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Current Concepts in the Scientific and Clinical Rationale Behind Exercises for Glenohumeral and Scapulothoracic Musculature

The biomechanical analysis of rehabilitation exercises has gained recent attention. As our knowledge of specific muscle biomechanics and function has increased, we have seen a gradual progression towards more scientifically based rehabilitation exercises. Several investigators have sought to describe common rehabilitation exercises using kinematics, kinetics, and electromyographic (EMG) data in an attempt to better understand the implications of each exercise on the soft tissues of the glenohumeral and scapulothoracic joints. Advances in the understanding of the biomechanical factors of rehabilitation have led to the enhancement of rehabilitation programs that seek to facilitate recovery, while placing minimal strain on specific healing structures.

Though the fields of orthopedics and sports medicine have evolved to emphasize the necessity of evidence-based practice, few studies have been conducted to determine the efficacy of specific shoulder rehabilitation exercises. Thus, knowledge of anatomy, biomechanics, and function of specific musculature is critical in an attempt to develop the most advantageous rehabilitation programs.

The purpose of this paper is to provide an overview of the biomechanical and clinical implications associated with the rehabilitation of the glenohumeral and scapulothoracic joints. We will review the function and biomechanics of each muscle, with specific emphasis on many commonly performed rehabilitation exercises. The goal of this is to provide the clinician with a thorough overview of the available information to develop safe, potentially effective, and appropriate exercise programs for injury rehabilitation and prevention.

Rotator Cuff Muscles

The rotator cuff has been shown to be a substantial dynamic stabilizer of the glenohumeral joint in multiple shoulder positions. Appropriate rehabilitation progression and strengthening of the rotator cuff muscles are important to provide appropriate force to help elevate and move the arm, compress and center the humeral head within the glenoid fossa during shoulder movements (providing dynamic stability), and provide a counterforce to humeral head superior translation resulting from del...
to the frontal plane) with glenohumeral abduction at 100° with full ER, or prone full can, position. The results of studies comparing these exercises provide inconsistent results due to methodological limitations, including lack of statistical analysis, lack of data for all 3 exercises, and absence of data on deltoid muscle activity.

Recently, Reinold et al. comprehensively evaluated the EMG signal of the supraspinatus and deltoid musculature during the full can, empty can, and prone full can exercises in an attempt to clarify the muscular activation during these exercises. The results showed that all 3 exercises provide a similar amount of supraspinatus activity ranging from 62% to 67% of maximal voluntary isometric contraction (MVIC). However, the full can exercise demonstrated a significantly lower amount of middle and posterior deltoid activity compared to the 2 other exercises. This is clinically significant when trying to strengthen the supraspinatus while simultaneously minimizing potentially disadvantageous superior shearing force due to deltoid activity.

In patients with shoulder pain, weakness of the rotator cuff, or inefficient dynamic stabilization, it is the authors’ opinion that activities that produce higher levels of deltoid activity in relation to supraspinatus activity, such as the empty can and prone full can exercise, may be detrimental. This is due to the increased amount of sup-

CLINICAL COMMENTARY

Jobe was the first to recommend elevation in the scapular plane (30° anterior to the frontal plane) with glenohumeral IR, or the “empty can” exercise, to strengthen the supraspinatus muscle. Other authors have suggested the “full can” position, or elevation in the scapular plane with glenohumeral ER, to best strengthen and test the supraspinatus muscle. Furthermore, compared to the empty can exercise, Blackburn reported significantly greater supraspinatus activity during prone horizontal abduction at 100° with full ER, or prone full can, position. The results of studies comparing these exercises provide inconsistent results due to methodological limitations, including lack of statistical analysis, lack of data for all 3 exercises, and absence of data on deltoid muscle activity.

The supraspinatus compresses, abducts, and generates a small ER torque to the glenohumeral joint. Supraspinatus activity increases as resistance increases during abduction/scaption movements, peaking at 30° to 60° of elevation for any given resistance. At lower elevation angles, supraspinatus activity increases, providing additional humeral head compression within the glenoid fossa to counter the humeral head superior translation occurring with contraction of the deltoid. Due to a decreasing moment arm with abduction, the supraspinatus is a more effective abductor in the scapular plane at smaller abduction angles.

Relatively high supraspinatus activity has been measured in several common rotator cuff exercises and in several exercises that are not commonly thought of as rotator cuff exercises, such as standing forward scapular punch, rowing exercises, push-up exercises, and 2-hand overhead medicine ball throws. These results suggest the importance of the rotator cuff in providing dynamic glenohumeral stability by centering the humeral head within the glenoid fossa during all upper extremity functional movements. This is an important concept for the clinician to understand. The muscle’s ability to generate abduction torque in the scapular plane appears to be greatest with the shoulder in neutral rotation or in slight IR or ER. This biomechanical advantage has led to the development of exercises in the plane of the scapula to specifically strengthen the supraspinatus.

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In patients with shoulder pain, weakness of the rotator cuff, or inefficient dynamic stabilization, it is the authors’ opinion that activities that produce higher levels of deltoid activity in relation to supraspinatus activity, such as the empty can and prone full can exercise, may be detrimental. This is due to the increased amount of supe-
rior humeral head migration that may be observed when the rotator cuff does not adequately compress the humerus within the glenoid fossa to counteract, or oppose, the superior pull of the deltoid (FIGURE 1). Poppen and Walker have shown that the empty can exercise results in a greater superior-orientated force vector than the full can exercise. This superior humeral head migration may result in subacromial impingement, subdeltoid bursa trauma, bursal thickening, and may result in tendon degeneration and eventual failure. Clinically, superior humeral head migration may be disadvantageous to patients with rotator cuff pathology or a deficiency in glenohumeral dynamic stabilization that are symptomatic. This may partially explain why the empty can position often elicits a certain amount of pain and discomfort in patients.

In addition to the altered ratio of supraspinatus to deltoid muscle activity, there are several reasons why the full can exercise may be preferred over the empty can exercise during rehabilitation and supraspinatus testing. Anatomically, the IR of the humerus during the empty can exercise does not allow the greater tuberosity to clear from under the acromion during arm elevation, which may increase subacromial impingement risk because of decreased subacromial space width.

Biomechanically, shoulder abduction performed in extreme IR progressively decreases the abduction moment arm of the supraspinatus from 0° to 90° of abduction. A diminished mechanical advantage may result in the supraspinatus needing to generate more force, thus increasing the tensile stresses in the injured or healing tendon. This may also make the exercise more challenging for patients with weakness, facilitating compensatory movements such as a shoulder “shrug.”

Scapular kinematics are also different between these exercises, with scapular IR, or “winging” (which occurs in the transverse plane with the scapular medial border moving posterior away from the trunk) and anterior tilt (which occurs in the sagittal plane with the scapular inferior angle moving posterior away from the trunk) being greater with the empty can compared to the full can exercise. This occurs in part because IR of the humerus in the empty can position tensions both the posteriorinferior capsule of the glenohumeral joint and the rotator cuff (primarily the infraspinatus). Tension in these structures contributes to anterior tilt and IR of the scapula, which contribute to scapular protraction. This is clinically important because scapular protraction has been shown to decrease the width of the subacromial space, increasing the risk of subacromial impingement. In contrast, scapular retraction has been shown to both increase subacromial space width and increase supraspinatus strength potential (enhanced mechanical advantage), when compared to a more protracted position. These data also emphasize the importance of

FIGURE 1. Direction of the magnitude of the resultant force vector for different glenohumeral joint positions as a function of different muscle activity, (A) deltoid activity, (B) rotator cuff activity, (C) combined deltoid and rotator cuff activity. Reprinted with permission from Morrey et al.

FIGURE 2. The position of the resultant force vector of the rotator cuff and deltoid for different positions of arm elevation with (N) neutral rotation, (I) internal rotation, and (X) external rotation. Reprinted with permission from Poppen and Walker.
strengthening the scapular retractors and maintaining a scapular retracted posture during shoulder exercises. The authors routinely instruct patients to emphasize an upright posture and a retracted position of the scapula during all shoulder and scapula strengthening exercises.

Thus, the full can exercise appears to be the most advantageous exercise while the empty can exercise is not commonly recommended. The prone full can exercise warrants further consideration because the exercise results in greater EMG signal of the posterior deltoid than the middle deltoid, which may result in lesser superior sheer force. The prone full can exercise may also be beneficial because of scapular muscle recruitment.

**Infraaspinatus and Teres Minor**
The infraspinatus and teres minor comprise the posterior cuff, which provides glenohumeral compression and resists superior and anterior humeral head translation by exerting an interpose of force on the humeral head.50 The posterior cuff muscles provide glenohumeral ER, which functionally helps clear the greater tuberosity from under the coracoacromial arc during overhead movements, thus minimizing subacromial impingement.

Based on 3-D biomechanical shoulder models, the maximum predicted isometric infraspinatus force was 723 N for ER at 90° of abduction and 909 N for ER at 0° of abduction.24 The maximum predicted teres minor force was much less than for the infraspinatus during maximum ER at both 90° (111 N) and 0° abduction (159 N).24 The effectiveness of the muscles of the posterior rotator cuff to externally rotate the arm depends on glenohumeral position. The superior, middle, and inferior heads of the infraspinatus have their largest ER moment arm (approximately 2.2 cm) and generate their greatest torque at 0° abduction.46 As the abduction angle increases, the moment arms of the inferior and middle heads stay relatively constant, while the moment arm of the superior head progressively decreases until it is about 1.3 cm at 60° abduction.65 These data imply that the infraspinatus is a more effective external rotator at lower shoulder abduction angles. The teres minor has a relatively constant ER moment arm (approximately 2.1 cm) and the ability to generate torque throughout shoulder abduction movement, which implies that shoulder abduction angle does not affect the effectiveness of the teres minor to generate ER torque.65

Several studies have been designed to test the results of the model; but, as in studies on the supraspinatus, variations in experimental methodology have resulted in conflicting results and controversy in exercise selection.3,5,17,19,27,31,44,45,46,70,79,81 Several exercises have been recommended based on EMG data, including shoulder ER in the side-lying,27,70 standing,27,70 or prone3,70 positions performed at 0°,3,70 45°,27,70 and 90°3,70 of abduction. Another exercise that has been shown to generate a high EMG signal of the infraspinatus and teres minor is prone horizontal abduction with ER.5,70

Reinold et al70 analyzed several different exercises commonly used to strengthen the shoulder external rotators to determine the most effective exercise and position to recruit muscle activity of the posterior rotator cuff. The authors report that the exercise that elicited the most combined EMG signal for the infraspinatus and teres minor was shoulder ER in side-lying (infraaspinatus, 62% maximal voluntary isometric contraction [MVIC]; teres minor, 67% MVIC), followed closely by standing ER in the scapular plane at 45° of abduction (infraaspinatus, 53% MVIC; teres minor, 55% MVIC), and finally prone ER in the 90° abducted position (infraaspinatus, 50% MVIC; teres minor, 48% MVIC).

Exercises in the 90° abducted position are often incorporated to simulate the position and strain on the shoulder during overhead activities such as throwing. This position produced moderate activity of the external rotators but also increased activity of the deltoid and supraspinatus. It appears that the amount of infraspinatus and teres minor activity progressively decreases as the arm moves into an abducted position, while activity of the supraspinatus and deltoid increases. This suggests that as the arm moves into a position of increased vulnerability away from the body, the supraspinatus and deltoid are active to assist in the ER movement, while providing some degree of glenohumeral stability through muscular contraction.

While standing ER exercises performed at 90° of shoulder abduction may have a functional advantage over exercises performed at 0° of shoulder abduction or performed in the scapular plane, due to the close replication in sporting activities, the combination of shoulder abduction and ER places strain on the shoulder capsule, particularly the anterior band of the inferior glenohumeral ligament.30,50,51 The clinician must carefully consider this when designing programs for patients with capsulolabral pathology.

