Nonoperative Management of Secondary Shoulder Impingement Syndrome

Abdulazeem Kamkar, MS, PT
James I. Irrgang, MS, PT, ATC
Susan L. Whitney, PhD, PT, ATC

Shoulder pain and disability in throwing athletes are common orthopaedic problems seen by physical therapists (29). Two common etiologies of shoulder pain are shoulder instability and impingement syndrome. Neer (33) defined impingement syndrome as "impingement of the rotator cuff beneath the coracoacromial arch." Conservative and surgical management of this syndrome are well described in the literature (16, 28, 33, 38). Nonoperative management consists of rest, anti-inflammatory medications, and therapeutic exercises emphasizing the function of the rotator cuff muscles. Recently, electromyographic studies have been performed to analyze the function of shoulder muscles in sport and exercise (3, 18, 19, 37, 43). Electromyographic activity of the serratus anterior muscle during shoulder function in overhead sports has been documented (19, 37, 43). Nuber et al (37) proposed that fatigue of the serratus anterior muscle from repetitive use may cause impingement because of improper temporal sequencing of the scapulothoracic musculature. The purpose of this paper is to review the pertinent anatomy and biomechanics of the shoulder, review primary and secondary impingement syndromes, and describe nonoperative management of shoulder impingement syndromes.

Shoulder pain secondary to impingement of the rotator cuff tendons underneath the coracoacromial arch is a common problem seen in athletes who perform repetitive overhead activities. Shoulder impingement has been classified into primary and secondary types. Several factors contribute to impingement, including rotator cuff weakness, posterior capsule tightness, and subacromial crowding. Recently, it has been proposed that scapulothoracic muscle weakness could be a factor that contributes to impingement. Traditional rehabilitation protocols for shoulder impingement syndrome stress individualized rotator cuff strengthening. The authors propose that individualized scapulothoracic muscle strengthening should be a part of any protocol for nonoperative treatment of secondary shoulder impingement syndrome.

Key Words: scapulothoracic muscles, shoulder impingement syndrome, rehabilitation

1 Resident, Orthopedic Manipulative Therapy, Laurel Rehabilitation and Sports Therapy, Uniontown, PA 15401; staff physical therapist, Industrial Rehabilitation, St. Francis Medical Center, 3rd Floor, Medical Office Building, 4221 Penn Ave., Pittsburgh, PA 15224
2 Assistant professor, Department of Physical Therapy, University of Pittsburgh; director, Outpatient PT and Sports Medicine, University of Pittsburgh Medical Center, Center for Sports Medicine and Rehabilitation, Pittsburgh, PA
3 Assistant professor, Department of Physical Therapy, University of Pittsburgh, Pittsburgh, PA

This paper was submitted by A. Kamkar as partial fulfillment of the requirements of the master of science degree at the University of Pittsburgh.

REVIEW OF LITERATURE

Anatomy

Coracoacromial Arch and Rotator Cuff In reviewing the anatomy of the shoulder related to impingement syndrome, the coracoacromial arch and the subacromial elements are the focus of attention. The coracoacromial arch, as the name implies, is formed by the coracoid and acromion processes and the connecting coracoacromial ligament. Underneath this arch are the subacromial-subdeltoid bursa, the rotator cuff tendons, the long head of the biceps, the glenohumeral joint capsule, and the upper surface of the humeral head (Figures 1 and 2). The coracoacromial arch protects the humeral head and the subacromial structures from direct trauma. The coracoacromial arch also prevents superior dislocation of the humeral head. However, in abnormal states, impingement may occur as the rotator cuff and other subacromial structures become encroached between the greater tuberosity and the coracoacromial arch (28).

The rotator cuff tendons include the subscapularis tendon anteriorly, the supraspinatus tendon superiorly, and the infraspinatus and teres minor tendons posteriorly. The four
tendons blend with each other and with the capsule of the glenohumeral joint to attach to the lesser tuberosity, the greater tuberosity, and the transverse humeral ligament (Figures 1 and 2). The long head of the biceps penetrates the rotator cuff between the supraspinatus and the subscapularis tendons and courses over the humeral head. Passage of the rotator cuff tendons under the coracoacromial arch is facilitated by the interposition of the subacromial-subdeltoid bursa, which acts as a lubricating medium (28, 40).

The supraspinatus and infraspinatus muscles are innervated by the suprascapular nerve (C4, 5, 6), the teres minor is innervated by the axillary nerve (C4, 5, 6), and the subscapularis is innervated by the upper and lower subscapular nerves (C5, 6, 7) (49).

