Impingement syndrome historically has been considered to be a continuum of a single pathologic condition involving the subacromial soft tissue. As our understanding of this complex problem has developed, the simple continuum model has become less effective in guiding appropriate treatment. The purpose of this lesson is to provide the reader with more precise classifications of impingement syndrome and the impingement instability complex and their associated impairments, to provide more efficient and effective interventions that address the primary abnormality.

**COMPRESSION CUFF DISEASE**

Impingement syndrome, or compressive cuff disease, was originally described by Neer as mechanical impingement of the supraspinatus and the long head of the biceps tendon underneath the acromial arch. The primary pathologic condition involves a bursal surface lesion. Many investigators also classify mechanical impingement as an “outside-to-inside” lesion because the initial insult to the rotator cuff tendon occurs at its bursal surface, as opposed to its humeral surface (“inside-to-outside lesion”). The condition is often classified as primary impingement syndrome, in contrast to secondary impingement, which involves primary instability and is discussed later. Because primary impingement is recognized to involve a spectrum of lesions of tissues in the supra-humeral space, a working knowledge of its structural interrelationships will facilitate an understanding of the factors that result in abnormalities.

**Suprahumeral Space**

The suprahumeral space, also known as the subacromial space or supraspinatus outlet, is formed by the superior aspect of the humeral head below and the inferior surface of the acromion, the acromioclavicular joint, and the coracoacromial ligament above (Fig. 1). Within the subacromial space are the rotator cuff tendons (supraspinatus, infraspinatus, and teres minor), the long head of the biceps, and the subacromial-subdeltoid bursa. The subacromial distance is quite small, and it has been measured on radiographs and used as an indicator for proximal or superior humeral subluxation related to rotator cuff abnormality. The distance was found to be between 9 and 10 mm in 175 asymptomatic shoulders. A distance of less than 6 mm was considered indicative of rotator cuff disease.

**Coracohumeral Space**

A second space for potential primary impingement was identified by Patte as the coracohumeral compartment. The coracohumeral space is the space between the tuberosity and the lesser tubercle of the humerus. Within the confines of this space are situated the subscapularis bursa, subscapularis tendon, and subcoracoid bursa. In the resting position with the arm in medial rotation, the distance between the tip of the coracoid and the most prominent part of the lesser tuberosity has been measured at approximately 8.7 mm in healthy shoulders and 6.8 mm in the presence of subcoracoid impingement. A decrease in the size of the subcoracoid space, caused by a fracture trauma to the tip of the coracoid process, has been implicated in primary subcoracoid impingement. The clinician should be aware of this condition in the differential diagnosis of primary impingement, as well as in those patients who have not responded to conservative treatment, particularly after acromioplasty.

Because of the narrow confines of the subacromial space, a small margin of error exists to allow for normal excursion of the suprahumeral tissue to pass safely under the acromial process. Several factors have been implicated in abnormal narrowing of the subacromial space and in the resulting primary impingement syndrome.
FACTORS RELATED TO PATHOLOGIC CONDITION

For purposes of description, factors related to this pathologic condition can be divided into intrinsic and extrinsic factors. Intrinsic factors directly involve the subacromial space and include changes in vascularity of the rotator cuff, degeneration, and anatomic or bony anomalies. Extrinsic factors include impairments associated with postural changes, muscle imbalances, and motor control problems of the rotator cuff (scapulohumeral) and thoracoscapular muscles, as well as precipitating factors, including training errors and occupational or environmental hazards. Because several of these problems can coexist with primary impingement, isolating a specific factor as a cause is difficult. More likely, primary impingement has multiple causes, necessitating a thorough and circumspect evaluation of all possible intrinsic and extrinsic factors to injury.

Extrinsic Factors

According to Neer, the anterior-inferior one third of the acromion is thought to be the causative factor in mechanical wear of the rotator cuff through a process called impingement. Neer believed that the supraspinatus and long head of the biceps are subjected to repeated compression when the arm is raised in forward flexion. Neer called this the functional arc of elevation of the arm (Fig. 2). Arthrokinematic movement dictates that forward flexion of the humerus causes concomitant internal rotation of the humeral head. The result is that the suprathoracic tissue is effectively driven directly under the anterior-inferior one third of the acromion. The coracoacromial ligament and acromioclavicular joint can

Figure 2

A. The functional arc of elevation occurs from the sagittal to the plane of the scapula. B. Superior view of anterior acromion. Elevation in the functional arc internally rotates the humerus under the anterior-inferior one third of the acromion.
also be involved in impingement during this functional movement. The Neer impingement test involves forced forward flexion with internal rotation of the humerus to simulate movement in the functional arc and to provoke pain in symptomatic individuals (Fig. 9-3). By focusing on the anterior acromion as the source of impingement rather than the entire acromion, Neer helped to target the technique and approach to acromial decompression to the area of the anterior-inferior acromion, thus avoiding excision of the lateral acromion and significant deltoid muscle morbidity. The overall result after acromial decompression or anterior acromioplasty is an accelerated and aggressive rehabilitation program.

Scapular Muscle Imbalances

Control of the scapula and humerus is primarily dictated by a series of muscle force couples.25 A force couple is two forces of equal magnitude, but in opposite directions, that produce rotation on a body.26 The scapula force couple is formed by the upper fibers of the trapezius muscle, the levator scapulae muscle, and the upper fibers of the serratus anterior muscle. The lower portion of the force couple is formed by the lower fibers of the trapezius muscle and the lower fibers of the serratus anterior muscle.27 Simultaneous contraction of these muscles produces a smooth, rhythmic motion to rotate and protract (abduct) the scapula along the posterior thorax during elevation of the arm. The scapula functions to provide a stable base of support for the rotating humerus to allow the humeral head to maintain its normal pathway or rotation along the glenoid.28 Weakness of the serratus anterior and the trapezius muscles can limit the upward (outward) rotation of the scapula, or it can result in an unstable base of support for the humerus. An unstable scapula, in turn, may produce inefficient action of the rotator cuff muscles to control the humeral head properly along the glenoid fossa during overhead elevation. In addition, the acromion may not elevate sufficiently to provide adequate clearance of the greater tuberosity of the humerus. Furthermore, weakness of the scapular retractors (adductors; the middle trapezius and rhomboid muscles) may increase protraction of the scapula that may narrow the space under the acromion and facilitate impingement of suprahumeral structures. The coordinated action of the scapula muscles is therefore believed by most clinicians to be indispensable to overall normal shoulder function, and current treatment programs are designed to restore normal parascapular muscle control.

Scapular Postural Changes and Altered Kinematics

Clinical researchers have examined the relationships among scapular muscle balance, position, movement, and shoulder pain, particularly as related to impingement. Kibler,19 for example, observed consistent and abnormal scapular postural changes and altered scapular kinematics in overhead athletes with shoulder impingement and coined the term scapular dyskinesis. The best-known clinical test, developed by Kibler, is the lateral scapula slide test, which measures the ability of the scapular muscles to control the medial border of the scapula during three positions of the limb: adduction, hands on hips, and 90° of abduction.19 In his clinical examination, Kibler found that an increase of 1 cm or more in two of the three positions correlated with shoulder impingement and instability in baseball players. Similarly, Burkhart, Morgan, and Kibler29 observed consistent asymmetrical malposition of the scapula in throwing athletes with shoulder impingement, and these investigators coined the term SICK scapular syndrome. The acronym SICK refers to their findings of scapular malposition, inferior-medial border prominence, coracoid pain and malposition, and dyskinesis of scapular movement.

Sahrmann30 classified scapular positional impairments in patients with selected shoulder conditions including impingement. Based on her years of clinical observations, she reported scapular postural changes of downward rotation and anterior tilt in patients with primary impingement. According to Sahrmann, downward scapular rotation syndrome occurs when the inferior-medial border of the scapula is closer to thoracic midline than the corresponding superior-medial border. Sahrmann observed that patients with a chronically downwardly rotated scapular position had insufficient scapular upward rotation during overhead elevation of the arm, with resulting subacromial pain and impingement.