Side-lying ER may be the optimal exercise to strengthen the external rotators based on the previously mentioned studies. The inclusion of this exercise should be considered in all exercise programs attempting to increase ER strength or decrease capsular strain.

Theoretically, ER performed at 0° of shoulder abduction with a towel roll between the rib cage and the arm provides both the low capsular strain and also a good balance between the muscles that externally rotate the arm and the muscles that adduct the arm to hold the towel. Our clinical experience has shown that adding a towel roll to the ER exercise provides assistance to the patient by ensuring that proper technique is observed without muscle substitution. Reinold et al20 report that adding a towel roll to the exercise consistently exhibited a tendency towards higher activity of the posterior rotator cuff muscles as well. An increase of 20% to 25% in EMG signal of the infraspinatus and teres minor was noted when using the towel roll compared to no towel roll.

What is not readily apparent is the
significant role of the infraspinatus as a shoulder abductor in the scapular plane. From 3-D biomechanical shoulder models, predicted infraspinatus force during maximum isometric effort scapular plane abduction (90° position) was 205 N, nearly twice the predicted force from the supraspinatus in this position. Liu et al reported that in scapular plane abduction with neutral rotation the infraspinatus has an abductor moment arm that was small at 0° abduction, but increased to 1 cm at 15° abduction, and remained fairly constant throughout increasing abduction angles. Moreover, infraspinatus activity increases as resistance increases, peaking at 30° to 60° for any given resistance. As resistance increases, infraspinatus activity increases to help generate a higher shoulder scapular abduction torque, and, at lower elevation angles, infraspinatus activity increases to resist superior humeral head translation due to the action of the deltoid.

In contrast to the infraspinatus, the teres minor generates a weak shoulder adductor torque due to its relatively lower attachments to the scapula and humerus. A 3-D biomechanical model of the shoulder reveals that the teres minor does not generate scapular plane abduction torque when it contracts, but, rather, generates an adduction torque and 94 N of force during maximum effort scapular plane adduction. In addition, Otis et al reported that the adductor moment arm of the teres minor was approximately 0.2 cm at 45° of IR and approximately 0.1 cm at 45° of ER. These data imply that the teres minor is a weak adductor of the humerus, regardless of the rotational position of the humerus. In addition, because of its posterior position at the shoulder, it also helps generate a weak horizontal abduction torque. Therefore, although its activity is similar to the infraspinatus during ER, it is hypothesized that the teres minor would not be as active as the infraspinatus during scapular abduction, abduction, and flexion movements, but would show activity similar to that of the infraspinatus during horizontal abduction. This hypothesis is supported by EMG and magnetic resonance imaging data, which show that teres minor activity during flexion, abduction, and scapular abduction is drastically less than infraspinatus activity. Even though the teres minor generates an adduction torque, it is active during these different elevation-type movements, as it likely acts to enhance joint stability by resisting superior humeral head translation and providing humeral head compression within the glenoid fossa. This is especially likely the case at lower shoulder abduction angles and when abduction and scapular abduction movements are performed against greater resistance. In contrast to the movements of shoulder abduction, scapular abduction, and flexion, teres minor activity is much higher during prone horizontal abduction at 100° abduction with ER, exhibiting similar activity as the infraspinus.

**Subscapularis**

The subscapularis provides glenohumeral compression, IR, and anterior stability of the shoulder. From 3-D biomechanical shoulder models, predicted subscapularis force during maximum effort IR was 1725 N at 90° abduction and 1297 N at 0° abduction. Its superior, middle, and inferior heads all have their largest IR moment arm (approximately 2.5 cm) and torque generation at 0° abduction. As the abduction angle increases, the moment arms of the inferior and middle heads stay relatively constant, while the moment arm of the superior head progressively decreases until it is about 1.3 cm at 60° abduction. These data imply that the upper portion of the subscapularis muscle (innervated by the upper subscapularis nerve) may be a more effective internal rotator at lower abduction angles compared to higher abduction angles. However, there is no significant difference in upper subscapularis activity among IR exercises performed at 0°, 45°, or 90° abduction. Abduction angle does not appear to affect the ability of the lower subscapularis (innervated by the lower subscapularis nerve) to generate IR torque. However, lower subscapularis muscle activity is affected by abduction angle, where some EMG data show significantly greater activity with IR at 0° abduction compared to IR at 90° abduction, while EMG data of another study show greater activity with IR exercise performed at 90° compared to 0° abduction. Performing IR at 0° abduction produces similar amounts of upper and lower subscapularis activity.

Although biomechanical data remain inconclusive as to which position to perform IR exercises (0° versus 90° abduction), during IR at 0° abduction the action of the subscapularis is assisted by several large muscles, such as the pectoralis major, latissimus dorsi, and teres major. Clinically, this may allow for compensation of larger muscles during the exercise in the presence of subscapularis weakness. Deck et al demonstrated that IR at 90° abduction produced less pectoralis major activity compared to 0° abduction. The authors' findings revealed that pectoralis major and latissimus dorsi activity increased when performing IR exercises in an adducted position or while moving into an adducted position during the exercise. Thus, IR at 90° abduction may be performed if attempting to strengthen the subscapularis while minimizing larger muscle group activity.

The subscapularis is active in numerous shoulder exercises other than specific IR of the shoulder. Decke et al reported high subscapularis activity during the push-up with plus and dynamic-hug exercises. These authors also described another exercise that consistently produced high levels of subscapularis activity, which they called the "diagonal exercise" (FIGURE 3). Relatively high subscapularis activity has been measured while performing side-lying shoulder abduction, standing shoulder extension from 90° to 0°, military press, D2 diagonal proprioceptive neuromuscular facilitation (PNF) pattern flexion and extension, and PNF scapular...
clinch rotation, depression, elevation, protraction, and retraction movements.17,33,44,53,75,79

The subscapularis also generates an abduction torque during arm elevation.20,44 From 3-D biomechanical shoulder models, predicted subscapularis force during maximum effort scapular plane abduction at 90° was 283 N, approximately 2.5 times the predicted force for the supraspinatus in this position.34 This was similar to that of the infraspinatus, highlighting the theoretical force couple that the 2 muscles provide to center the humeral head within the glenoid fossa during abduction. Liu et al50 reported that in scapular plane abduction with neutral rotation the subscapularis had a peak abductor moment arm of 1 cm at 0° abduction, which slowly decreased to 0 cm at 60° abduction. Moreover, the abductor moment arm of the subscapularis generally decreased as abduction was performed with greater shoulder IR,20 such as performing the empty can exercise. In contrast, the abductor moment arm of the subscapularis generally increased as abduction was performed with greater shoulder ER, similar to performing the full can exercise.

Otis et al65 reported that the superior, middle, and inferior heads of the subscapularis all have an abductor moment arm (greatest for the superior head and least for the inferior head) that varies as a function of humeral rotation. The lengths of the moment arm for the 3 muscle heads are approximately 0.4 to 2.2 cm at 45° of ER, 0.4 to 1.4 cm in neutral rotation, and 0.4 to 0.5 cm at 45° of IR. These data suggest that the subscapularis is most effective as a scapular plane abductor with the shoulder in ER and least effective with the shoulder in IR. Therefore, the simultaneous activation of the subscapularis and infraspinatus during arm elevation generates both an abductor moment and an inferiorly directed force to the humeral head to resist superior humeral head translation.24 In addition, a simultaneous activation neutralizes the IR and ER torques these muscles generate, further enhancing joint stability.

DELTOID

The deltoid plays an important role in shoulder biomechanics and during glenohumeral and scapulothoracic exercises. Extensive research has been conducted on deltoid activity during upper extremity weight-lifting exercises, such as bench press, dumbbells, military press, and push-ups.44,53,63,79,81,83

The abductor moment arm is approximately 0 cm for the anterior deltoid and 1.4 cm for the middle deltoid when the shoulder is in 0° abduction and neutral rotation in the scapular plane.50,65 The magnitude of these moment arms progressively increases with shoulder abduction, such that, by 60° of abduction, they are approximately 1.5 to 2 cm for the anterior deltoid and 2.7 to 3.2 cm for the middle deltoid. From 0° to 40° of abduction the moment arms for the anterior and middle deltoids are less than the moment arms for the supraspinatus, subscapularis, and infraspinatus.50,65 These data suggest that the anterior and middle deltoids are not effective shoulder abductors at low abduction angles and the shoulder in neutral rotation, especially the anterior deltoid. This is in contrast to the supraspinatus and to a lesser extent the infraspinatus and subscapularis, which are more effective shoulder abductors at low abduction angles. These biomechanical data are consistent with EMG data, in which anterior and middle deltoid activity generally peaks between 60° to 90° of abduction in the scapular plane, while supraspinatus, infraspinatus, and subscapularis activity generally peaks between 30° and 60° of shoulder abduction in the scapular plane.65

The abductor moment arm for the anterior deltoid changes considerably with humeral rotation, increasing with ER and decreasing with IR.20 At 60° ER and 0° abduction, a position similar to the beginning of the full can exercise, the anterior deltoid moment arm is 1.5 cm (compared to 0 cm in neutral rotation), which makes the anterior deltoid an effective abductor even at small abduction angles.20 By 60° abduction with ER, its moment arm increased to approximately 2.5 cm (compared to approximately 1.5 to 2 cm in neutral rotation).20 In contrast, at 60° IR at 0° abduction, a position similar to the beginning of the empty can exercise, its moment arm was...
0 cm (the same as with neutral rotation), which suggests that in this position the anterior deltoid is not an effective abductor.49

It has been reported that, given a peak isometric abduction torque of 25 N·m at 0° abduction and neutral rotation, up to 35% to 65% of this torque may be generated by the middle deltoid, 30% by the subscapularis, 25% by the supraspinatus, 10% by the infraspinatus, 2% by the anterior deltoid, and 0% by the posterior deltoid.49 Interestingly, the rotator cuff provides a significant contribution to the abduction torque. The ineffectiveness of the anterior and posterior deltoids to generate abduction torque with neutral rotation may appear surprising;50,60 However, it is important to understand that the low abduction torque for the anterior deltoid does not mean that this muscle is only minimally active. In fact, because the anterior deltoid has an abductor moment arm near 0 cm, the muscle could be very active and generate very high force but very little torque (in 0° abduction this force attempts to translate the humeral head superiorly).

The aforementioned torque data are complemented and supported by muscle force data from Hughes and An.34 These authors reported predicted forces from the deltoid and rotator cuff during maximum effort abduction with the arm 90° abducted and in neutral rotation. Posterior deltoid and teres minor forces were only 2 N and 0 N, respectively, which further demonstrates the ineffectiveness of these muscles as shoulder abductors. In contrast, middle deltoid force was the highest at 434 N, which suggests a high contribution of this muscle during abduction. The anterior deltoid generated the second highest force of 323 N. This may appear surprising given the low abductor torque for this muscle reported above, but it should be re-emphasized that force and torque are not the same, and that the shoulder was positioned at 90° abduction in the study by Hughes and An,49 in contrast to 0° abduction in the study by Liu et al.50 As previously mentioned, the moment arm of the anterior deltoid progressively increases as abduction increases, and it becomes a more effective abductor. It is also important to remember that muscle force is generated not only to generate joint torque, but also to provide stabilization, such as joint compression. Also of interest is the 608-N force that, collectively, the subscapularis (283 N), infraspinatus (205 N), and supraspinatus (117 N) generate. These large forces are generated not only to abduct the shoulder but also to compress and stabilize the joint, and neutralize the superiorly directed force generated by the deltoid at lower abduction angles.

