilitation
  - Type, location, and frequency of injections
- Related symptoms
  - Cervical spine
  - Radicular symptoms
  - Brachial plexus injury
  - Peripheral nerve entrapment
- Medical information
  - Past medical/surgical history
  - Medications
  - Allergies
  - Family/social history
  - Review of test, symptoms, and systems

APPENDIX B

PHYSICAL EXAMINATION OF THE THROWING SHOULDER

Subjective History

Observation/Inspection

Palpation

1. Sternoclavicular joint
2. Acromioclavicular joint
3. Clavicle, acromion, coracoid
4. Bicipital groove
5. Scapula
6. Musculature

Range of Motion

1. Crepitus
2. Glenohumeral motion
   a. Active
   b. Passive
3. Scapulothoracic motion

Motor Strength

1. Glenohumeral
2. Scapular
3. Arm/forearm

Impingement Signs

1. Neer/Hawkins signs
2. Cross-chest adduction test
3. Internal impingement sign

Stability Tests

1. Sulcus sign
2. Anterior drawer
3. Anterior fulcrum
4. Relocation test
5. Posterior drawer
6. Posterior fulcrum
7. Push-pull test

Special Tests, Biceps

1. Speed's test
2. Yergason's test

Special Tests, SLAP

1. Clunk test
2. O'Brien's active compression
3. Biceps load
4. Lemak test
5. Pronated biceps load
6. Resisted supinated external rotation test

Neurologic Examination

Cervical Spine Examination

Performance Testing

1. Isokinetic testing
2. Motion analysis testing

APPENDIX C

CLASSIFICATION OF MOST COMMON SHOULDER LESIONS IN OVERHEAD ATHLETES

Rotator Cuff Lesions
- Tendonitis
- Tendonosis
- Strains
- Bursitis

Rotator Cuff Tears
- Partial thickness
- Full thickness
- Internal impingement

Glenohumeral Joint Capsular Lesions
- Laxity
- Instability
- Capsulitis

Superior Labral Tear (SLAP)
- Frayed (type I)
- Tear (type III, IV)
- Detached (type II)
- Peel-back

Osseous Lesions
- Glenoid osteochondritis dissecans
- Bennett's lesion

Biceps Tendon Lesions
- Tendinitis
- Tendonosis
- Subluxation

Neurovascular Lesions
- Axillary neuropathy, quadrilateral space
- Long thoracic neuropathy
- Thoracic outlet syndrome

APPENDIX D

NONOPERATIVE REHABILITATION OF THE OVERHEAD ATHLETE: PHASES AND GOALS

Phase 1: Acute phase

Goals:
- Diminish pain and inflammation
- Normalize motion
- Delay muscular atrophy
- Reestablish dynamic stability (muscular balance)
- Control functional stress/strain

Exercises and modalities:
- Cryotherapy, iontophoresis, ultrasound, electrical stimulation
- Flexibility and stretching for posterior shoulder muscles to improve shoulder internal rotation and horizontal adduction
- Rotator cuff strengthening (especially external rotator muscles)
- Scapular muscles strengthening (especially retractor and depressor muscles)
- Dynamic stabilization exercises (rhythmic stabilization)
- Weight-bearing exercises
- Proprioception training
- Abstain from throwing

Phase 2: Intermediate phase

Goals:
- Progress strengthening exercises
- Restore muscular balance
- Enhance dynamic stability
- Control flexibility and stretches

Exercises and modalities:
- Continue stretching and flexibility (especially shoulder internal rotation and horizontal adduction)
- Progress isotonic strengthening
  - Complete shoulder program
  - Thrower's Ten program
- Rhythmic stabilization drills
- Initiate core lumbopelvic region strengthening program
- Initiate lower extremity program

Phase 3: Advanced strengthening phase

Goals:
- Aggressive strengthening
- Progress neuromuscular control
- Improve strength, power, and endurance

Exercises and modalities:
- Flexibility and stretching
- Rhythmic stabilization drills
- Thrower's Ten program
- Initiate plyometric program
- Initiate endurance drills
- Initiate short-distance throwing program

Phase 4: Return-to-activity phase

Goals:
- Progress to throwing program
- Return to competitive throwing
- Continue strengthening and flexibility drills

Exercises:
- Stretching and flexibility drills
- Thrower's Ten program (see Wilk et al[115] for full program)
- Plyometric program

Progress interval throwing program to competitive throwing (see Reinold et al[92] for full program)