Figure 3 Neer’s impingement test. Forceful elevation of the humerus with internal rotation results in impingement of the rotator cuff tendons and long head of the biceps underneath the anterior-inferior acromion. A positive result is provocation of subacromial pain.
Sahrmann theorized that long-term changes in muscle length correspond to long-term changes in scapular posture. In the case of a downwardly rotated scapula, for example, the lower trapezius and lower fibers of the serratus anterior muscle lengthen, whereas the levator scapulae and upper trapezius muscles shorten. Muscles that lengthen tend to gain sarcomeres in series and shift the abilities of those muscles to generate tension to the right of a standard length-tension curve. Conversely, muscles that shorten tend to lose sarcomeres in series and shift the abilities of those muscles to generate tension to the left of a standard length-tension curve. The result is a change in muscle balance and force couple capabilities of the scapular muscles to produce outward scapular rotation.

Well-known orthopedic clinician researchers such as Kendall and McCreary, and Janda, have also observed consistent postural changes and muscle imbalances associated with shoulder conditions. Kendall and McCreary observed impaired shoulder elevation in patients with a pattern of muscle imbalances associated with chronic forward head and rounded shoulder posture that included shortness of the pectoralis major and minor and subscapularis muscles with lengthening of the middle trapezius and rhomboid muscles. Finally, Janda observed delays in recruitment of the lower trapezius and serratus anterior muscles in patients with postural impairment and shoulder conditions.

Sophisticated motion analysis studies of scapular kinematics in patients with shoulder impingement confirmed clinical findings related to scapular positional and movement changes. Most of these studies indicated that identified deviations can be summarized by a loss of scapular outward rotation (excessive scapular downward rotation) and reduction of scapular posterior tilting (excessive scapular anterior tilting).

In summary, clinical and motion analysis studies confirm the role of scapular positional changes and movement changes as primary impairments related to shoulder pain in general, and impingement symptoms in particular. In view of these insights and research findings on the role the scapular in shoulder impingements, current approaches to interventions for shoulder impingement emphasize the importance of scapular muscle training as an essential component of shoulder rehabilitation.

**Rotator Cuff Muscle Imbalance**

Budoff et al described the origin of impingement as a primary instability and with secondary impingement. The sequence of events that causes the instability is described as glenohumeral muscle imbalance. The supraspinatus is a small and relatively weak muscle in a key position and is susceptible to overuse injury. When repetitive eccentric overload occurs to the rotator cuff muscles, weakness of the musculotendinous unit results in damage to the tendon. Weak, fatigued, or injured rotator cuff muscles, infraspinatus, teres minor, and subscapularis are unable to oppose the superior pull of the deltoid muscle.

The inferiorly and horizontally directed rotator cuff muscle force vectors maintain the humeral head within the shallow glenoid and thereby resist the upward shear of the deltoid generated during active elevation of the arm. The result is that the rotator cuff muscles in effect “steer” the humeral head along the glenoid during movement of the humerus. The combination of the resultant contractions of the rotator cuff muscles and the deltoid produces the glenohumeral joint force couple (Fig. 4). With an intact and normally functioning rotator cuff muscle group, the center of the humeral head is restrained in a very small arc of motion (within 3 mm) along the glenoid fossa. Poppen and Walker and Weiner and MacNab found that, in the presence of rotator cuff disease, the arc of motion of the humeral head increases to 6 mm or greater. The loss of the rotator cuff force couple results in superior migration of the humeral head, which causes the greater tuberosity and the rotator cuff to come in contact with the undersurface of the acromion and the coracoacromial ligament. The repetitive contact of the humeral head against the acromion causes reactive and degenerative osseous changes Osteophytic spurring occurs along the undersurface of the acromion. Additional traction spurs may form at the anterior medial corner of the acromion. The traction spur may easily be mistaken for an abnormal acromial hook, or type III acromion. Therefore, superior migration of the humerus can produce repetitive impingement of the suprathoracoid soft tissue. The result is an inflammatory cascade culminating in rotator cuff disease.

**Anterior and Posterior Glenoid Impingement**

Jobe described the pathomechanics of posterior-superior labrum impingement. Overhead-throwing athletes are susceptible to forces that may result in impingement of the head of the humerus against the posterior-superior labrum. During throwing, the glenohumeral joint is between 60° and 90° of abduction, maximal external rotation, and horizontal
extension. The head of the humerus is angulated in a posterior-superior direction relative to the glenoid. In addition, the greater tuberosity moves posteriorly, secondary to external rotation of the humeral head. Angulation of the humeral head on the glenoid is limited by the inferior glenohumeral ligament and the subscapularis. The cause of impingement is hyperangulation of the humeral head to the glenoid secondary to lack of resistance from a poorly conditioned and fatigued subscapularis muscle. The subscapularis is unable to control the excessive external rotation and extension angulation of the humeral head. Angulation, as opposed to translation, places an uneven stretch to the capsule. The failure of the capsule results from overstretching and instability of the anterior capsule causing subluxations. The deep surface of the supraspinatus is impinged between the humeral head and the posterior-superior labrum.

Gerber and Sebesta38 described impingement of the deep surface of the subscapularis tendon and the coracohumeral ligaments (reflection pulley) on the anterior-superior glenoid rim. With increasing internal rotation, the lesser tuberosity and biceps tendon are brought close to the anterior superior glenoid rim. Between 100° and 90° of shoulder flexion and full internal rotation, the subscapularis, the biceps tendon, and the superior and middle glenohumeral ligaments are impinging on the anterior glenoid labrum and rim. Patients who perform overhead movements, which are typical of racquet sports and overhead-throwing athletic activities, are more susceptible to anterior-superior glenoid rim impingement. Eccentric overload of the glenohumeral external rotator is common in overhead-throwing athletes. Poorly conditioned and fatigued infraspinatus and teres minor muscles result in excessive internal rotation of the humerus. In the final phase of pitching, the shoulder is in flexion and internal rotation. Excessive internal rotation of the humerus in the flexed position between 100° and 90° could result in impingement of the foregoing soft tissue structures on the anterior-superior glenoid rim.

Precipitating Factors
Precipitating factors to injury are any activities that involve repetitive use of the arm, usually overhead or above the shoulder level, that result in subacromial impingement.21,22 The baseball pitcher who pitches a nine-inning game early in the season, the retiree who decides to spend the weekend painting her house, and the stock clerk who works two 12-hour shifts to stock inventory are examples of individuals with precipitating factors that result in overuse of the shoulder. A caveat to practicing clinicians is to identify these factors early during a comprehensive history and to modify activities appropriate to the stage of the pathologic condition of impingement and degree of clinical reactivity.

Intrinsic Factors
The primary intrinsic factors can be divided into vascular, degenerative, and anatomic. The original significance of rotator cuff tendon vascularity was described by Codman.11 Codman referred to a critical zone in which a rupture occurred in the supraspinatus. This zone was located approximately 1 cm medial to the insertion of the tendon. Moseley and Goldie59 noted that the anastomosis of the osseous and tendinous vessels in the supraspinatus occurred at this site. Rothman and Parke9 believed that this location was relatively avascular, a condition intensified by aging. Microinjection studies of normal shoulders in cadavers showed an area of decreased vascularity within the tendinous portion of the supraspinatus tendon. Rathbun and Macnab10 noted that the critical zone of the rotator cuff had an adequate blood supply when the vessels were injected with the arm in the abducted position, but this area was hypovascular when the injection was given with the arm in the adducted position. These investigators proposed a hypothesis of transient hypovascularity in the critical zone caused when vessels are “wrung out” when the arm is in the adducted position. These investigators also indicated that most degenerative rotator cuff tears occur within this zone, a finding suggesting that hypovascularity of the supraspinatus tendon may play a role in the pathogenesis of rotator cuff tears. Lohr and Uhthoff40 found that the area of hypovascularity in the critical zone was more pronounced along the articular than the bursal surface of the supraspinatus tendon and within the site of early degeneration. Other investigators have disputed the hypovascularity findings.41,42 A laser Doppler study of the rotator cuff vasculature showed substantial blood flow in the region of the critical zone and increased blood flow at the margins of rotator cuff tears.42 Although definitive scientific evidence of a direct cause-and-effect relationship is not yet available, the finding seems to indicate a vascular predisposition to the pathogenesis of rotator cuff disease and impingement.