It should also be noted that deltoid muscle force in different shoulder positions may also affect shoulder stability. All 3 heads of the deltoid generate a force that increases shoulder stability at 60° abduction in the scapular plane (helps to stabilize the humeral head in the glenoid fossa) but decreases shoulder stability at 60° abduction in the frontal plane (tends to translate the humeral head anterior).48 These data provide evidence for the use of scapular abduction exercises instead of abduction exercises for individuals with anterior instability.

Thus, it appears that the 3 heads of the deltoid have different roles during upper extremity movements and, therefore, different implications for exercise selection. The middle deltoid may have the most significant impact on superior humeral head migration, and exercises with high levels of middle deltoid activity (as well as anterior deltoid activity), such as the empty can exercise, should likely be minimized for most patients. Conversely, high levels of posterior deltoid activity may not be as disadvantageous as high levels of middle or anterior deltoid activity. It does not appear that the posterior deltoid has a significant role in providing abduction or superior humeral head migration. Thus, exercises such as the prone full can, which generates high levels of rotator cuff and posterior deltoid activity, may be both safe and effective for rotator cuff strengthening.

### SCAPULOTHORACIC MUSCLES

The primary muscles that control scapular movements include the trapezius, serratus anterior, levator scapulae, rhomboids, and pectoralis minor. Appropriate scapular muscle strength and balance and are important because the scapula and humerus move together in coordination during arm movement, referred to as scapulohumeral rhythm. During humeral elevation, the scapula upwardly rotates in the frontal plane, rotating approximately 1° for every 2° of humeral elevation until 120° humeral elevation, and thereafter rotates approximately 1° for every 1° humeral elevation until maximal arm elevation, achieving at least 45° to 55° of upward rotation.52,58 During humeral elevation, in addition to scapular upward rotation, the scapula also normally tilts posteriorly approximately 20° to 40° in the sagittal plane and externally rotates approximately 15° to 35° in the transverse plane.52,58

When the normal 3-D scapular movements are disrupted by abnormal scapular muscle firing patterns, fatigue, or injury, it has been hypothesized that the shoulder complex functions less efficiently, leading to injuries to the shoulder, including the glenohumeral joint.10,11,12,18,58,76,80,82 During arm elevation in the scapular plane, individuals with subacromial impingement exhibit decreased scapular upward rotation, increased scapular IR (winging) and anterior tilt, and decreased subacromial space width, compared to those without subacromial impingement.24,37 Altered scapular muscle activity is commonly associated with impingement syndrome. For example, upper and lower trapezius activity increased and serratus anterior activity decreased in individuals with impingement as compared to those without impingement.32 Therefore, it is important to include the scapulothoracic musculature in the rehabilitation of patients with shoulder pathology.32

**Serratus Anterior**

The serratus anterior works with the
pectoralis minor to protract the scapula and with the upper and lower trapezius to upwardly rotate the scapula. The serratus anterior is an important muscle because it contributes to all components of normal 3-D scapular movements during arm elevation, which includes upward rotation, posterior tilt, and external rotation.\textsuperscript{52,58} The serratus anterior is also important in athletics, such as during overhead throwing, to accelerate the scapula during the acceleration phase of throwing. The serratus anterior also helps stabilize the medial border and inferior angle of the scapula, preventing scapular IR (winging) and anterior tilt.

Several exercises elicit high serratus anterior activity, such as D1 and D2 diagonal PNF pattern flexion, D2 diagonal PNF pattern extension, supine scapular protraction, supine upward scapular punch, military press, push-up plus, glenohumeral IR and ER at 90° abduction, and shoulder flexion, abduction, and scaption with ER above 120°.\textsuperscript{16,20,32,62,63} Serratus anterior activity tends to increase in a somewhat linear fashion with arm elevation.\textsuperscript{2,20,29,62} However, increasing arm elevation increases subacromial impingement risk,\textsuperscript{15,71} and arm elevation at lower abduction angles also generates relatively high serratus anterior activity.\textsuperscript{20}

It is interesting that performing shoulder IR and ER at 90° of abduction generates relatively high serratus anterior activity, because these exercises are usually thought to primarily work rotator cuff muscles.\textsuperscript{20,63} However, during IR and ER at 90° abduction the serratus anterior helps stabilize the scapula. It should be noted that the rotator cuff muscles also act to move the scapula (where they originate) in addition to the humerus. For example, the force exerted by the supraspinatus at the supraspinous fossa has the ability to downwardly rotate the scapula if this force is not counterbalanced by the scapulothoracic musculature.

Not surprising is high serratus anterior activity generated during a push-up exercise. When performing the standard push-up, push-up on knees, and wall push-up, serratus anterior activity is greater when full scapular protraction occurs after the elbows fully extend (push-up plus).\textsuperscript{53} Moreover, serratus anterior activity was lowest in the wall push-up plus, exhibited moderate activity during the push-up plus on knees, and relatively high activity during the standard push-up plus.\textsuperscript{16,53} Compared to the standard push-up, performing a push-up plus with the feet elevated produced significantly greater serratus anterior activity.\textsuperscript{37} These findings demonstrate that serratus anterior activity increases as the positional (gravitational) challenge increases.

Decker et al\textsuperscript{16} compared several common exercises designed to recruit the serratus anterior. The authors identified that the 3 exercises that produced the greatest serratus anterior EMG signal were the push-up with a plus, dynamic hug (\textcopyright KH), and punch exercises (similar to a jabbing protraction motion).

Ekstrom\textsuperscript{20} also looked at the activity of the serratus anterior during common exercises. His data indicated that the serratus anterior is more active when performing a movement that simultaneously creates scapular upward rotation and protraction, as with the serratus anterior punch performed at 120° of abduc-
tion and during a diagonal exercise that incorporated protraction with shoulder flexion, horizontal adduction, and external rotation. It appears that the punch exercise can be enhanced by starting at 0° abduction and extending the elbow, while elevating and protracting the shoulder (FIGURE 5).

Hardwick et al.29 compared the wall push-up plus, full can, and a wall slide exercise. The wall slide begins by slightly leaning against the wall with the ulnar border of the forearms in contact with the wall, elbows flexed 90°, and shoulders abducted 90° in the scapular plane. From this position the arms slide up the wall in the scapular plane, while leaning into the wall. Interestingly, the wall slide produces similar serratus anterior activity compared to scapular abduction above 120° abduction with no resistance. One advantage of the wall slide compared to scapular abduction is that, anecdotally, patients report that the wall slide is less painful to perform.29 This may be because during the wall slide the upper extremities are supported against the wall, making it easier to perform while also assisting with compression of the humeral head within the glenoid. Thus, this may be an effective exercise to perform during the earlier protective phases of some rehabilitation programs.

**Trapezius**

General functions of the trapezius include scapular upward rotation and elevation for the upper trapezius, retraction for the middle trapezius, and upward rotation and depression for the lower trapezius. In addition, the inferomedial-directed fibers of the lower trapezius may also contribute to posterior tilt and external rotation of the scapula during arm elevation,23 which decreases subacromial impingement risk24,52 and makes the lower trapezius an important area of focus in rehabilitation. Relatively high upper trapezius activity occurs in the shoulder shrug, prone rowing, prone horizontal abduction at 90° and 135° of abduction with ER and IR, D1 diagonal PNF pattern flexion, standing scapular dynamic hug, PNF scapular clock, military press, 2-hand overhead medicine ball throw, and scapular abduction and abduction below 80°, at 90°, and above 120° with ER.20,62,63,75,84 Significant lower trapezius activity occurs during the prone full can exercise.3 As previously mentioned, the lower trapezius is an extremely important muscle in shoulder function due to its role in scapular upward rotation, external rotation, and posterior tilt.

Ekstrom et al.90 reported that the greatest EMG signal amplitude of the lower trapezius occurred during the prone full can, prone ER at 90°, and prone horizontal abduction at 90° with ER exercises. Based on these results, it appears that the prone full can exercise should not be performed at a set degree of abduction, but should be individualized based on the alignment of the lower trapezius fibers.3

**FIGURE 6.** The proper alignment of the upper extremity during the prone horizontal abduction exercise with external rotation. Note how the upper extremity is aligned with the muscle fiber orientation of the lower trapezius.

Relatively high middle trapezius activity occurs with shoulder shrug, prone rowing, and prone horizontal abduction at 90° and 135° of abduction with ER and IR.2,16,20 Some authors have reported relatively high middle trapezius activity during scapular abduction at 90° and above 120°, while authors of another study showed low EMG signal amplitude of the middle trapezius during this exercise.52

Relatively high lower trapezius activity occurs in the prone rowing, prone horizontal abduction at 90° and 135° of abduction with ER and IR, prone and standing ER at 90° abduction, D2 diagonal PNF pattern flexion and extension, PNF scapular clock, standing high scapular rows, and scapular abduction, flexion, and abduction below 80° and above 120° with ER.50,52,63,75 Lower trapezius activity tends to be relatively low at angles less than 90° of scapular abduction, abduction, and flexion, and then increases exponentially from 90° to 180°.2,20,29,62,75,94 Significantly greater lower trapezius activity has been reported during the prone ER at 90° abduction exercise compared to the empty can exercise.20 As previously mentioned, the lower trapezius is an extremely important muscle in shoulder function due to its role in scapular upward rotation, external rotation, and posterior tilt.

It is often clinically beneficial to enhance the ratio of lower trapezius-to-upper trapezius strength.3 In the opinion of the authors, poor posture and muscle imbalance often seen in patients with a variety of shoulder pathologies is often the result of poor muscle balance between the upper and lower trapezius, with the upper trapezius being more dominant. McCabe et al.56 report that bilateral ER at 0° abduction resulted in the greatest lower trapezius-upper trapezius ratio compared to several other similar trapezius exercises (FIGURE 7). Cools et al.10 also identified side-lying ER and prone horizontal abduction at 90° abduction and ER as 2 beneficial exercises to enhance the ratio of lower trapezius to upper trapezius activity.

**Rhomboids and Levator Scapulae**

Both the rhomboids and levator scapulae function as scapular retractors, downward rotators, and elevators. Exercises used to strengthen rotator cuff and scapulothoracic musculature are also effective in eliciting activity of the rhomboids and levator scapulae. Relatively high rhomboid activity has been
reported during D2 diagonal PNF pattern flexion and extension, standing shoulder ER at 0° and 90° abduction, standing shoulder IR at 90° abduction, standing shoulder extension from 90° to 0°, prone shoulder horizontal abduction at 90° abduction with IR, scapular abduction, abduction, and shoulder flexion above 120° with ER, prone rowing, and standing high, mid, and low scapular rows.62,63 Relatively high rhomboids and levator scapulae activity has been reported with scapular abduction above 120° with ER, prone horizontal abduction at 90° abduction with ER and IR, prone rowing, and prone extension at 90° flexion.62 Therefore, the prone extension exercise may be performed in addition to many of the previously mentioned exercises for other scapulothoracic muscles. Other specific exercises to activate the rhomboids and levator scapulae muscles are not often necessary to perform.

**RECOMMENDATIONS**

The preceding review can be used to identify appropriate rehabilitation exercises for specific muscles. Based on the reported studies and the collective experience of the authors, we recommend that exercises should be selected based on the appropriate anatomical, biomechanical, and clinical implications. We have identified a set of exercises that the current authors use clinically for rehabilitation and injury prevention (TABLE). These exercises have been selected based on the results of the numerous studies previously cited and take into consideration these implications for each exercise described. Furthermore, the authors encourage the clinician to carefully consider emphasizing posture and scapular retraction during the performance of glenohumeral and scapulothoracic exercises.