Muscles of the Scapulothoracic Articulation The scapulothoracic articulation lacks the characteristics of a true joint and is regarded as an articulation (27). Lack of ligamentous restraints at this "joint" delegates the function of stability fully to the muscles that attach the scapula to the thorax. Hence, the scapulothoracic articulation is a prime example of dynamic stability in the human body. Several muscles control the motion at the scapulothoracic articulation, and, therefore, their proper function is vital to the normal biomechanics of the shoulder. These muscles include the serratus anterior, trapezius, levator scapulae, rhomboid major, rhomboid minor, latissimus dorsi, pectoralis major, and pectoralis minor (40, 44). It has been suggested that the serratus anterior and trapezius muscles are the most important muscles acting upon the scapulothoracic articulation (6, 16, 23).

The muscular digitations of the serratus anterior originate from the upper eight to 10 ribs and fascia over the intercostals. The first digit of the serratus anterior originates from the first and second ribs, plus the intercostal fascia. The other digits of the serratus anterior originate from a single rib. The lowest four digits of the serratus anterior interdigitate with the upper five digits of the obliquus externus abdominis. This broad origin on the thoracic wall runs ventral to the scapula and inserts on the medial border of the scapula. The first digit of the serratus anterior attaches ventrally and dorsally to a triangular area on the superior scapular angle. The next two or three digitations form a triangular sheet and attach to the ventral surface of the medial border of the scapula. The lower four or five digits form a musculotendinous attachment that inserts on a triangular area on the inferior scapular angle. This attachment is mostly ventral to the scapula, with a small insertion on the tip of the inferior scapular angle (Figure 3). The serratus anterior is innervated by the long thoracic nerve (C5, 6, 7) (49).

The trapezius muscle originates from the medial third of the superior nuchal line, the external occipital protuberance, the ligamentum nuchae, the apices of the seventh cervical vertebrae, all the thoracic spinous processes, and the supraspinous ligaments of the cervical and thoracic vertebrae. The upper fibers descend to attach to the lateral third of the posterior border of the clavicle. The middle fibers of the trapezius run horizontally to the medial acromial margin and superior lip of
the spine of the scapula. The inferior fibers ascend to attach to an aponeurosis gliding over a smooth triangular surface at the medial end of the spine of the scapula to a tubercle at the scapular lateral apex (Figure 4). The trapezius muscle is innervated by the spinal accessory nerve and second, third, and fourth cervical ventral rami (49).

The levator scapulae muscle originates by tendinous slips from the transverse processes of the atlas, axis, C3, and C4 vertebrae and descends diagonally to insert on the medial superior angle of the scapula. The scapular end of the muscle consists of two “folds” or “flaps” (an anterior fold and a posterior fold) that partly fuse just above the superior scapular angle. The posterior fold attaches to the dorsal aspect of the medial margin of the scapula opposite the supraspinous fossa by way of an aponeurosis. The anterior fold has an attachment to the fascia of the serratus anterior. This fold tapers to a narrow tendon attached to the costal surface of the medial border of the scapula at the level of the root of the scapular spine (Figure 4). The levator scapulae is innervated by the dorsal scapular nerve (C3, 4, 5) (49).

The rhomboid major muscle originates from the second to fifth thoracic spinous processes and the overlying supraspinous ligaments. The fibers descend to insert on the medial scapular border between the root of the scapular spine and the inferior angle of the scapula (Figure 4) (49). The rhomboid minor muscle originates from the lower ligamentum nuchae and the seventh cervical and first thoracic spinous processes to attach to the medial scapular border at the root of the scapular spine (Figure 4). The rhomboids are innervated by the dorsal scapular nerve (C4, 5) (49).

The latissimus dorsi originates from the spinous processes of the last six thoracic vertebrae, the lower three or four ribs, the lumbar and sacral spinous processes through the thoracolumbar fascia, the posterior one-third of the external lip of the iliac crest, and a slip from the inferior scapular angle (Figure 4). It is the scapular slip that allows the latissimus dorsi to act at the scapulothoracic articulation. The latissimus dorsi inserts on the intertubercular sulcus of the humerus (Figure 4). The latissimus dorsi is innervated by the thoracodorsal nerve (C6, 7, 8) (49).

The pectoralis major originates from the sternal half of the clavicle, half of the anterior surface of the sternum to the level of the sixth or seventh costal cartilages, the sternal end of the sixth rib, and the aponeurosis of the obliquus externus abdominis. The fibers of pectoralis major converge to form a tendon that inserts on the lateral lip of the intertubercular sulcus of the humerus (49). Although the pectoralis major does not insert on the scapula, it acts upon the scapulothoracic articulation through its insertion on the humerus (Figure 6). The pectoralis major is innervated by the medial and lateral pectoral nerves (C5, 6, 7, 8; T1) (49).

The pectoralis minor originates from the outer surface of the upper margins of the third to fifth ribs near their cartilage. The fibers of pectoralis minor ascend laterally, converging to a tendon that inserts on the coracoid process of the scapula (Figure 3). The pectoralis minor is innervated by the medial and lateral pectoral nerves (C6, 7, 8) (49).