Degeneration
Evidence indicates natural age-related degeneration and tendinosis of the rotator cuff tendons. Codman11 noted that rotator cuff tendon rupture in older patients normally occurred bilaterally and in the presence of preexisting tendon degeneration. Uhthoff et al12 and Ozaki et al13 found insertional tendinopathy or preexisting tendon degeneration in human specimens. These changes included histologic changes in the arrangement of tendon fibers, fiber disruption at their insertion site, and microcysts and osteopenia along the insertion site. These changes found along the articular side (humeral side) were not usually associated with changes in the acromial process.

Anatomic Anomalies
Morrison and Bigliani7 studied the shape of the anterior-inferior acromion in anatomic specimens and in patients. They identified three types of acromions: type I (flat), type II (curved), and type III (hooked) (Fig. 5). The development of type II or II acromial processes remains controversial. The older theory is that these are congenital anomalies, although little evidence indicates that youngsters exhibit changes in
acromial morphology. More logically, the development of type II or III acromial processes may result from excessive superior shear of the humeral head under the acromion, as a result of muscle imbalance in the parascapular or rotator cuff muscle. The repetitive impingement is thought to cause remodeling of the undersurface of the acromion.

Regardless of cause, in the anatomic specimen studies of Morrison and Bigliani,7 70% of rotator cuff tears were associated with type II or III acromions. None had type I acromions. Although no causal relationship between the shape of the acromion and rotator cuff tears or impingement can be concluded, the clinical findings support Neer’s theory of impingement occurring primarily along the anterior-inferior acromion.

STAGES OF PATHOLOGY AND PRINCIPLES OF TREATMENT

Program design for conservative management of primary impingement syndrome is predicated on a problem-solving approach. This approach necessitates a thorough evaluation to clarify the nature and extent of the pathologic condition, the stage of reactivity, underlying impairments—including extrinsic problems to formulate a physical therapy diagnosis—and other factors that may affect treatment planning and outcome (e.g., age of the patient, motivation, and underlying disease). Classifying the pathologic condition based on the progression described by Neer can be correlated with clinical signs and symptoms and can provide a basic framework for preliminary treatment planning and progression. All program designs should be divided into treatment phases that include specific goals and criteria for progression and continual reevaluation of both subjective and objective findings. Table 1 presents a summary of the stages of pathologic conditions described by Neer. The stages are presented separately, but they represent a continuum of abnormality that in some cases overlap in a particular patient.

Stage I ImpingementStage I of impingement is characterized by edema and hemorrhage (inflammation) of the rotator cuff and suprhumeral tissue. The patient is usually less than 25 years of age and normally has a precipitating factor of overuse of the shoulder. The clinical symptoms include pain along the anterior and lateral aspect of the shoulder, which when acute or reactive will extend below the elbow. The pain is usually described as a deep, dull ache, with sharp subacromial pain during elevation of the limb. The patient has full active range of motion (AROM) and passive ROM (PROM), a painful arc (pain between 60° to 90° and 120° of elevation of the limb), and an abnormal impingement sign. Muscle strength is usually normal for the abductors and external rotators of the glenohumeral joint, but muscles can be painful and weak in an acute state. Palpation elicits subacromial tenderness, usually along the greater tubercle and bicipital groove. Muscle spasms are often present along the ipsilateral upper trapezius, levator scapulae, and subscapularis muscles. Many of these patients exhibit scapular postural changes including excessive scapular downward rotation and anterior tilting.

Principles of Treatment

Principles of treatment for stage I are based on the stage of clinical reactivity and associated impairments. Because stage I primary impingement usually is acute, the goals of treatment
are to reduce and eliminate inflammation, increase the patient’s awareness of impingement syndrome, improve proximal (parascapular) muscle control, and prevent muscle atrophy or weakness caused by disuse at the glenohumeral joint. The patient should be instructed to rest from activity, but not function, and to perform all activities in front of the shoulder and below shoulder level. A thorough (but understandable) explanation of the impingement process is helpful for many patients to comprehend harmful positions. Forceful active elevation above the shoulder level can produce a painful arc and impingement and can perpetuate the inflammatory response. The patient would do well to take an oral nonsteroidal anti-inflammatory medication, in conjunction with anti-inflammatory modalities including ice, interferential stimulation, or pulsed or low-intensity ultrasound. Soft tissue work and stretching should be used to alleviate muscle spasms. Exercise, including manual resistance, can be used early to facilitate scapular parascapular muscle control without further aggravation of the supragnohumeral tissue (Fig. 9-6).

As reactivity diminishes with elimination of rest pain and pain below the elbow, and with elimination of painful arc and subacromial tenderness, the patient progresses into a dynamic strengthening program that emphasizes reestablishment of the force couple mechanisms at both the scapulothoracic junction and the glenohumeral joint. Table 2 lists exercises that are normally effective at this stage. The emphasis should be on high repetitions (3 to 5 sets of 15 repetitions for each exercise), multiple sessions of 3 to 4 daily, working initially in a pain-free range, and using both concentric and eccentric muscle contraction. Exercises are slowly increased to 7 to 10 different movement patterns to isolate different muscle groups. The proper use of these exercises with a low-weight (never greater than 5 lb) and high-repetition format is recommended to enhance local muscle endurance of the rotator cuff muscle and parascapular muscles. Moncrief et al studied the effects of a 5 times per week training program of rotator cuff exercises with 2 sets of 15 repetitions for 1 month in healthy.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Clinical Presentation</th>
<th>Treatment Principles</th>
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<tbody>
<tr>
<td>Stage I</td>
<td>Age: less than 25 years</td>
<td>Subacromial pain and tenderness</td>
</tr>
<tr>
<td>Pathologic conditions: edema and hemorrhage</td>
<td>Positive impingement and Neer’s test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strong and painful for resisted abduction and external rotation</td>
<td></td>
</tr>
<tr>
<td>Stage II</td>
<td>Age: 25–40 years</td>
<td>Add: capsular pattern of limitation at glenohumeral joint</td>
</tr>
<tr>
<td>Pathologic condition: tendinitis, bursitis, and fibrosis</td>
<td>Reestablishment of glenohumeral capsular mobility</td>
<td></td>
</tr>
<tr>
<td>Stage III</td>
<td>Age: more than 40 years</td>
<td>Add: weakness abduction and external rotation, “squaring” of acromion</td>
</tr>
<tr>
<td>Pathologic conditions: bone spurs and tendon disruption</td>
<td>Based on size of tear</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Neer Stages of Impingement

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supraspinatus</td>
<td>Prone horizontal abduction</td>
</tr>
<tr>
<td></td>
<td>Scaption in internal rotation</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>Prone horizontal abduction in external rotation</td>
</tr>
<tr>
<td>Teres minor</td>
<td>Prone horizontal abduction in external rotation</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Scaption in internal rotation</td>
</tr>
<tr>
<td></td>
<td>Military press with dumbbell</td>
</tr>
<tr>
<td>Anterior deltoid</td>
<td>Scaption in internal and external rotation</td>
</tr>
<tr>
<td>Posterior deltoid</td>
<td>Prone extension</td>
</tr>
<tr>
<td>Upper trapezius</td>
<td>Rowing (prone with dumbbell)</td>
</tr>
<tr>
<td></td>
<td>Shrug</td>
</tr>
<tr>
<td>Middle trapezius</td>
<td>Prone horizontal abduction in neutral position</td>
</tr>
<tr>
<td>Lower trapezius</td>
<td>Prone horizontal abduction in external rotation</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>Rowing (prone with dumbbell)</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>Prone horizontal abduction in neutral position</td>
</tr>
<tr>
<td></td>
<td>Push-up with a plus</td>
</tr>
</tbody>
</table>

Table 2 Shoulder-Strengthening Exercises

Figure 6 Manual technique illustrating resisted posterior scapular depression to facilitate early recruitment of the parascapular muscles.
uninjured subjects. Subjects were pretested and post-tested on an isokinetic dynamometer to quantify internal and external rotation strength objectively. Results of the 1-month rotator cuff training program showed an 8% to 10% gain in isokinetically measured internal and external rotation strength in the training arms of the study and no significant improvement in strength in a control group.