A common recommendation in rehabilitation is to limit the amount of weight used during glenohumeral and scapulothoracic exercises to assure that the appropriate muscles are being utilized and not larger compensatory muscles. Two recent studies have analyzed this theory and appear to prove the recommendation inaccurate and not necessary. Alpert et al studied the rotator cuff and deltoide muscles during scapular plane elevation and noted that EMG signal amplitude of the smaller rotator cuff muscles and larger deltoid muscles increased linearly in relation to the amount of weight used. This finding is consistent with that of Dark et al, who showed similar results for the rotator cuff, deltoide, pectoralis, and latissimus dorsi during ER and IR at 0° abduction. Thus, it appears that larger muscle groups do not overpower smaller groups, such as the rotator cuff. Weight selection should be based on the individual goals and performance of each patient. It does not appear necessary to limit the amount of weight performed during these rotator cuff exercises.

As our understanding of the anatomical and biomechanical implications associated with exercise selection continues to grow, we are seeing advances in exercise selection and the integration of the whole-body kinetic-chain approach to strengthening and rehabilitating injuries. This may involve strengthening multiple joints simultaneously and during movement patterns that mimic athletic and functional daily activities of living. The authors often employ these techniques when our patients improve in strength yet continue to have symptoms during activities. In addition, we often attempt to further challenge our patients by performing many of the recommended exercise on various unstable surfaces (such as foam or physioballs), with altered bases of support (such as sitting, standing, or single-leg balancing), in an attempt to recruit whole-body muscle patterns that interact together to perform active range of motion while stabilizing other areas of the body. We believe that these concepts are important to consider in addition to straight-plane, isolated movements of specific muscle groups, and that strength, posture, balance, and neuromuscular control are all vital components to any injury prevention of rehabilitation program. Future research on the validity of these techniques is needed to justify their use. We believe that this is the next step in the evolution of research on the clinical and biomechanical implications of exercise selection for the glenohumeral and scapulothoracic musculature.

**CONCLUSION**

A thorough understanding of the biomechanical factors associated with normal shoulder movement, as well as during commonly performed exercises, is necessary to safely and effectively design appropriate programs. We have reviewed the normal biomechanics of the glenohumeral and scapulothoracic muscles during functional activities, common exercises, and in the presence of pathology. These findings can be used by the clinician to design appropriate rehabilitation and injury prevention programs.
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Exercise</th>
<th>Anatomical Implications</th>
<th>Biomechanical Implications</th>
<th>Clinical Implications</th>
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<tbody>
<tr>
<td>Supraspinatus</td>
<td>1. Full can</td>
<td>1. Enhances scapular position and subacromial space</td>
<td>1. Decreased deltoid involvement compared to empty can</td>
<td>1. Minimizes chance of superior humeral head migration by deltoid overpowering supraspinatus</td>
</tr>
<tr>
<td></td>
<td>2. Prone full can</td>
<td>2. Enhances scapular position and subacromial space</td>
<td>2. High posterior deltoid activity with similar supraspinatus activity</td>
<td>2. High supraspinatus activity and also good exercise for lower trapezius</td>
</tr>
<tr>
<td>Infraspinatus and teres minor</td>
<td>1. Side-lying ER</td>
<td>1. Position of shoulder stability, minimal capsular strain</td>
<td>1. Increased moment arm of muscle at 0° abduction, Greatest EMG activity</td>
<td>1. Most effective exercise in recruiting infraspinatus activity. Good when cautious with static stability</td>
</tr>
<tr>
<td></td>
<td>2. Prone ER at 90° abduction</td>
<td>2. Challenging position for stability, higher capsular strain</td>
<td>2. High EMG activity</td>
<td>2. Strengthens in a challenging position for shoulder stability. Also good exercise for lower trapezius</td>
</tr>
<tr>
<td></td>
<td>3. ER with towel roll</td>
<td>3. Allows for proper form without compensation</td>
<td>3. Increased EMG activity with addition of towel, also incorporates adductors</td>
<td>3. Enhances muscle recruitment and synergy with adductors</td>
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<tr>
<td>Subscapularis</td>
<td>1. IR at 0° abduction</td>
<td>1. Position of shoulder stability</td>
<td>1. Similar subscapularis activity between 0° and 90° abduction</td>
<td>1. Effective exercise, good when cautious with static stability</td>
</tr>
<tr>
<td></td>
<td>2. IR at 90° abduction</td>
<td>2. Position of shoulder instability</td>
<td>2. Enhances scapular position and subacromial space, Less pectoralis activity</td>
<td>2. Strengthens in a challenging position for shoulder stability</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>1. Push-up with plus</td>
<td>1. Easy position to produce resistance against protraction</td>
<td>1. High EMG activity</td>
<td>1. Effective exercise to provide resistance against protraction, also good exercise for subscapularis</td>
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<tr>
<td></td>
<td>2. Dynamic hug</td>
<td>2. Performed below 90° abduction</td>
<td>2. High EMG activity</td>
<td>2. Easily perform in patients with difficulty elevating arms or performing push-up. Also good exercise for subscapularis</td>
</tr>
<tr>
<td>Lower trapezius</td>
<td>1. Prone full can</td>
<td>1. Can properly align exercise with muscle fibers</td>
<td>1. High EMG activity</td>
<td>1. Effective exercise, also good exercise for supraspinatus</td>
</tr>
<tr>
<td></td>
<td>2. Prone ER at 90° abduction</td>
<td>2. Prone exercise below 90° abduction</td>
<td>2. High EMG activity</td>
<td>2. Effective exercise, also good exercise for infraspinatus and teres minor</td>
</tr>
<tr>
<td></td>
<td>3. Prone horizontal abduction at 90° abduction with ER</td>
<td>3. Prone exercise below 90° abduction</td>
<td>3. Good ratio of lower to upper trapezius activity</td>
<td>3. Effective exercise, also good exercise for middle trapezius</td>
</tr>
<tr>
<td></td>
<td>4. Bilateral ER</td>
<td>4. Scapular control without arm elevation</td>
<td>4. Good ratio of lower to upper trapezius activity</td>
<td>4. Effective exercise, also good for infraspinatus and teres minor</td>
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<tr>
<td>Middle trapezius</td>
<td>1. Prone row</td>
<td>1. Prone exercise below 90° abduction</td>
<td>1. High EMG activity</td>
<td>1. Effective exercise, good ratios of upper, middle, and lower trapezius activity</td>
</tr>
<tr>
<td></td>
<td>2. Prone horizontal abduction at 90° abduction with ER</td>
<td>2. Prone exercise below 90° abduction</td>
<td>2. High EMG activity</td>
<td>2. Effective exercise, also good exercise for lower trapezius</td>
</tr>
<tr>
<td></td>
<td>3. Prone horizontal abduction at 90° abduction with ER</td>
<td>3. Prone exercise below 90° abduction</td>
<td>3. High EMG activity</td>
<td>3. Effective exercise, also good exercise for lower trapezius</td>
</tr>
<tr>
<td>Rhomboids and levator scapulae</td>
<td>1. Prone row</td>
<td>1. Prone exercise below 90° abduction</td>
<td>1. High EMG activity</td>
<td>1. Effective exercise, good ratios of upper, middle, and lower trapezius activity</td>
</tr>
<tr>
<td></td>
<td>2. Prone horizontal abduction at 90° abduction with ER</td>
<td>2. Prone exercise below 90° abduction</td>
<td>2. High EMG activity</td>
<td>2. Effective exercise, also good for lower and middle trapezius</td>
</tr>
</tbody>
</table>

Abbreviations: EMG, electromyography; ER, external rotation; IR, internal rotation.
REFERENCES


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The American Society of Shoulder and Elbow Therapists’ Consensus Rehabilitation Guideline for Arthroscopic Anterior Capsulolabral Repair of the Shoulder

The maintenance of shoulder stability is the result of a complex interplay of static and dynamic factors. Shoulder instability may require surgical stabilization to resolve the anatomical deficits causing the instability and to restore shoulder function. A variety of surgical techniques exist. The chronicity, magnitude (dislocations or subluxations), and direction (anterior, posterior, or multidirectional) of instability are the key factors considered during preoperative planning. In addition, patient factors, such as a need for mobility in the case of an overhead athlete, must be considered.

As the majority of patients with anterior instability have injuries to their capsulolabral complex, the arthroscopic anterior capsulolabral repair is a commonly utilized procedure. Arthroscopic anterior capsulolabral repair seeks to restore shoulder stability by suturing back to the glenoid the detached or unstable anterior inferior labrum, known as a Bankart lesion (FIGURE 1). In addition to a Bankart repair, capsular plication is added as necessary to address permanent plastic deformation of the glenohumeral joint capsule that often accompanies recurrent anterior inferior dislocations. Rehabilitation following the surgery must balance the restoration of motion and function with the desired result of an appropriately taut capsulolabral complex.

As the majority of patients with anterior capsulolabral repair seek to regain range of motion (ROM) more easily going arthroscopic repair today generally outweighs the benefits of the conventional Bankart repair, capsular plication is added as necessary to address permanent plastic deformation of the glenohumeral joint capsule that often accompanies recurrent anterior inferior dislocations.

**SYNOPSIS:** This manuscript describes the consensus rehabilitation guideline developed by the American Society of Shoulder and Elbow Therapists. The purpose of this guideline is to facilitate clinical decision making during the rehabilitation of patients following arthroscopic anterior capsulolabral repair of the shoulder. This guideline is centered on the principle of the gradual application of stress to the healing capsulolabral repair through appropriate integration of range of motion, strengthening, and shoulder girdle stabilization exercises during rehabilitation and daily activities. Components of this guideline include a 0- to 4-week period of absolute immobilization, a staged recovery of full range of motion over a 3-month period, a strengthening progression beginning at postoperative week 6, and a functional progression for return to athletic or demanding work activities between postoperative months 4 and 6. This document represents the first consensus rehabilitation guideline developed by a multidisciplinary society of international rehabilitation professionals specifically for the postoperative care of patients following arthroscopic anterior capsulolabral repair of the shoulder. J Orthop Sports Phys Ther 2010;40(3):155-168. doi:10.2519/jospt.2010.3186

**KEY WORDS:** Bankart repair, capsular plication, postoperative rehabilitation, shoulder instability, therapeutic exercise
AIM OF THE GUIDELINE

This consensus rehabilitation guideline of the American Society of Shoulder and Elbow Therapists (ASSET) was designed for use with patients who have undergone arthroscopic anterior capsulolabral repair in which the detached labrum was suture anchored back to the glenoid rim and/or capsular tension is restored through suture tightening of the plicated capsule. This rehabilitation guideline is not intended for use with other surgical procedures to address glenohumeral instability because of the variation in surgical approaches, initial fixation strength, and varying potential for lost ROM following the procedures. Additionally, the repair of associated lesions, such as a rotator cuff tear or superior labrum anterior-to-posterior (SLAP) tear, would also require a different rehabilitation program.

This consensus rehabilitation guideline, created by the members of ASSET, is not intended to serve as the standard of medical care. Instead, this document should serve as a guideline and, as such, should be used in conjunction with a thorough history and physical examination of the individual patient. The rehabilitation processes described herein are designed to provide the clinician with a guideline for rehabilitation and description of the expected outcome; however, outcome may differ for individual patients. Individual patient values, expectations, preferences, and goals should be used in conjunction with this guideline. Our guideline should evolve with advances in knowledge and technology. ASSET takes no responsibility and assumes no liability for improper use of this guideline. As the balance between mobility and shoulder stability is delicate and involves a host of anatomic, neuromuscular, and patient-centric factors, strict adherence to this guideline does not guarantee a successful outcome. In our opinion, the best chance for success is when an informed, educated patient works together with a competent, knowledgeable surgeon and rehabilitation specialist, who are themselves working in concert to provide the patient with information and techniques which are current and grounded in science.

METHODS OF DEVELOPMENT

This guideline evolved after representatives from the American Shoulder and Elbow Surgeons Society (ASES) approached ASSET about the need for clinical guidelines for postoperative rehabilitation. In response, ASSET identified a panel of members with extensive experience treating patients following arthroscopic capsulolabral repairs to review the literature and begin developing a rehabilitation guideline. This panel included members with clinical specialty certifications and terminal research degrees and whose members were also selected to represent different geographic regions of the United States.

In the development of this guideline, our goal was to cite the best available evidence, relying on randomized controlled trials when available. The panel searched for clinical trials and basic science evidence from multiple databases up to August, 2009 (Cochrane, PubMed, CINAHL, SportDiscus), using only English language articles for this guideline. Because of the paucity of randomized controlled trials comparing rehabilitation protocols or no treatment postoperatively, we used basic science and mechanistic studies, along with ASSET member expertise and clinical opinion, to develop this rehabilitation guideline. After initial development by the subpanel of the major principles and time frames guiding rehabilitation, the guideline was sent to all members of ASSET to review and provide feedback from which to develop consensus. In addition, the specifics of the guideline (ie, immobilization time frames, when to initiate active ROM, time to restore normal ROM, etc) were openly debated until consensus was reached at 2 subsequent annual meetings of ASSET. Finally, an ASES member with experience performing arthroscopic anterior capsulolabral repairs was recruited to add a surgeon’s perspective. The final guideline (APPENDIX) represents an international consensus rehabilitation guideline developed by a multidisciplinary society of rehabilitation professionals (athletic trainers, occupational therapists, and physical therapists who are American or foreign members of ASSET). This is the first clinical guideline developed for the rehabilitation of patients following arthroscopic anterior capsulolabral repair.

REHABILITATION GUIDELINE PRINCIPLES

A successful outcome following shoulder instability surgery is defined as a pain-free and stable shoulder that has enough mobility, strength, and muscle control for a pa-
Patient’s desired level of activity and participation. Four principles are of critical importance for the rehabilitation professional to successfully apply controlled stress to the shoulder and optimize patient outcome: (1) an understanding of the surgical procedure, (2) an understanding of the anatomic structures which must be protected, how they are stressed, and the rate at which they heal, (3) the identification and skilled application of techniques to impart varying levels of stress to the healing tissues, and (4) managing the initial immobilization period and the rate of ROM progression (Table 1).

Guiding Principle 1
Understanding the surgical procedure is important for the rehabilitation specialist. An arthroscopic anterior capsulolabral repair begins with a thorough arthroscopic examination of the glenohumeral joint, which is performed to assess the extent of pathology (ie, labral detachment and capsular attenuation) and to develop a plan for restoring stability.57 During the classic anterior-inferior traumatic glenohumeral dislocation, the humeral head is driven anterior-inferior and usually lodges inferior to the coracoid process in what is referred to as a subcoracoid dislocation.84 As the head is forced out of the glenoid socket, it detaches the anterior-inferior labrum from approximately the 3-to 6-o’clock position (ie, Bankart lesion) (Figure 1).84 Capsular attenuation is also frequently present as the forces that drive the humeral head out of the glenoid are sufficient to cause plastic, unrecoverable deformation of the capsuloligamentous restraints.53,83 Therefore, some surgeons perform capsular plication in all patients undergoing arthroscopic instability repairs.41 In patients with congenital or atraumatic instability and an intact labrum, capsular attenuation is the primary pathology addressed by the surgery. Associated injuries, such as a Hill Sachs lesion, rotator cuff tears, or osteochondral injuries, may also be present.80 It is essential for the rehabilitation specialist to communicate with the surgeon to determine the extent of any associated injuries and if anything was done at the time of surgery to address them that may impact the rehabilitation progression.

In patients with anterior instability but without a significant labral injury, the surgeon tightens the capsule and the glenohumeral ligaments with an arthroscopic capsular plication or capsular shift procedure.83 Either biodegradable suture anchors are placed along the anterior-inferior labral articular surface without disturbing the intact labrum or the capsule is sutured directly to the intact labrum without the use of suture anchors. In either case, special instruments are used to shuttle the suture through the capsule and labrum, and a ras or synovial resector is used to lightly abrade the capsular tissue that is to be retenioned. The amount of capsular tightening or retenioning is based on the preoperative examination and history, the amount of laxity demonstrated during the examination under anesthesia, and the pathologic findings from the diagnostic arthroscopic examination.84 In a typical capsular shift without a Bankart repair, 3 suture anchors with a single suture in each anchor are utilized (Figure 2), and the capsule is shifted approximately 5 to 10 mm with each suture limb from an inferior to a superior direction (Figure 3), thus eliminating the capsular redundancy in the anteroinferior joint compartment.23,83

The presence of a Bankart lesion, bony Bankart lesion, or other labral injury requires mobilization of the capsulolabral complex from the anterior glenoid neck or rim.84,85 An arthroscopic elevator is utilized, first followed by a synovial resector or small burr to abrade the glenoid rim at the articular margin, so as to promote healing of the labrum to bone after repair. It is generally not necessary to shift or tighten the capsule in a Bankart repair. The labral-capsular complex is repaired anatomically.

Guiding Principle 2
Understanding the anatomic structures that must be protected, how they are stressed, and the rate at which they heal...
is also important before rehabilitation begins. Arthroscopic anterior capsulolabral repair involves a direct repair of damaged capsular and labral structures. Repair is achieved via suture and/or suture anchor reattachment, which requires protection from excessive stresses to facilitate appropriate tissue healing. It is well documented that specific portions of the capsule and labrum are selectively tensioned with specific glenohumeral motions. A standard anterior capsulolabral repair, addressing attenuation of the anterior inferior capsule, is most directly stressed by external rotation, particularly above 90° of abduction. In a cadaveric model, Itoi et al demonstrated that with the arm by the side, external rotation to 30° could safely be applied to the shoulder without separating a simulated Bankart lesion.

Forward flexion stresses the inferior part of the glenohumeral joint capsule. Therefore, based on the stress to the inferior capsule, we recommend limiting flexion to less than 90° until 3 weeks postsurgery, then gradually increasing flexion to 135° through postoperative week 6.

During the classic open Bankart repair, the subscapularis is either detached or split to access the capsule and is then subsequently reattached or closed with sutures, necessitating protection from active internal rotation during the early postoperative period. However, during the standard arthroscopic anterior capsulolabral repair, the subscapularis is not detached or split, therefore it does not need specific protection from excessive stress during the rehabilitation program.

It is imperative that activities be limited to those which produce less stress to the healing tissues than the failure strength of the repair. The challenge for guiding rehabilitation based upon the tissue healing is the limited ability for clinicians to measure tissue healing. Moreover, the amount of stress imparted by many rehabilitation activities remains unknown.

The rehabilitation process is divided into 3 phases of 6 to 12 weeks in duration, because we believe these time frames coincide with the healing and clinical milestones. The first 6 weeks postoperative include the inflammatory and the proliferative (fibroplasia and wound contraction) phases and the beginning of the scar maturation phase of tissue healing. Scar maturation and remodeling of the tissue likely continues throughout the rehabilitation process and may not be complete until 40 to 50 weeks after surgery.

Other factors, such as the patient’s age and the presence of comorbidities, may affect tissue healing and should be considered when deciding how quickly to progress an individual patient. Diabetes mellitus, peripheral vascular disease, and connective tissue disorders may impair healing; therefore patients with these diseases may have or require a slower rehabilitation progression. No studies have examined the influence of comorbidities on shoulder function following capsulolabral repair. Comorbidities do negatively influence outcome following rotator cuff repair and shoulder arthroplasty. Therefore it is possible that comorbidities may negatively impact rehabilitation and outcomes after capsulolabral repair.

Guiding Principle 3
Correct selection and use of techniques to apply varying levels of stress to the surgical repair is important for a successful outcome. Following surgical repair, the healing capsulolabral structures require appropriate stress to stimulate optimal healing, while protecting the repair from excessive tension. The gradual application of stress is a stimulus for further proliferation and differentiation of fibroblasts. A gradual increase in applied stress, in a process analogous to Wolff’s law of bone healing, results in enhanced structural integrity of the capsulolabral complex as additional collagen fibers are laid down in response to controlled stresses. However, it is equally important to understand that with excessive stress to the capsulolabral complex, either in terms of magnitude or timing, the tissues will be unable to adequately adapt and damage will result to either the healing tissues or the suture anchors. During rehabilitation, there are 3 mechanisms by which rehabilitation providers apply stress to the surgical repair to positively affect patient outcome: (1) absolute ROM, (2) controlled submaximal tissue loading, and (3) dynamic stabilization.

Immediately following surgery, the repair is completely reliant on the mechanical strength of the sutures and/or suture anchors. Therefore, the absolute ROM limit that is initially deemed safe is based upon the surgical fixation and structural integrity of the repair. As time passes, the repaired tissues begin to heal through fibrous scar formation and gradually increase in tensile strength. In the case of a Bankart lesion, the labrum develops immature connective tissue links to the glenoid rim, and in the case of a capsular plication, the plicated layers of the capsule initiate formation of immature connective tissue links to one another. Excessive stretching during ROM activities may overload the structural integrity of these immature cross-links in the healing tissues.

Much in the same way micromotion prevents bony union during fracture healing, submaximal tissue loading also has the potential to disrupt the tenuous tissue healing bonds between the labrum and bone and between the plicated layers of the capsule. Repeated submaximal stress of a ligament plication in an animal model has been shown to negatively affect mechanical resistance properties, even as late as postoperative week 12. While direct extrapolation cannot be made to a pathologic human condition, these findings are similar to the effects of submaximal loading in human cadavers. Repetitive submaximal loading has been shown to increase the length and decrease the subsequent load to failure of the anterior inferior glenohumeral ligament. The exact effect of submaximal loading during various rehabilitation interventions is currently unknown. Thus, clini-
cians should keep in mind that repeated and excessive submaximal tensioning of the repair during the remodeling phases of tissue healing may theoretically cause the capsule to heal at a longer length. Therefore, even though they are below the failure strength of the capsulolabral tissues, repetitive submaximal stresses should be carefully controlled as they pose a potential threat to capsuloligamentous integrity.

While excessive submaximal loading may be detrimental, dynamic stabilization or active stabilization of a joint by the muscles directly surrounding it provides protection to the surgical repair by supporting the joint capsule, increasing joint compression forces, and resisting joint displacement. It is vital to understand that these 3 mechanisms (absolute ROM, submaximal tissue loading, and dynamic stabilization) do not occur in isolation but are interrelated in all rehabilitation activities and should be the primary considerations when selecting interventions during rehabilitation.

Guiding Principle 4
Appropriate management of the initial immobilization period and ROM progression are also important for the rehabilitation specialist because the tensile strength of the arthroscopic anterior capsulolabral repair is reduced through the first 12 postoperative weeks. Therefore, it is important to protect the surgical repair from undue stress during the first 2 phases of rehabilitation (12 weeks total) by controlling the rate at which ROM is regained. Gaining ROM too quickly can limit the normal tissue-healing process and lead to capsuloligamentous attenuation. Therefore, an initial period of immobilization is common after arthroscopic anterior capsulolabral repair to facilitate healing of the surgically repaired tissues, theoretically allowing the surgically reattached labrum a chance to bind to the glenoid and the plicated layers of capsule to heal to each other.

Absolute immobilization (no glenohumeral ROM exercises and constant sling use) in the first 6 weeks following arthroscopic capsulolabral repair of the shoulder was advocated during the infancy of these procedures, when surgical techniques were rapidly evolving and failure rates were high. However, studies advocating absolute immobilization as a means to decrease long-term failure rates utilized surgical procedures such as transglenoid sutures or staple repair that are no longer common. Current surgical methods typically employ sutures and suture anchors to repair the labrum, rotator cuff, or Bankart lesion only without the presence of a bony fragment (bony Bankart). Therefore, the need for absolute immobilization after arthroscopic Bankart repair has been reexamined in recent years.