Neer suggested that a patient should continue this conservative approach for several months before considering surgical treatment. If the patient is an athlete, as signs and symptoms permit, an additional program of sport-specific exercises and functional training should be incorporated into the program. More recent studies showed the effectiveness of a structured and supervised exercise program for patients with shoulder impingement that was comparable to surgical acromioplasties.

Stage II Impingement

Stage II impingement is characterized by fibrosis of the glenohumeral capsule and subacromial bursa and tendinitis of the involved tendons. The condition is normally seen in patients between 20 and 40 years old. The clinical presentation can be similar to that of stage I, except the patient has loss of AROM and PROM because of the capsular fibrosis. The loss of ROM normally appears in the capsular pattern, described by Cyriax, as a significant loss of external rotation and abduction, with less loss of internal rotation.

Principles of Treatment

The principles of treatment are similar to those for stage I impingement, except that a major goal is to restore full AROM and PROM to prevent further impingement and tissue damage. Cofield and Simonet described how patients with adhesive capsulitis of the glenohumeral joint developed subacromial impingement. Specifically, posterior capsule tightness caused the humeral head to roll forward and superiorly into the subacromial arch and anterior-inferior acromion. Subsequent treatment should be directed at restoring capsular extensibility, to allow the humeral head to attain its normal center of rotation. The force and direction of the mobilizing force should be based on the stage of reactivity and clinical mobility testing. Treatment time in patients with a stage II pathologic condition is longer than in stage I, and the prognosis and functional outcome may be more limited.

Stage III Impingement

Stage III impingement is the most difficult to treat conservatively and is characterized by disruption of the rotator cuff tendons. The patient is normally more than 40 years old. Clinically, muscle testing yields weakness, usually for external rotation and abduction. Visual observation indicates a “squaring” of the acromion, a finding that indicates atrophy.

Treatment principles are based partly on the size and location of the tear (Table 3). Tears are classified by size, diameter, location, or topography. The small and moderate-size tears can do relatively well with limited functional goals. The patient progresses similarly to the previous treatment principles. If treatment is ineffective and the patient continues to have pain and inability to raise the arm overhead, surgical options include rotator cuff débridement and anterior acromioplasty, or a mini-open repair. For those with large and massive tears, surgery is usually the most effective option, followed by an extensive rehabilitation program incorporating the basic treatment principles for the impingement syndrome and adherence to soft tissue healing guidelines.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Classification of Rotator Cuff Tear Based on Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (cm)</td>
<td>Treatment Principles</td>
</tr>
<tr>
<td>1</td>
<td>Conservative</td>
</tr>
<tr>
<td>1–3</td>
<td>Conservative, acromioplasty, débridement, or mini-open repair</td>
</tr>
<tr>
<td>3–5</td>
<td>Mini-open repair</td>
</tr>
<tr>
<td>5</td>
<td>Open repair</td>
</tr>
</tbody>
</table>
This case represents a typical progression for a patient who has symptoms of primary impingement syndrome. Goals and treatment are based on some of the principles of treatment discussed in the previous sections.

**General Demographics**
Mr. Smith is a 40-year-old male construction worker with a 1-week history of right shoulder pain. He is right-hand dominant.

**Social History**
Mr. Smith is married with two teenage daughters. He smokes and drinks sparingly. He enjoys tennis.

**Employment**
He is a construction worker.

**Living Environment**
Mr. Smith lives with his wife and children in a ranch type of house.

**Growth and Development**
He is muscular with no external deformities.

**Past Medical History**
He has a history of arthritis in his cervical spine that occasionally results in tingling and pain into his right shoulder and arm. He reports that, at the age of 14 years, he had a “separated right shoulder” while playing football.

**History of Chief Complaint**
Mr. Smith spent the weekend painting his house. Since then, he reports pain in the anterior and lateral aspect of his right shoulder. He reports some tingling in his right hand. He describes the pain in his shoulder as a dull ache but sharp during active elevation of his arm. He had difficulty sleeping on his right shoulder at night.

**Prior Treatment for this Condition**
His family physician prescribed ibuprofen (Motrin) and referred him for a trial of physical therapy with a diagnosis of right shoulder muscle strain.

**Structural Examination**
During relaxed standing from behind, the scapulae are positioned between T2 and T8. The left scapular inferior-medial and superior-medial borders are in line and approximately 2 inches from the midthoracic spine. The right scapular inferior-medial border is closer to the midthoracic spine than is the corresponding superior-medial border. In addition, the inferior angles of the right and left scapulae are rotated posteriorly away from the thoracic chest wall.

**Screening Tests**
- Positive Spurling’s test result: Testing of the right cervical spine reproduces tingling in the right hand.
- The result of Adson’s test is negative.
- AROM: Scapulohumeral elevation in the scapular plane produces pain from 60° to full overhead elevation.
- PROM: The patient has full and pain-free PROM in all planes of motion.
- Accessory motion testing of the glenohumeral joint: Results show normal mobility and symmetry with the uninvolved side.
- Resisted testing: The response is painful and strong (empty can test [refer text for more details] and Speed’s test).

<table>
<thead>
<tr>
<th>Muscle Testing</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower trapezius</td>
<td>4/5</td>
<td>3/5</td>
</tr>
<tr>
<td>Serratus anterior</td>
<td>4/5</td>
<td>3+/5</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>5/5</td>
<td>4/5</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>5/5</td>
<td>4/5</td>
</tr>
<tr>
<td>Teres minor</td>
<td>5/5</td>
<td>4/5</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>4/5</td>
<td>3+/5</td>
</tr>
</tbody>
</table>

**Flexibility and Soft Tissue**
With the patient supine, both scapulae are elevated from the treatment table. Passive pressure applied to the anterior scapulae reveals tissue resistance associated with pectoralis minor muscle shortening and tightness.

**Special Tests**
The result of Neer’s impingement test is positive.

**Tenderness**
Palpation elicits tenderness of the greater tubercle and along the bicipital groove.

**Physical Therapy Evaluation**
Based on presenting signs and symptoms, onset, and patient’s age, the physical therapist classifies a stage I primary impingement. The stage of clinical reactivity is acute. The patient has pain to the elbow, is unable to sleep on the involved side, has a painful arc, pain with manual resistance, and a positive impingement sign. Resisted testing and palpation seem to indicate primary involvement of the supraspinatus muscle tendon and the long head of the biceps tendon (empty can and Speed’s tests). A secondary problem of tingling in the right hand is likely related to cervical radiculopathy from long-term cervical arthritis (degenerative disk disease). This condition was also most likely exacerbated by painting.

Primary impairments (extrinsic) factors related to pathology include the following:
- Scapular downward rotation and anterior tilting syndromes

Continued
Rotator cuff disorder in the athlete is generally known as secondary impingement. Differentiating primary impingement from secondary impingement is crucial in the proper management of the two conditions. When secondary impingement is treated as primary impingement, the underlying impairment of instability fails to resolve. Instability in this case is defined as symptomatic hypermobility of the humeral head that occurs during function. Instability is often contrasted with asymptomatic clinical laxity. The following sections review the classification of secondary impingement—which occurs primarily in the overhead-throwing athlete—the related clinical signs and symptoms, and approaches to treatment.

Classification

Rotator cuff abnormality in the athlete represents a continuum of problems that may coexist, thus making the primary diagnosis difficult. General classification of rotator cuff abnormality in athletes includes tensile overload, compressive impingement (Neer's classification), instability, and acute traumatic tears. Meister and Andrews classified rotator cuff disease as (1) primary compressive cuff disease, (2) instability with secondary compressive disease, (3) primary tensile overload, (4) secondary tensile overload, and (5) macrotraumatic failure. Primary tensile overload is the result of deceleration forces in the absence of instability, whereas secondary tensile overload is precipitated by underlying instability. Neer's classification of compressive impingement is also observed in the athletic...
fatigue and failure of the dynamic stabilizers. Microtrauma during decelerative functions that results in
the midsupraspinatus posterior to the midinfraspinatus, Angelo described rotator cuff tears in throwers located from
throwing puts the rotator cuff at risk for failure. Andrews and
activity was found to be 71% of the MMT during late cocking
and diminished to 49% and 51% of the MMT during the late cocking and
the early cocking phase at 60% of the MMT and diminished
fraspinatus and teres minor muscle activity has been found in
increases to 45% of the MMT during late cocking. Peak in-
be 40% of the maximum manual muscle test (MMT), with
activity seen on electromyography (EMG) has been shown to
donc.54 During the early cocking phase of throwing, supraspinatus
activity seen on electromyography (EMG) has been shown to
40% of the maximum manual muscle test (MMT), with
activities produce problems similar to those encountered
in swimming or throwing. The underlying mechanics, which
result in overuse, must be analyzed relative to the respective
signs and symptoms.

**Primary Tensile Overload**

Primary tensile overload can be defined as rotator cuff failure under tensile loads. These
tensile loads are primarily the result of eccentric muscle
contractions and are associated with activities such as
throwing. In this case, the rotator cuff functions to decelerate the
horizontal adduction, internal rotation, anterior
translation, and distraction forces seen during deceleration.
During the early cocking phase of throwing, supraspinatus
activity has been shown to be 40% of the maximum manual muscle test (MMT), with
increases to 45% of the MMT during late cocking. Peak in-
fraspinatus and teres minor muscle activity has been found in
the late cocking and follow-through phases of pitching. DiGiovine et al found that supraspinatus activity peaked in
the early cocking phase at 60% of the MMT and diminished
to 49% and 51% of the MMT during the late cocking and
acceleration phases, respectively. Infraspinatus activity peaked
at 74% of the MMT during late cocking, whereas teres minor
activity was found to be 71% of the MMT during late cocking and
84% of the MMT during deceleration. Thus, repetitive
throwing puts the rotator cuff at risk for failure. Andrews and
Angelo described rotator cuff tears in throwers located from
the midsupraspinatus posterior to the midinfraspinatus,
consistent with the deceleration function of these muscles.
The mechanism of primary tensile overload is repetitive
microtrauma during decelerative functions that results in
fatigue and failure of the dynamic stabilizers.

In addition to the rotator cuff’s function in deceleration and
abduction, the supraspinatus, infraspinatus, and teres minor
muscles also function to stabilize the humeral head on the
glenoid. This is the dynamic component of shoulder stability,
and static stabilization is provided by the labrum and capsulo-
ligamentous structures. When the rotator cuff
fatigues as a result of repetitive overload, not only is the decel-
erative function affected, but also the stabilization function is
impaired. The result may be secondary overload on the capsulo-
labral structures (relative instability) or secondary compressive
impingement. As pain persists, subtle changes in movement
patterns can exacerbate the problem. Gowen et al described the
patterns in EMG in amateur baseball pitchers and compared the
patterns with those of professional pitchers. The professional
pitchers used the shoulder muscles more efficiently than the
amateurs, who used the rotator cuff and biceps brachii muscles
during the acceleration phase.

Evaluation of the shoulder with primary tensile rotator cuff
dysfunction reveals a stable shoulder without true compressive
impingement. Resistive testing of the rotator cuff is painful,
and the rotator cuff may be weak with single or multiple
repetition testing. Andrews and Giduman described the
hallmark of primary tensile cuff disease to be a partial
“undersurface” rotator cuff tear. As noted previously, this type
of tear is described as an inside-outside tear. Frequently, no
signs of compressive impingement are found at surgery.

The treatment principles are embedded in the knowledge of
the underlying pathologic condition, the healing process of soft
tissue, and functional demands of the shoulder. Given the
premise that primary tensile overload is the result of excessive
eccentric muscle contractions and resultant rotator cuff fatigue,
the focus of rehabilitation should address these issues.
Numerous training techniques challenge the rotator cuff
eccentrically. The therapist should be familiar with these tech-
niques and the muscle physiology of eccentric contractions. The
problem can be exacerbated if eccentric work is initiated too
vigorously in the early stages. Failure of conservative measures
may result in surgical intervention to débride the rotator cuff
tear. Subacromial decompression is rarely necessary because
associated compressive cuff disease is uncommon.

**Secondary Tensile Overload**

Secondary tensile overload, like primary tensile overload, is
defined as rotator cuff failure under tensile loads. In this case,
excessive rotator cuff loading is caused by underlying
instability. The concept of dynamic stability is important to
appreciate in these patients. The subscapularis, supraspinatus,
infraspinatus, and teres minor function to compress the
humeral head into the glenoid and provide dynamic
stability. The rotator cuff muscles therefore must provide
eccentric control of the humerus during throwing while steer-
ing the humeral head along the glenoid fossa. This double
function leads to early fatigue failure, tendinitis, and possible
secondary mechanical impingement.

As a result of the demands placed on the rotator cuff muscles
during throwing, secondary tensile load results from the
simultaneous requirements of deceleration and stabilization.
Although both demands are present and are generally tolerated
in the normal shoulder, the unstable shoulder places an
additional burden on the rotator cuff. Because the static stabi-
lizers are compromised, the rotator cuff is overloaded, result-
ing in dysfunction and injury.
Evaluation of the shoulder with secondary tensile overload is similar to that of primary tensile overload, with the addition of underlying instability. Instability can be unidirectional or multidirectional and is evaluated by traditional instability testing. However, the symptoms may be those of pain rather than instability, and careful evaluation is necessary to delineate the underlying abnormality. Impingement signs may be positive if secondary compressive impingement coexists. Arthroscopic findings demonstrate instability and an associated undersurface rotator cuff tear.

As with primary tensile overload, the treatment principles should address the underlying pathologic condition. In this case, the emphasis is on dynamic stabilization. Again, supraspinatus, infraspinatus, and teres minor strengthening are important because of their role in both eccentric deceleration and stabilization. Additionally, the subscapularis muscle should be trained because of its role in opposing superior humeral head translation and in contributing to rotator cuff moment.58,61

Failure of conservative treatment may necessitate surgical intervention. Stabilization procedures and débridement of a partial rotator cuff tear are the appropriate surgical measures to address the underlying pathologic condition.

### Instability-Impingement Complex

The scheme of instability and associated impingement noted by Jobe and associates50-52,62 uses a four-group classification system, with instability as the central theme. In the young athlete, participation in overhead sports such as throwing, swimming, tennis, and volleyball requires large ranges, forces, and repetitions. These demands result in microtrauma to the static and dynamic structures, laxity in the anterior capsule, anterior humeral head subluxation, and posterior capsule tightness. This combination has been described as the instability-impingement complex and is discussed in the following scheme.50

### Instability-Subluxation-Impingement-Rotator Cuff Tear

Individuals with pure compressive rotator cuff impingement whose examination findings include positive impingement signs and negative apprehension signs constitute group 1. Older recreational athletes are generally found in this group, whereas younger athletes are rarely in group 1. Arthroscopic examination reveals a stable shoulder with an undersurface rotator cuff tear and associated subacromial bursitis. The labrum and glenohumeral ligaments are normal. Treatment principles are based on clinical examination findings and follow the general guidelines presented in Neer's model of compressive cuff disease.

Group 2 consists of individuals with impingement-associated instability with labral or capsular injury, instability, and secondary impingement. Findings include positive impingement, apprehension and relocation signs and arthroscopic findings of instability, labral damage, and an undersurface rotator cuff tear. However, the instability findings are often so subtle, even when the patient is examined under anesthesia, that the underlying abnormality may be overlooked. As with group 1 impingement, most individuals respond to a conservative program that addresses the specific mobility, strength, and endurance deficits. Recognition of the underlying instability is the key to successful rehabilitation. In the event of failed conservative treatment, surgical intervention to stabilize the shoulder and débride any rotator cuff damage provides the best results. Isolated acromioplasty can exacerbate underlying instability.