Studies have shown short periods of absolute immobilization result in no greater recurrence rate of shoulder instability and have demonstrated improved ROM over the course of recovery. In a randomized controlled trial comparing 3 weeks of absolute immobilization to immediate staged ROM in a select group of patients undergoing Bankart repair, Kim et al. found that immediate ROM yielded no greater recurrence rate in dislocation, or difference in pain or function scores. These results apply to patients with recurrent (nonacute) instability brought on by a traumatic event, and a Bankart lesion only without the presence of a bony fragment (bony Bankart).

These results do not apply to those patients actively participating in sports, or to those patients with multidirectional or posterior instability, other labral lesions, a rotator cuff tear, or a larger bony Bankart lesion involving greater than 30% of the glenoid. Additionally, considering that the capsulolabral complex appears to be within the safe boundaries of stress with the arm in adduction and up to 90° of external rotation, immediate postoperative ROM in this range is safe.

Based on this evidence and our significant clinical experience rehabilitating patients following this surgery, we recommend a variable period between 0 up to 4 weeks of absolute immobilization following an arthroscopic anterior capsulolabral repair, in which sutures or suture anchors are utilized. Relative immobilization (out of sling only for ROM exercises or short periods of sitting or standing) is recommended for 6 weeks, followed by sling use for comfort. We offer ranges of immobilization as a general guideline because we recognize that surgeon preference plays a major role in the postoperative immobilization time frames for patients undergoing this procedure and want to provide a wide range that is safe, both in terms of early motion and protecting the repair, and restricted motion in terms of preventing contractures and adhesions. Immobilization periods should be determined by the surgeon and rehabilitation provider for each individual patient, considering the extent of the pathology, the integrity or the repair, as well as the patient’s goals, age, and comorbidities.

Regardless of the period of absolute and relative immobilization, controlling the rate of ROM progression is vitally important. The integrity of the surgical repair is thought to be negatively affected by the patient regaining ROM too quickly during the first 8 to 12 weeks postoperatively. Staged ROM goals are an effective tool to guide the rate of ROM progression. We have proposed a general guideline for staged ROM goals that we were able to achieve consensus on from our multidisciplinary team of shoulder rehabilitation specialists (Table 2). As with the specific period of immobilization, ROM goals may be modified by the surgeon or rehabilitation provider, based on the individual patient. The ROM goals have the patient comfortably progressing their ROM to the specified angle. If the patient's ROM is less than the targeted range, gentle stretching should be implemented to facilitate ROM gains to the targeted range and to prevent the development of contractures and adhesions. On the other hand, if the targeted ROM is easily obtained, then stretching in the
stages in which the target motions have already been met should be avoided to prevent overstretching the healing tissues.29

**REHABILITATION GUIDELINE**

The Appendix contains ASSET’s Consensus Rehabilitation Guideline for Arthroscopic Anterior Capsulolabral Repair. The guideline is divided into 3 phases, based on general time frames of capsulolabral healing. In addition to time, short-term goals or milestones at each phase are used to determine progression from one phase to the next of the treatment program. Clinician-rated impairments and patient-rated outcome tools are used to judge these milestones. Goals for each phase include surgical healing, staged attainment of passive and/or active ROM, pain, adherence to immobilization and home exercise program, scapular posture and dynamic control during ROM and exercise, and restoration of shoulder function. Clinician-rated impairments and patient-rated outcomes are used to assess the achievement of these goals. Healing of the surgical repair is assessed by time frames, and adherence to the precautions, immobilization, and ROM guidelines. Active and passive ROM should be measured with an inclinometer or goniometer. Pain should be assessed with a patient-rated numeric pain rating scale (NPRS). Scapular posture should be assessed visually for winging or other abnormal motion during active elevation of the arm or as the patient completes the supervised portion of their exercise program. Completion of strengthening program should be assessed by comparing the exercise program performed to the protocol. Finally, measurement of shoulder functional loss or disability is best evaluated with a patient-rated outcome measure.

Both the clinical milestones and time frames should be met prior to progression to the next phase. Clinician-rated impairments should be performed every 1 to 2 weeks, to closely monitor response to treatment and achievement of milestones. It is critical to use patient-rated measures of function and disability to comprehensively assess patient response to treatment. There are numerous patient-rated measures with established measurement properties available to assess shoulder function and disability. Recent studies of patient-rated measures of shoulder functional loss and disability in patients with instability or undergoing shoulder surgery indicate that one measure is likely not superior to another.89,100 The scales recommended for use are patient-rated measures specifically for instability, such as the Western Ontario Instability Index (WOI) or a general shoulder measure such as the ASES Form patient-rated section.127,146,161

### Phase 1: Postoperative Weeks 0 to 6

The focus of phase 1 rehabilitation, which constitutes the first 6 postoperative weeks, is to maximally protect the surgical repair and achieve, but not to exceed, the staged ROM goals (Table 2), while being especially mindful to not exceed external rotation limits. Because of the minimally invasive nature of the surgical procedure, some patients experience little pain and may be able to use their arm more than is advisable during this phase. Therefore, patient education is critical to convey the importance of staying within the prescribed ROM limits and not overloading the shoulder, so as to protect the healing tissues from excessive stress and possible anchor or tissue failure. Potentially injurious forces can be avoided by slowly progressing through staged ROM goals, controlling submaximal loading forces by limiting repetitive activity of the arm, and avoiding forces that may overstretch the structural integrity of the capsulolabral repair by not lifting heavy objects. Wetzler et al109 estimated that a shoulder would typically experience 1000 to 2000 loading cycles during the first 6 weeks of rehabilitation following capsulolabral repair. Based upon their analysis, the maximum load any particular suture anchor could accommodate is 60 to 100 N, based upon the location of the suture anchors, with lower forces to failure on the more inferior portions of the glenoid. Additionally, the pull-out strength decreased precipitously within the first 100 cycles until the suture anchor “settled.” Therefore, despite the fact that the suture anchor-bone construct is strongest initially, the loads during the first few weeks of rehabilitation should be minimized until the suture anchor has “settled” into its final position. Direct application of these data clinically is limited, as cadaveric specimens were used with an average age older than the typical patient undergoing arthroscopic capsulolabral repair. Still, we believe these findings provide some support for minimizing the number and amount of repetitive loads, particularly during the first phase of rehabilitation.92

### Table 2: Staged Range-of-Motion Goals Following Arthroscopic Anterior Capsulolabral Repair

<table>
<thead>
<tr>
<th></th>
<th>PFE</th>
<th>PER at 20° Abd</th>
<th>PER at 90° Abd</th>
<th>AFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>POW 3</td>
<td>90°</td>
<td>10°-30°</td>
<td>Contraindicated</td>
<td>NA</td>
</tr>
<tr>
<td>POW 6</td>
<td>135°</td>
<td>35°-50°</td>
<td>45°</td>
<td>115°</td>
</tr>
<tr>
<td>POW 9</td>
<td>155°</td>
<td>50°-65°</td>
<td>75°</td>
<td>145°</td>
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<tr>
<td>POW 12</td>
<td>WNL</td>
<td>WNL</td>
<td>WNL</td>
<td>WNL</td>
</tr>
</tbody>
</table>

**Abbreviations:** Abd, abduction; AFE, active forward elevation in the scapular plane; NA, not applicable; PER, passive external rotation; PFE, passive forward elevation; POW, postoperative week; WNL, within normal limits.
active assistive exercises can be performed immediately for the patient following arthroscopic capsulolabral repair.

Forward elevation and external rotation in slight abduction within the prescribed ROM limits are the glenohumeral motions performed during phase 1, as they allow for glenohumeral ROM without adversely stressing the surgical repair. Exercises to regain forward elevation may include rope-and-pulley-assisted elevation, self-assisted elevation in the supine position, or wand-assisted elevation in the supine position. A table step-back exercise (FIGURE 4), where the patient's hands remain stationary on a surface, while the patient slowly walks his or her body back, bending at the waist to achieve forward elevation, may be helpful for patients who have difficulty relaxing. To regain external rotation ROM, the clinician or family member may perform passive external rotation with the arm at the side, or the patient could perform active assisted external rotation with a cane or bar to assure that ROM limits are not exceeded and the shoulder is not positioned in extension during any external rotation ROM exercise.

To protect the surgical repair, ROM should never be forceful during phase 1. During phase 1, it is recommended that stretching exercises stop at the point when the patient experiences a sensation of a light stretch, as long as the ROM is less than the staged ROM goals. If ROM exceeds the staged goals without any sensation of stretch, then the patient no longer has a ROM deficit. If this circumstance occurs, ROM exercises in this plane are discontinued until ROM is consistent with the staged goals. During phase 1, ROM exercises should not be used that stretch into end range external rotation, particularly at 90° of abduction, have the patient positioned in shoulder extension, or stretch into straight-plane abduction, with or without humeral external rotation, because they directly stress the anterior or anterior inferior glenohumeral capsule.

Scapular exercises and active motion of the uninvolved joints of the upper extremity, such as the elbow or wrist, are recommended during phase 1 but are considered supplementary activities. Exercises to achieve scapular control are encouraged; however, positions and exercises that stress the capsulolabral structures should be avoided, such as scapular protraction with concomitant horizontal abduction of the shoulder. Postures or exercises that include scapular retracation should be encouraged, as scapular retraction minimizes the amount of shoulder extension needed for functional tasks and therefore limits stress on the anterior-inferior capsule and labrum. However, even though scapular elevation and retraction are relatively safe, these activities should only be completed with very light or no resistance.

Although the rotator cuff does not specifically require protection following arthroscopic stabilization, glenohumeral active ROM and rotator cuff strengthening are purposefully de-emphasized during the early postoperative period because of the potentially detrimental effect to the healing tissues. Light strengthening and active ROM within the staged ROM goals would not likely result in excessive loading; however, in our opinion, it sends an inconsistent message to the patient during this early postoperative period that some strengthening is approved yet significant restrictions of activities of daily living and immobilization are necessary. We believe this inconsistency can lead to excessive arm use, in terms of both loading and ROM, resulting in too much stress to the surgical repair. Healing is the first priority in phase 1. During phase 1, the only form of strengthening recommended is submaximal isometric strengthening of the shoulder and elbow, with the arm adducted to the side in neutral rotation.

Phase 2: Postoperative Weeks 6 to 12
Phase 2 begins at postoperative week 6 and after the clinical milestones identified in phase 1 (APPENDIX) have been achieved. The focus of this phase is continued patient education regarding postoperative activity limitations, staged ROM goals (TABLE 2), and the initiation of rotator cuff and scapular neuromuscular control activities within the allowed ROM. This is achieved by gradual increase in ROM, submaximal tissue loading, and dynamic stabilization.

The goal is to achieve full ROM in all planes at 12 weeks postoperative, with the exception of end range external rotation at 90° of abduction. The motions of forward elevation and external rotation in slight abduction remain the focus of this phase, and it is also important to measure and, if limited, begin interventions to increase glenohumeral joint horizontal abduction and internal rotation. Posterior shoulder
mobility is important to maintaining normal arthrokinematics of the glenohumeral joint, as a tightness of the posterior shoulder has been shown to increase superior humeral head migration, which may lead to impingement. Cross-body stretching has been shown to yield superior gains in internal rotation ROM when compared to a “sleeper” stretch.

If forward elevation or external rotation ROM lag behind staged ROM goals, joint mobilizations or stretching can be performed. Based upon data regarding fatigue properties of suture anchors, rehabilitation professionals should be cautious during the use of joint mobilizations. We recommend their use only when active assisted and passive ROM has not allowed the patient to achieve staged ROM goals.