Those individuals classified into group 3 have hyperelastic soft tissue resulting in anterior or multidirectional instability and associated impingement. Hyperelasticity, as evidenced by joint hyperextension, is the distinguishing characteristic between groups 2 and 3. In this case, results of impingement, apprehension, and relocation signs are positive. Arthroscopic examination reveals an unstable shoulder, an attenuated but intact labrum, and an undersurface rotator cuff tear. Jobe and Glousman62 emphasized the difficulty in clarifying the diagnosis in groups 2 and 3. Once the diagnosis is made and the underlying pathologic condition is identified, appropriate rehabilitation measures are generally effective in returning the athlete to his or her sport. Group 4 consists of those individuals with pure anterior instability without associated impingement. Injury is caused by a traumatic event, resulting in an acute partial or complete dislocation. Clinical and arthroscopic examinations are consistent with an unstable shoulder, without impingement.

### Posterior Impingement

As previously described, posterior-superior glenoid impingement (internal impingement) is an additional source of rotator cuff abnormality and is suggested to be the primary cause of rotator cuff disease in athletes.63-67 In this case, the rotator cuff is impinged between the greater tuberosity and the posterior-superior glenoid labrum. This disorder often occurs in throwers and others involved in overhead activity. It is often associated with mild anterior instability, whereas patients with significant instability do not have posterior impingement. Some investigators have challenged the assumption that this problem is seen primarily in athletes and in those with mild instability and have found no statistically significant relationships among the position of contact and the mechanism of injury, ROM, throwers versus nonthrowers, or impingement signs.67

Several theories have been posited to explain the underlying mechanism of posterior-superior impingement.68-70 Because many of these patients have a loss of internal rotation ROM greater than 20° (compared with their contralateral side), the thought is that internal rotation loss with a shortened posterior capsule creates a posterior-superior translation of the humeral head, particularly during the cocking phase of throwing.70 As a result, the posterior cuff tendons are susceptible to entrapment between the posterior-superior humeral head and the corresponding glenoid fossa.

Patients with posterior impingement often complain of posterior pain, which is worse when in a position of abduction.
Rehabilitative Issues

Overview

Jobe and Pink reported that approximately 95% of patients with the instability-impingement complex respond to conservative treatment. The remaining 5% will require a surgical procedure that addresses the primary pathologic condition. Anywhere from 2 to 3 to 6 to 12 months of appropriate conservative rehabilitation have been recommended before one should consider surgical intervention, depending on the specific impingement problem. The rehabilitation program should be based on the underlying pathologic condition, the clinical examination results, and the patient's goals. The concept that everyone with impingement should be treated with a stretching and strengthening program neglects the spectrum of impingement problems. Jobe et al emphasized this fact in suggesting that stretching should be performed judiciously and only on demonstration of specific musculotendinous tightness. In the presence of internal impingement, for example, Morgan et al suggested a program of stretching the posterior capsule of the glenohumeral joint to increase internal rotation. In contrast, excessive stretching of already lax anterior shoulder structures may exacerbate the problem.

Rehabilitative exercises have been recommended for treating the unstable shoulder. Burhead and Rockwood treated 115 patients with 140 unstable shoulders with an exercise program. Subjects had traumatic or atraumatic recurrent anterior, posterior, or multidirectional shoulder subluxation. In those individuals with atraumatic subluxation, 85% had a good or excellent result, compared with 13% of those with traumatic instability. These investigators emphasized the importance of continuing a maintenance strengthening program because several patients had recurrent symptoms when they stopped the exercises.

Mallon and Speer recommended strengthening of the rotator cuff, specifically the supraspinatus, because of its role in preventing inferior subluxation. Short-arc strengthening is advocated, and stretching is generally avoided. Kronberg et al evaluated the muscle activity and coordination in normal shoulders and concluded that muscle activity plays a significant role in stabilization through coordinated activation of prime movers and antagonists. A subsequent study analyzed shoulder muscle activity in patients with generalized joint laxity and shoulder instability compared with the control groups in the previous study. Results in patients demonstrated increased anterior and middle deltoid activity during flexion and abduction and decreased subscapularis activity during internal rotation as compared with the control groups. A nonsignificant increase in supraspinatus activity was recorded during all movements except flexion, a finding suggesting compensatory muscle function. These findings support the role of the supraspinatus in stabilization and underscore the importance of training this muscle in rehabilitation.

Examination

The varying muscle function throughout any upper extremity activity underscores the importance of the evaluation process. The first and most fundamental rehabilitation issue is clarification of the problem through a thorough evaluation. Subjective information should include the painful position or motion, with estimation of the force, direction, and magnitude of muscle activity. In addition to the primary movers, muscles functioning as stabilizers and antagonists must be identified. The therapist must be aware that underlying instability may be subtle and unrecognized by the athlete. Moreover, instability testing may reproduce pain, but not a feeling of apprehension. The rehabilitation program varies, depending on the absence or presence of underlying hyperelasticity, frank instability, or secondary compressive impingement. In all cases, the primary underlying abnormality is the focus of rehabilitation, and secondary problems are addressed simultaneously. This situation is clearly more difficult than in the individual who has a single problem. Many athletes have returned to the clinic with a recurrence of impingement with a previously unrecognized underlying dysfunction. This underlying dysfunction may not be evident in the shoulder girdle, but it may manifest as weakness in another link in the kinetic chain, resulting in excessive load on the shoulder. A lower extremity or back injury may alter movement patterns, which are amplified at the shoulder.

Itoi et al emphasized the importance of shoulder position in kinetic and kinematic analysis because muscle function changes depending on position. Moreover, an understanding of the differences in muscle activity between sports and among phases or positions of the same sport is the key to designing a rehabilitation program. Activity on EMG has been documented in swimming, throwing, golf, and tennis, as well as in painful and normal shoulders. When evaluating data from EMG, the type of muscle contraction should be considered. The MMT on which data from EMG are based is generally performed isometrically, whereas acquired data from EMG may be from isometric, concentric, or eccentric muscle contractions, depending on the muscle's role at any point in time. Because of the efficiency of eccentric muscle activity, the same force can be generated with fewer motor units, and the result is a lower percentage of MMT. Incorrect interpretation of these data could affect the rehabilitation program design. The type of muscle contraction required at the painful position and the number of repetitions guide the rehabilitation program design.

An important aspect of the evaluation process is the determination of the specific return to activity goals. If strength and endurance are the primary issues, these should be the primary focus of rehabilitation. Dynamic stabilization and
coordination drills should be at the program’s core in athletes with underlying instability. Not all athletes require a plyometric program to return to their sport, and the program should differ from one individual to the next most dramatically in the late stages. As the rehabilitation program proceeds, the exercise program should begin to resemble the athlete’s sport. This includes body posture, exercise range, type of muscle contraction, speed, load, and repetitions. Transition to the functional progression is facilitated by appropriate program design.

**Role of the Scapula**

As previously detailed, the scapular muscles place the scapula in a position for optimal glenohumeral function and provide a stable base for the glenohumeral rotator cuff muscles as well as the deltoid muscle. The scapular muscles include the rhomboid, trapezius, levator scapulae, serratus anterior, and pectoralis minor. Based on biomechanical and clinical studies, clinicians carefully evaluate and address scapular impairments as part of their overall treatment for impingement.53–85

Several of the scapular muscles have been studied in normal and in painful shoulders during functional activities to determine changes in firing patterns with pain. When investigators compared data from EMG during free-style swimming between individuals with normal and painful shoulders, significant differences were found.79,80 Patients with painful shoulders demonstrated the following differences when compared with persons with normal shoulders: (1) less anterior and middle deltoid activity at hand entry and exit, (2) more infraspinatus activity at the end of pull-through, (3) less subscapularis activity at midrecovery, (4) less rhomboid and upper trapezius activity at hand entry, and (5) more rhomboid and less serratus anterior activity during pulling. Decreased serratus anterior activity during the pulling phase sets the stage for impingement symptoms because it positions the shoulder in protraction and upward rotation to prevent impingement. Increased rhomboid activity may partially substitute for the serratus anterior by attempting to create a more subacromial space while preparing the shoulder for early hand exit. Similar findings were noted when comparing butterfly swimmers who had pain-free and painful shoulders.77–79 Again, the serratus anterior, along with the teres minor, demonstrated decreased activity, a finding suggesting an unstable base of support and an inability to assist with propulsion. In persons with normal shoulders, the subscapularis, serratus anterior, teres minor, and upper trapezius maintained high levels of activity throughout the stroke, thus predisposing these muscles to fatigue. As such, training programs should focus on increasing the endurance of these muscles.

Glosman et al,40 in a study of EMG in pitchers with normal shoulders and in those with anterior instability, noted decreased pectoralis major, latissimus dorsi, subscapularis, and serratus anterior muscle activity during throwing and especially during late cocking. During this phase, the serratus anterior functions to oppose the retractors while stabilizing and protracting the scapula. Additionally, the serratus anterior may assist in tipping the scapula to allow for maximal glenohumeral congruency during excessive external rotation.54 Decreased serratus anterior activity in late cocking places an additional load on the anterior static stabilizers and may contribute to anterior instability. Strength and endurance of these muscles are the keystones for shoulder rehabilitation in this population.

Moseley et al28 analyzed the activity on EMG in 8 scapular muscles during 16 rehabilitation exercises. Optimal exercises for each muscle were identified by the criteria of greater than 50% MMT over three consecutive arcs of motion. A group of four core exercises trained each of the eight muscles at the preset criteria and included scaption (elevation in the scapular plane), rowing, push-up with a plus (additional scapular protraction), and press-up. Closer evaluation of the data will allow the therapist to make appropriate choices regarding scapular-strengthening activities. For example, the criteria for the core exercise group necessitated that each muscle be used at the predetermined minimum level. The only qualifying exercise for the pectoralis minor was the press-up, so it was included in the core group. The press-up did not meet minimal criteria for any other muscle group. Additionally, the highest activity on EMG in the middle serratus anterior was produced during flexion and abduction, from 120° to 150°. Moreover, the standard deviations of some exercises are greater than 50% of the original value. As such, the therapist should choose exercises judiciously based on the examination and activity kinetics and should monitor the exercise quality carefully to ensure proper performance (Fig. 9-8).

**Closed and Open Chain Exercise**

Closed chain exercises have been advocated for lower extremity rehabilitation and have been suggested for the treatment of upper extremity problems.87–90 Traditional physical therapy application of the closed kinetic chain concept assumes the distal segment to be fixed to an object that provides considerable external resistance, whereas in an open chain, the distal segment is free to move in space. The definition of “considerable external resistance” could potentially be met in a traditional open chain activity.89 Dillman et al89 suggested a new classification of this model because of inadequate standardized definitions, lack of quantitatively based definitions, classification of some exercises into opposing categories, and comparison of exercises with different mechanics. These investigators suggested the following three-level classification:

1. (1) moveable boundary, no external load (MNL); (2) moveable boundary, external load (MEL); and (3) fixed boundary, external load (FEL). The MNL classification is like a traditional open chain exercise, the FEL is like a traditional closed chain exercise, and the MEL is like the “gray” area. Activities representative of the MEL classification are a resisted bench press, hack squat, and leg press. Matched MEL and FEL exercises in a single subject demonstrated that exercises with similar biomechanics result in comparable muscular activity.

Principles of closed chain exercise in the lower extremity have been applied to the upper extremity. Further study is necessary to determine whether this application is appropriate. The supposition that closed chain shoulder exercise enhances static stability during dynamic activity through mechanoreceptor education needs further testing.
Specificity of exercise guidelines would suggest little carryover from closed chain exercise to open chain activity. The value of closed chain exercise in the athlete participating in a closed chain sport is evident. Closed chain exercise training in an open chain sport may be of value for reasons yet to be clarified. Muscular cocontraction in closed chain activity can provide dynamic stabilization for the individual with an unstable shoulder. Carryover of this cocontraction into an open chain is essential for the open chain sport athlete and is discussed in further detail in the next section.

Closed chain exercise for the upper extremity includes activities such as wall push-ups, modified and full push-ups with a plus, weight shifts in weight-bearing positions, and press-ups (Fig. 9; see also Fig. 8). The progression should be from partial weight bearing against a wall, to increasing weight bearing on a table, to the quadrupedal position, to the modified and full push-up positions. Exercises may be progressed from two-arm to single-arm support, and eventually to plyometrics. Use of gymnastic balls, stair steppers, slide boards, treadmills, rocker boards, and other traditional lower extremity equipment challenges the shoulder dynamically. It is critical that the quality of the exercise be maintained throughout. As the scapular stabilizers fatigue, the scapulae may begin to wing, resulting in improper motor programming and possible injury. The therapist and athlete alike must be aware of and be able to recognize this situation.

The activity on EMG has been well documented during open and closed chain shoulder rehabilitation exercises. Townsend et al.91 studied 9 muscles during 17 shoulder exercises. Exercises were considered a challenge if they produced more than 50% of the MMT over three consecutive arcs, and four exercises were found to load each of the nine muscles at least once at the given criteria. These exercises included (1) scaption in internal rotation, (2) flexion, (3) horizontal abduction in external rotation, and (4) press-up (Fig. 10; see also Fig. 8A and C). As with the data from Moseley and Goldie,39 closer scrutiny can provide the therapist with a wealth of information to guide rehabilitation. Again, the press-up was included because of the preset criteria, whereas activity on EMG was noted only in the pectoralis major and latissimus dorsi. For the therapist wanting to train the rotator cuff selectively, other exercises tested would be more appropriate. Although the assumption is made that the exercise with the greatest activity on EMG should be chosen to strengthen a specific muscle, in rehabilitation that is not always the case. Occasionally, such an activity is too strenuous for the individual recovering from an injury or

**Figure 8** A, Scaption in internal rotation. B, Press-up. C, Rowing. D, Push-ups with a plus (additional scapular protraction).
surgery. In this case, the data from Townsend et al.\(^91\) provide the therapist with different choices that may be more appropriate. For example, if scaption in internal rotation is too weak or painful, scaption in external rotation will require less, but still significant, supraspinatus activity.

**Neuromuscular Retraining**

Neuromuscular retraining has been advocated by many investigators in the treatment of shoulder dysfunctions, especially the instability complex.\(^92-96\) Lephart et al.\(^94\) found decreased passive repositioning sense and threshold to detection of passive motion in individuals with anterior shoulder instability. Following reconstruction, values for these same variables were the same as the normal control group. The relationship between static and dynamic structures was explored by Cain et al.\(^99\) who found that contraction of the infraspinatus and teres minor muscles reduced strain on the anterior-inferior glenohumeral ligament at 90° of abduction. Guanche et al.\(^100\) noted a reflex arc from mechanoreceptors within the glenohumeral capsule to muscles crossing the joint. These findings reinforce the synergistic activity of the static and dynamic structures about the shoulder. However, Borsa et al.\(^93\) suggested that damage to the mechanoreceptors disables the reflexive dynamic stability and thus increases the instability problem.

Exercises purporting to facilitate development of proprioception should consider the multilevel aspect of nervous system training. Reflexive patterning at the spinal cord level

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occurs on a subconscious level and is only one aspect of neuromuscular retraining. Higher levels are involved with the planning and execution of motor tasks. The basal ganglia are involved in the more complex aspects of motor planning and ultimately influence the spinal motor neuron pool by forming a control loop with motor areas of the cortex involved with the planning and execution of voluntary motor tasks. The cerebellum regulates some of the specific parameters of motor control, including synergistic coordination and background muscle tone. The question of the cognitive role in proprioceptive training deserves attention. One purpose of a proprioceptive rehabilitation program is to enhance cognitive appreciation of the joint relative to position and motion, and most rehabilitation programs necessitate cognitive attention to the task. However, when throwing a ball, serving volleyball, or swimming, the athlete is unlikely to be thinking about his or her shoulder. As such, removal of the cognitive aspect of activity must be incorporated at some time in the rehabilitation process. Mentally attending to something besides the task at hand will challenge the nervous system in a more realistic situation. Counting back by serial sevens, or engaging in unrelated conversation while performing challenging activities, will facilitate this skill. Conversion of a conscious task to unconscious motor programming, stored as central commands, is the goal.