In addition, there is an often theorized link between anterior glenohumeral laxity and excessive external rotation ROM, particularly in overhead athletes. Increased laxity and greater external rotation ROM have been found in the dominant shoulders of professional baseball pitchers. However, this finding is far from universal, as several authors have demonstrated no asymmetry in laxity between the dominant and nondominant shoulders of professional pitchers.

The most direct evidence linking capsular loading, laxity, and ROM may have been provided by Mihata et al, who demonstrated a linear increase in length of the inferior glenohumeral ligament and the amount of glenohumeral anterior translation as a result of a prolonged, excessive stretch into external rotation. Therefore, it is important to remember not to perform passive stretching to gain end range external rotation or external rotation at 90° of abduction unless significant tightness is present, as these are the motions that impart the greatest stress to the healing capsulolabral repair.

As ROM targets are met, the focus of rehabilitation can shift to neuromuscular retraining. A program which focuses on scapular stability and maintaining the humeral head in a centralized position within the glenoid fossa has been shown to minimize strain on the capsule and thereby offers a protective effect for the surgical repair.

The neuromuscular retraining must be carried out within the staged ROM goals, and must provide a stepwise increase in muscular demand. If muscular demand is increased too quickly, abnormal movement patterns are likely to occur at the scapulothoracic and glenohumeral joints. We recommend exercises for which the magnitude of specific muscle activation has been documented through electromyographic studies, to provide the clinician with the ability to objectively apply gradually increasing loads to specific muscles.

A strengthening program that integrates the ROM progression, progressively increasing muscular activity levels, and repetitive submaximal loading is detailed in the phase 2 strength and endurance section of the appendix.

Phase 3: Postoperative Weeks 12 to 24

Phase 3 rehabilitation begins at approximately postoperative week 12, once the criteria to progress to phase 3 (APPENDIX) are met. The primary focus of this final phase of rehabilitation is normalizing neuromuscular function with strengthening, endurance, power, and dynamic stability exercises. This must be continued in a way that assures gradual advancement of stress to the capsulolabral structures through graded progressions of ROM, repetitive submaximal loading, and dynamic stabilization. Any remaining limitations in ROM should be directly addressed early in phase 3 through low-load, prolonged stretching and joint mobilizations.

Time frame for the initiation of high-
loading exercises and activities following capsular plication or labral repair have not been established.\textsuperscript{10,44,45} A 12-week period is often cited as the minimum postoperative time frame to begin vigorous activities,\textsuperscript{24,26,29,59} and this time frame is consistent with our review of the literature for healing rates of the capsulolabral complex.\textsuperscript{10,45} No clinical trial evidence supports this recommendation, only consensus from a multidisciplinary group of rehabilitation specialists. Prior to initiating any high-load activities, the patient should demonstrate excellent shoulder girdle strength, endurance, and neuromuscular control.

The ultimate goal of rehabilitation is to maximize the patient’s ability to return to full activities of daily living, work, and recreational activities. Setting appropriate goals should occur early in the rehabilitation process and result from a team effort between the patient, physician, and rehabilitation specialist. Because each patient’s goals are different, phase 3 interventions should be tailored to each patient. For example, an athlete who desires a return to competitive baseball will require a greater amount of external rotation ROM in the 90° abducted position, an ability to control the shoulder girdle at high speeds, and endurance and power of the entire upper extremity, torso, and lower body. In contrast, a patient who desires a return to work on an assembly line may require the ability to lift heavy loads at waist level and moderate loads repeatedly to shoulder level. A patient who desires only to return to normal daily activities would not require extreme ROM and would not require high levels of strength, endurance, and neuromuscular control needed for overhead sport or repetitive work demands.

Although these patients have the same entry point into this last phase of rehabilitation, every patient is unique and will require goal-specific phase 3 programs. The final rehabilitation step for the sedentary person may be establishing a home exercise routine consisting of selected phase 2 exercises. Rehabilitation of the assembly line worker would emphasize endurance through general weight lifting, as well a progressive routine of functional lifting. Rehabilitation of the throwing athlete would emphasize activities with progressively higher speed and multiplanar sport-specific movements. Examples include exercises performed rapidly against elastic resistance (FIGURE 5) and progressive plyometrics.\textsuperscript{24,26,29,59}

Due to the extremely high sport-specific stresses placed on the upper quarter with overhead activities, it is necessary to progress to sport-specific programs.\textsuperscript{2,24,26,29} These programs should incorporate a gradual build-up in volume and intensity, and include adequate rest.\textsuperscript{2,24,26,29} Return to sporting activities should be made in consultation with the surgeon and patient and should not occur until specific milestones are achieved. Athletes must be symptom free and should not return to sport until they have demonstrated appropriate ROM, strength, control, endurance, and power necessary for their particular sport or activity.

CONCLUSION

A SSET developed this consensus rehabilitation guideline based upon 4 critical principles (TABLE 1), to guide the rehabilitation process and optimize patient outcome. Each fundamental principle has been reviewed and incorporated into the development of the consensus guideline for which the staged ROM goals (TABLE 2) and time frames of this consensus guideline are based. The graded application of stress to the healing capsulolabral tissues guides rehabilitation; this stress can be modulated through absolute ROM limits, repetitive submaximal loading, and dynamic stabilization.

This document represents a consensus guideline for the typical patient; modifications to the specific application of the guideline may be required, based on the individual patient’s pathology, goals, age, or comorbidities. Because of the wide variety of patients who undergo arthroscopic capsulolabral repair, we feel that final re-
habilitation status should be determined by the patient’s ability to complete his or her desired functional tasks without pain, limitation, or residual sensations of instability. Typically, patients are able to return to low-demand activities at 8 to 16 weeks postoperative and return to very high-demand activities at 24 to 32 weeks. Periodic updates to this guideline will be necessary, as arthroscopic surgical techniques improve and our understanding of the implementation and effects of specific therapeutic interventions evolves.

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THE AMERICAN SOCIETY OF SHOULDER AND ELBOW THERAPISTS’ CONSENSUS REHABILITATION GUIDELINE FOR ARTHROSCOPIC ANTERIOR CAPSULOLABRAL REPAIR OF THE SHOULDER

Phase I: POW 0 to POW 6

Goals
- Maximally protect the surgical repair (capsule, ligaments, labrum, sutures)
- Achieve staged ROM goals. Do not significantly exceed them:
  - PPE: POW 3, 90°; POW 6, 135°
  - PER at 20° abduction: POW 3, 10°-30°; POW 6, 35°-50°
  - PER at 90° abduction: POW 3, contraindicated; POW 6, 45°
  - AFE: POW 3, NA; POW 6, 115°
- Patient education in postoperative restrictions
- Minimize shoulder pain and inflammatory response
- Ensure adequate scapular function

Intervention to Avoid
- Do not allow or perform ROM stretching significantly beyond staged ROM goals, especially external rotation both by the side and in abduction
- Do not allow the patient to use arm for heavy lifting or any use of the arm that requires ROM greater than the staged ROM goals

Specific Interventions
Activities of primary importance:
- Patient education regarding limiting use of the arm despite lack of pain or other symptoms
- Protection of repair
- Achieve staged ROM goals through gentle ROM activities
- Minimize inflammation
- Normalize scapular position, mobility, and dynamic stability
- ROM of uninvolved joints
- Begin restoration of shoulder strength through isometric exercises

Immobilization:
- Via standard sling
- Absolute immobilization (no glenohumeral ROM exercises and constant sling use) for variable time of 0 up to 4 weeks, based on patient-specific factors and surgeon recommendation
- Relative immobilization (out of sling for ROM exercises, sitting with the arm supported, and standing for short periods), starting after the period of absolute immobilization and continuing for the remainder of phase 1, followed by sling use for comfort

Patient education:
- Explain nature of the surgery
- Discuss precautions specific to the nature of the surgical repair
- Importance of not significantly exceeding staged ROM goals
- Importance of tissue healing
- Proper sling use (assure sling provides upward support to the glenohumeral joint)
- Limiting use of arm for ADLs

ROM:
- Following the absolute immobilization period begin:
  - Pendulum exercises (unweighted)
  - Passive/active assisted forward elevation to achieve staged ROM goals listed earlier: ROM should not be forceful
  - Passive/active assisted external rotation with the shoulder in slight abduction to achieve staged ROM goals listed earlier: ROM should not be forceful
  - Scapular clock exercises or alternately elevation, depression, protraction, retraction. Progress to scapular strengthening as patient tolerates
  - Active ROM of uninvolved joints

Miscellaneous:
- Submaximal rotator cuff isometrics as tolerated
- Postural awareness/education
  - Activity restriction
  - Proper fitting of sling to support arm
  - Electrophysical agents

APPENDIX
• Physician prescribed or over-the-counter medications

Milestones (Testing Criteria) to Progress to Phase 2
• Appropriate healing of the surgical repair by adhering to the precautions and immobilization guidelines.
• Staged ROM goals achieved but not significantly exceeded
• Minimal to no pain (NPRS, 0-2/10) with ROM

Phase 2: POW 6 to POW 12

Goals
• Achieve staged ROM goals to normalize passive ROM and active ROM. Do not significantly exceed:
  - PPE: POW 9, 155°; POW 12, WNL
  - PER at 20° abd: POW 9, 50°-65°; POW 12, WNL
  - PER at 90° abd: POW 9, 75°; POW 12, WNL
  - AFE: POW 9, 145°; POW 12, WNL
• Minimize shoulder pain
• Begin to increase strength and endurance
• Increase functional activities

Interventions to Avoid
• Do not perform stretching significantly beyond staged ROM goals.
• Do not perform any stretch to gain end range external rotation or external rotation at 90° abduction unless significant tightness is present
• Do not allow the patient to use arm for heavy lifting or any activities that require ROM beyond the staged ROM goals
• Do not perform any strengthening exercises that place a large load on the shoulder in the position of horizontal abduction or the combined position of abduction with external rotation (eg, no push-ups, bench press, pectoralis flys)
• Do not perform scapular plane abduction with internal rotation (empty can) at any stage of rehabilitation due to the likelihood of impingement

Specific Interventions

Activities of primary importance
• Continued patient education
• Passive/active assisted ROM as needed to achieve but not significantly exceed staged ROM goals
• Establish basic rotator cuff and scapular neuromuscular control with minimal to no pain
• Introduction of functional patterns of movement
• Progressive endurance exercises

Patient education:
• Counsel about using the upper extremity for appropriate ADLs in the pain-free ROM (starting with wrist-level activities and progressing to shoulder-level and finally to overhead activities over time)
• Continue education regarding avoidance of heavy lifting or quick, sudden motions

• Education to avoid positions that place stress on the anterior inferior capsule during ADLs
• Passive/active assisted ROM as needed to achieve staged ROM goals in all planes. Many times only light stretching or no stretching is needed
• If ROM is significantly less than staged ROM goals, gentle joint mobilizations may be performed. However, they should be done only into the limited directions and only until staged ROM goals are achieved
• Address scapulothoracic and trunk mobility limitations. Ensure normal cervical spine ROM and thoracic spine extension to facilitate full upper extremity ROM
• Address abnormal scapular alignment and mobility
  - Strengthen scapular retractors and upward rotators
  - Increase pectorals minor flexibility if limited
  - Biomechanical feedback by auditory, visual, or tactile cues
  - Weight-bearing exercises with a fixed distal segment. Examples: quadruped position while working to maintain proper position of the scapula, quadruped with scapula protraction, progressing from quadruped to tripod position, no push-ups
  - Address core stability deficits PRN
• Activities to improve neuromuscular control of the rotator cuff and shoulder girdle such as use of unstable surfaces, Bodyblade, manual resistance exercises