Proprioceptive neuromuscular facilitation (PNF) exercises have been advocated for the development of kinesthetic awareness. Additionally, Wilk and Arrigo recommended several movement awareness drills to enhance neuromuscular control of the shoulder. These drills are performed in the advanced phase, and they place the athlete in a position that challenges the stabilizing mechanisms. When performing any kinesthetic or movement awareness exercises, the therapist must closely attend to additional information derived from other sensory systems that may assist in proprioception. These factors may include tactile cueing from the supporting surface, tactile cueing from the therapist, visual cueing, and predictability of movement pattern and speed based on previous experience. Additionally, the position during exercise becomes critical when considering the role of the cerebellum and basal ganglia in postural set and motor programming. An activity performed with the patient in the supine position on a table does not require the same neuromuscular coordination as when the same activity is performed when the patient is standing.

The Impulse Inertial Exercise System (IES; Newnan, Ga) was originally developed with neuromuscular training as the chief consideration. High-speed ballistic activities in numerous movement patterns can be repetitively performed on the IES. Rapid ballistic movements have patterns of agonist muscle and antagonist muscle contractions different from patterns seen with slower-speed activities. Synchronous activation of agonists and antagonists occurs with ballistic movements as a result of triphasic muscle activation. The initial burst of agonist muscle contraction triggers the activity, and this activity ceases before the limb reaches its final position. Subsequently, the antagonist fires as a braking mechanism, and the final phase finds the agonist firing again to “clamp” the movement toward the target. The same movement pattern at a slow speed demonstrates only agonist muscle contraction, with braking provided by the passive viscoelastic properties of the tissue. The timing and amplitude of antagonist activity are affected by the distance and speed of the movement. Small-amplitude movements at higher speeds result in substantial overlap of burst activity in agonist and antagonist during acceleration, whereas coactivation occurs in bursts during deceleration. Finally, knowledge of the necessity for antagonist firing affects muscle activity. When a mechanical stop was placed in the testing apparatus, the antagonist burst disappeared within two to three trials, a finding suggesting some cognitive control over the braking mechanism. This work supports the use of high-speed ballistic activities to train open chain cocontraction in an unstable shoulder. Such activities can be achieved by use of the IES or resistive tubing (Figs. 11 and 12). Many different movement patterns can be trained, including shoulder rotation in abduction and PNF patterns.
CASE STUDY 2

General Demographics
Joan is a 16-year-old high school swimmer who comes to the clinic with a 4-month history of right shoulder pain. She is right-hand dominant.

Social History
Joan is single with no children. She does not smoke or drink.

Employment and Environment
She is a high-school student who swims competitively and also plays volleyball and softball.

Living Environment
She lives in a two-story house with her parents and younger brother.

Past Medical History
Joan has no history of shoulder or neck problems and no history of medical problems.

History of Chief Complaint
Joan is a butterfly swimmer who has been practicing, in her off-season, swimming and weight lifting to ready herself for her junior year in high school swimming. When she returned to swim practice, she noticed increasing pain in her right shoulder. Over the last month or so, the pain has become severe enough to interfere with her normal swimming regimen.

She is concerned because of the increasing pain and discomfort that may interfere with her upcoming swimming season, which begins in 3 weeks.

Prior Treatment for this Condition
She is currently taking a nonsteroidal anti-inflammatory drug prescribed by her primary physician. Other than that, she has received no additional treatment to her right shoulder.

Structural Examination
Physical Therapy Examination
On visual inspection, postural observation indicates that both scapulae are abducted approximately 4 inches from
her thoracic midline. In addition, both her medial scapulae borders and inferior scapulae angles are prominent posterioly.

**Range of Motion**
- AROM: Painful arc between 90° and 120° of elevation in the frontal plane; full ROM
- PROM: Full and pain free in all ranges

Accessory motion testing indicates that Joan’s glenohumeral joint is hypermobile in all directions, particularly in an inferior direction, thus producing a sulcus sign bilaterally.

**Tenderness**
On palpation, Joan reports tenderness over the biceps tendon and rotator cuff tendon.

**Muscle Performance**
Resisted testing results show 4/5 strength in resisted abduction without pain. Results of all other testing are strong and pain free. However, Joan has only 3/5 strength in both lower trapezius muscles and 4/5 strength in both serratus anterior muscles.

**Special Tests**
Neer’s and Hawkins’ impingement signs are positive. Results of horizontal crossover testing are negative. Results of biceps tension testing and apprehension and relocation testing are positive.

**Clinical Impression**
Given the history and physical examination of the young athlete’s shoulder, the physical therapist determines that she has impingement syndrome caused by underlying instability (impingement-instability complex). This problem is treated in a practice pattern focusing on impairments associated with connective tissue dysfunction. The stage of clinical reactivity is subacute. She has established good rotator cuff strength because of her cuff-strengthening program. However, she exhibits scapular postural changes and muscle weakness consistent with chronic scapular winging, anterior tiling, and abduction. As a result, underlying instability and scapular control have not been addressed, and they are the focus of the rehabilitation program.

**Treatment Plan**
The initial goal is to build on Joan’s strength base without aggravating her secondary impingement syndrome. She is started on a high-speed, short ROM program with yellow resistive bands for shoulder external rotation and shoulder abduction and red bands for shoulder flexion and extension. All exercises are performed in neutral abduction. After a warm-up, she performs 1 set for 30 seconds and attempts to perform 30 to 50 repetitions in 30 seconds. She is instructed to add an extra set of 15 seconds or more as tolerated during the next week.

Immediate scapular manual PNF patterns are instituted for posterior depression to emphasize isolated activation of her lower trapezius muscle, anterior elevation, and isolated abduction (serratus anterior muscle). Resistance is modulated based on the patient’s tolerance and her ability to complete smooth and synchronous scapular patterns. The resistance emphasizes both concentric and eccentric contractions. Furthermore, she is instructed to perform home exercises emphasizing scapular retraction with depression and scapular abduction (protraction), to fatigue.

On her return visit, she reports soreness for a day, with no fatigue in flexion and extension exercises after 2 days. Resisted external rotation is slightly sore but strong. Her flexion and extension exercises are progressed to 45° of abduction. One week later, she is improving steadily. She is up to 3 sets for 30 seconds of all exercises. Resisted external rotation is maintained in neutral, but with progression to red resistive bands. Flexion, extension, and abduction are discontinued, and horizontal abduction and adduction exercises are initiated at 90° of abduction with green bands. She is encouraged to try to perform up to 90 repetitions in 30 seconds.

By her fourth visit, she is feeling notably better. Internal and external rotation is initiated at 90° of abduction, and progress is made in the resistance of the bands. On her fifth visit, she has progressed to PNF D2 flexion exercises and reproduction of the throwing motion. She performs 3 sets each of more than 90 repetitions of each exercise in 30 seconds. On her sixth and final visit, the patient is placed on a functional progression for volleyball, as well as a maintenance strength and coordination program.

**Summary**
A 16-year-old high-school athlete is seen for a total of six visits to treat her impingement-instability complex. The key to successful rehabilitation is the recognition of the underlying instability, with exercise protocols addressing this problem. Rotator cuff strengthening alone is ineffective in this athlete, and the incorporation of dynamic stabilization exercises provides the needed dynamic control of her unstable shoulder.

**SUMMARY**
Impingement syndrome of the shoulder can result in a cascade of pathologic conditions that primarily affect the rotator cuff and result in subacromial pain and shoulder dysfunction. The causes of impingement presented in this lesson have multiple factors, but they can be divided into primary impingement and secondary impingement, depending on the presence of instability or impingement. These categories are further subdivided based on the pathomechanics of injury, the age of the patient, dysfunctions, and associated abnormalities. In the younger, athletic population, the basic problem is instability, which leads to subluxation, impingement, and
rotator cuff disease. Treatment is based on accurate classification of the ailment and is logically focused on the signs, symptoms, and nature of the dysfunction. For example, treat-
ment of impingement in younger athletes is designed to re-
store shoulder stability and control and to correct underlying mechanical problems associated with their sport. A systematic evaluation of the nature and extent of the injury is imperative for the clinician to classify the problem properly and to design an effective rehabilitation program.

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