Strength/Endurance:
• Scapula and core strengthening
• Balanced rotator cuff strengthening to maintain the humeral head centered within the glenoid fossa during progressively more challenging activities
  - Should be initially performed in a position of comfort with low stress to the glenohumeral joint, such as less than 45° elevation in the plane of the scapula (eg, elastic band or dumbbell external rotation, internal rotation, forward flexion)
  - Exercises should be progressive in terms of shoulder elevation (eg, start with exercises performed at wrist level progressing to shoulder level and finally overhead activities)
  - Exercises should be progressive in terms of muscle demand. It is suggested to use activities that have muscle activity levels documented with EMG
  - Elbow flexion/extension strengthening with elbow by shoulder performed (typically 30-50 reps) and relatively low resistance (typically 1-2 kg)
• Electrophysical agents as needed
• Pain management:
  - Ensure appropriate use of arm during ADLs
  - Ensure appropriate level of therapeutic interventions
  - Electrophysical agents as needed

Milestones to Progress to Phase 3
• Staged active ROM goals achieved with minimal to no pain (NPRS, 0-2/10) and without substitution patterns
• Appropriate scapular posture at rest and dynamic scapular control during ROM and strengthening exercises
• Strengthening activities completed with minimal to no pain (NPRS 0-2/10)

Phase 3: POW 12 to POW 24

Goals
• Normalize strength, endurance, neuromuscular control, and power
• Gradual and planned build-up of stress to anterior capsulolabral tissues
• Gradual return to full ADLs, work, and recreational activities

Interventions to Avoid
• Do not increase stress to the shoulder in a short period or in an uncontrolled manner
• Do not perform advanced rehabilitation exercises (such as plyometrics or exercises requiring end range ROM) if the patient does not perform these activities during ADLs, work, or recreation
• Do not progress into activity-specific training until patient has nearly full ROM and strength
• Do not perform weightlifting activities that place excessive stress on the anterior capsule. For instance, latissimus pull-downs, and military press performed with the hands behind the head stress the anterior capsule.

APPENDIX (CONTINUED)
### APPENDIX (CONTINUED)

<table>
<thead>
<tr>
<th>Specific Interventions</th>
<th>Milestones to Return to Work, Hobbies, Sport</th>
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<tbody>
<tr>
<td>- Suggested upper extremity exercises for early phase 3</td>
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<tr>
<td>• Bicep curls, shoulder adducted (added in phase 2)</td>
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<tr>
<td>• Tricep press-downs or kick-backs, shoulder adducted (added in phase 2)</td>
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<td>• Shoulder shrugs</td>
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<td>• Rows (scapular retraction), shoulder adducted</td>
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<tr>
<td>• Latissimus bar pull-downs, with hands in front of the head</td>
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<tr>
<td>• Dumbbell overhead shoulder press with hands starting in front of the shoulders (not in the abducted/externally rotated position)</td>
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<tr>
<td>• Push-ups as long as the elbows do not flex past 90°</td>
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<tr>
<td>• Suggested upper extremity exercises to be added in intermediate phase 3</td>
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<tr>
<td>• Isometric pressing activities (eg, flat or incline presses using machines, barbells, or dumbbells)</td>
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<td>• Dumbbell shoulder raises to 90°</td>
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<td>• Overhead presses with shoulders in abduction with external rotation (military press)</td>
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<td>• Pectorals major flys</td>
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<td>• Dead lift</td>
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<td>• Power cleans</td>
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<tr>
<td>• Upper extremity exercises that are not advisable for this patient population</td>
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<tr>
<td>• Dips</td>
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<tr>
<td>• Latissimus pull-downs or military press with the bar behind head</td>
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<tr>
<td>• Plyometric program (as necessary):</td>
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<tr>
<td>• Criteria to initiate plyometric program</td>
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<tr>
<td>- Goals of returning to overhead athletics or other work or recreational activities requiring large amounts of upper extremity power</td>
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<tr>
<td>- Adequate strength (4+5) of entire shoulder girdle musculature</td>
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<td>- Pain free with basic ADLs and current strengthening program</td>
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<tr>
<td>- At least 3 weeks of tolerance to high-speed multi-planar activities that progressively mimic functional demands</td>
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<td>- Parameters</td>
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<td>• Due to the explosive nature of this type of exercise, emphasis of plyometrics exercises should be on quality not quantity</td>
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<td>• Perform a few times a week and utilize moderate repetitions (eg, 3-5 sets of 15-20 repetitions)</td>
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<td>• Begin with unweighted balls and progress to lightly weighted balls (plyoballs)</td>
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Interval sport programs for activities such as throwing, swimming, and golf, once approved by physician (usually POW 16 or longer)

### APPENDIX (CONTINUED)

- Suggested upper extremity exercises for early phase 3
- Goals of returning to overhead athletics or other work or recreational activities requiring large amounts of upper extremity power
- Adequate strength (4+5) of entire shoulder girdle musculature
- Pain free with basic ADLs and current strengthening program
- At least 3 weeks of tolerance to high-speed multi-planar activities that progressively mimic functional demands

#### Abbreviations:
- Abd, abduction
- ADL, activities of daily living
- AFE, active forward elevation
- EMG, electromyography
- NPRS, numeric pain rating scale
- PER, passive external rotation
- PFE, passive forward elevation
- POW, postoperative week
- ROM, range of motion
- WNL, within normal limits

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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.42 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).24 Lastly, the thrower’s shoulder often exhibits excessive motion and laxity. Wilk et al112 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.

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**

**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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**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.


**KEYWORDS:** baseball, glenohumeral joint, labral lesions, pitching, rotator cuff
of abduction. Brown et al 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 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.

Wilks et al 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. We refer to this as the "total motion concept." Several authors have previously reported that total motion is equal comparing the throwing and nonthrowing shoulder.

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.” 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 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.

Borsa et al reported no difference in the throwing shoulder compared to the nonthrowing shoulder when objective glenohumeral joint laxity testing was performed on the Telos device. 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 have reported an osseous adaptation of the humeral head in the thrower’s shoulder. Crockett et al 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 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. Wilk et al 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

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<tr>
<th>Glenohumeral Muscular Strength Values in Professional Baseball Players (N = 83)</th>
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* 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.

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* Strength ratio of the dominant to the nondominant side for each muscle group.
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‡ Peak torque measured in ft-lb and body weight in lb.

The scapulothoracic musculature plays a vital role during the overhead throwing motion. Proper scapular movement and stability are imperative for asymptomatic shoulder function. These muscles work in a synchronized fashion and act as force couples about the scapula, providing both movement and stabilization. Wilk et al 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 to the nonthrowing side.

The scapula has changes in posture that result in a change of resting position of the scapula. Burkhardt et al 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. Bastian et al 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). Macrina et al 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. 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.
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.

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). Important information, such as onset of symptoms, changes in mechanics, development of a new pitch, training regimen, single-
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. 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. 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. O’Brien’s active compression test is frequently used. The examiner asks the patient to forward flex the affected arm 90°, with the elbow in full extension. The patient then addsucts 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. O’Brien et al 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, and resisted ER with supination test. 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.

There exist numerous joint stability tests. For a complete and thorough description of these tests the reader is encouraged to review Wilk et al. 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 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, tenonositis, 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 intratendinous disease, such as intrasubstance degeneration or tearing.

The patient clinical presentation of tendonitis or tenositis 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.27 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 tendinitis versus tendonosis is based on MRI and duration and frequency of symptoms. On MRI, the patient with tenositis will exhibit inflammation of the tendon sheath (the paratenon); conversely, when tenositis 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, tenositis/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.50 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.27 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 or glenoid rim and labrum in extremes of combined shoulder abduction and ER.60 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.2 Burkhart et al100 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 and muscular tightness, as opposed to capsular tightness.

Patients with internal impingement usually describe an insidious onset of pain in the shoulder. 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 presents 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.

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. Burkhart et al 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.

**Surgical Interventions**

**Rotator Cuff Tendonitis/Tendinitis/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 ro-
tator 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 subcapsularis 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.27 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.79

**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 reconstruction53 or thermal capsulolabral60 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.79 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.5 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.16

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 in-

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**References**

tra-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. 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 multi-phased 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 (NSALDs), 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.

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.

We believe that the loss of IR is most often due to osseous adaptations of the humerus and posterior muscle tightness. 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. 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.

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. 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.\textsuperscript{34,57,78,91} The lower trapezius muscle is an important muscle in arm deceleration in that it controls scapular elevation and protraction.\textsuperscript{78} 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.\textsuperscript{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 lumbopevic region and lower extremities.\textsuperscript{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.\textsuperscript{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.\textsuperscript{28,60,62,90,112,113} 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.\textsuperscript{46} Padua et al\textsuperscript{94} 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\textsuperscript{100} 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\textsuperscript{60-62} and axial loading exercises (upper extremity weight-bearing exercises). Active joint compression stimulates the articular receptors.\textsuperscript{26,59} Thus, axial loading exercises, such as weight shifts, weight shifting on a ball, wall push-ups, and quadraped positioning drills, are beneficial in restoring proprioception.\textsuperscript{106,112,113}

**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.\textsuperscript{106,119} This exercise program was developed based on the collective\textsuperscript{12,23,47,31,64,78,79,96,101,106} information derived from electromyographic research of numerous investigators and is referred to as the “Thrower’s Ten” program.\textsuperscript{100} 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.\textsuperscript{95}

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.\textsuperscript{31,56,57,65} Isotonic exercises are used to strengthen the scapular muscles. Furthermore, Wilk et al\textsuperscript{110} 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\textsuperscript{15} reported high levels of activation of the supraspinatus muscles during this exercise. Recently, Reinold et al\textsuperscript{60,110} reported that the best exercise for supraspinatus muscle was instead the “full can” exercise. Blackburn et al\textsuperscript{95} noted that the position with the patient lying prone and with the arm abducted to 100° and full ER produced the highest

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure9.png}
\caption{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.}
\end{figure}
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. 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 al18-112,114 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-throw. 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 al12 reported that a 6-week plyometric training program resulted in enhanced joint position sense, enhanced kinesthesia, and decreased time to peak torque generation during isokinetic testing. Fortun et al14 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 al19 documented that the overhead athlete is at greater risk for shoulder or elbow injuries when pitching when fatigued. Recently, Murray et al20 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 al21 documented a relationship between muscle fatigue and diminished proprioception. Chen et al22 demonstrated that once the rotator cuff...
muscles are fatigued, the humeral head migrates superiorly when arm elevation is initiated. Furthermore, Lyman et al\(^\text{38}\) 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 isotonics 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).\(^\text{17,25,32,39,65,102}\) These techniques are designed to enhance training, coordination, and the transfer of kinetic energy. Fortun et al\(^\text{44}\) 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.\(^\text{32,39,102}\) Conversely, the overweighted ball is generally used to enhance shoulder strength and power.\(^\text{32,39,102}\)

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\(^\text{92}\) 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 crouch 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.\(^\text{93}\) 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.\(^\text{94}\) Thus, the athlete is instructed when to begin such things as strength training and throwing.\(^\text{112}\) 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\(^\text{119}\) 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.
REFERENCES

CLINICAL COMMENTARY


APPENDIX A

BASELINE FOR ESTABLISHING A THROWING HISTORY IN OVERHEAD ATHLETES

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

Biceps Tendon Lesions
- Tendinitis
- Tendonosis
- Subluxation

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

Bennett's lesion

CLASSIFICATION OF MOST COMMON SHOULDER LESIONS IN OVERHEAD ATHLETES
### 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

#### 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 for full program)
- Plyometric program
- Progress interval throwing program to competitive throwing (see Reinold et al for full program)

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