**Biomechanics**

In shoulder movement, glenohumeral movement is associated with scapulothoracic movement. The movements of the scapula are not performed in isolation and are associated with movements at the sternoclavicular and acromioclavicular joints (14). Movement at the scapulothoracic articulation is important for the normal biomechanics of the shoulder joint. The scapulothoracic articulation orients the glenoid fossa so that it can provide a stable base for articulation with the humeral
head and maintain optimal contact with the moving humerus (36).

**Scapulohumeral Rhythm** The glenohumeral, scapulothoracic, sternoclavicular, and acromioclavicular joints have to participate in shoulder movement in a coordinated, concomitant, and smooth pattern. This complex pattern has been termed scapulohumeral rhythm by Codman (14). The scapulohumeral rhythm serves two important purposes. First, the distribution of the motion between the glenohumeral and scapulothoracic joints maintains the gelenoid fossa in an optimal position to receive the articular surface of the humeral head. Second, the concurrent motion of the scapula maintains the optimal length/tension relationship of the muscles acting on the humerus. This minimizes active and passive insufficiency of scapular muscles that act upon the humerus (36).

The scapulohumeral rhythm is the result of movement at four joints. To simplify this pattern, scapulohumeral rhythm will be divided into glenohumeral/scapulothoracic and acromioclavicular/sternoclavicular contributions. In reality, scapulohumeral rhythm is inseparable and occurs at all four joints concurrently.

**Glenohumeral/Scapulothoracic Contribution** Normal maximal shoulder elevation is 180°. The glenohumeral contribution to this motion is 120°, and the scapulothoracic contribution is 60° (36, 45). Overall, shoulder elevation could be divided into 2° of glenohumeral motion per 1° of scapulohumeral motion (45). The first 30–60° of arm elevation have been termed the setting phase (14). The setting phase of motion is accounted for primarily by glenohumeral motion. The type and amount of scapulothoracic contribution to the setting phase is inconsistent (14). It is suggested that the scapula is seeking a position of stability in relation to the humerus during the setting phase (14). Inman et al (14) have observed that in the setting phase, the scapula may remain fixed, protract, retract, or oscillate between protraction and retraction until stability is achieved. Following the setting phase, the contribution of the scapulothoracic articulation equals the contribution of the glenohumeral joint until the end range of shoulder flexion, where the glenohumeral contribution increases (36).

**Sternoclavicular/Acromioclavicular Contribution** The involvement of the sternoclavicular and acromioclavicular joints in the scapulohumeral rhythm is an unavoidable consequence of their involvement in a closed kinematic chain with the scapulothoracic articulation. Motion at the scapulothoracic joint inescapably produces motion at the sternoclavicular and acromioclavicular joints. In full shoulder elevation, the scapula moves in a 60° arc, which is the result of movement at the acromioclavicular and sternoclavicular joints and is produced by the force couple of the serratus anterior and trapezius (36).

As shoulder elevation takes place, the upper and lower parts of the trapezius and serratus anterior combine to form a force couple that upwardly rotates the scapula. However, the coracoclavicular ligament limits upward rotation of the scapula at the acromioclavicular joint, which leads to the elevation of the clavicle at the sternoclavicular joint. This clavicular elevation leads to 30° of upward scapular rotation around an axis through the base of the scapular spine. After the first 30° of upward rotation, clavicular elevation is stopped by tautness of the costoclavicular ligament. The force couple of the serratus anterior and trapezius continues to attempt further upward rotation of the scapula, and increased tension at the coracoclavicular ligament leads to forward rotation of the superior aspect of the clavicle around its longitudinal axis. This clavicular rotation will lead to elevation of the acromial end of the clavicle without causing further elevation at the sternoclavicular joint. At this point, the acromioclavicular joint becomes the instant axis of rotation for the scapula. The force couple of the serratus anterior and trapezius will lead to further upward scapular rotation and abduction and an additional 30° of rotation (36).

In summary, the first 90° of shoulder flexion involves 60° of glenohumeral motion and 30° of scapulothoracic motion (36). The scapular movement is the result of clavicular elevation at the sternoclavicular joint. The final 90° of shoulder flexion involves 60° of glenohumeral motion with lateral rotation and 30° of scapulothoracic motion. The scapular motion is the result of clavicular rotation and elevation at the acromioclavicular joint (36).

It becomes clear that a delicate mechanism exists in the performance of shoulder flexion. Disruption of motion at any of the involved joints may affect the total motion produced (36). Also, the contribution of the force couple of the trapezius and serratus anterior muscles should not be ignored. An imbalance, weakness, or dysfunction of this force couple may disrupt scapulohumeral rhythm.

**Function of the Rotator Cuff** The rotator cuff muscles consist of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles. The combined forces of the infraspinatus, teres minor, and subscapularis join the force of the deltoid to form a force couple (36). The functions of the subscapularis, teres minor, and infraspinatus are depression of the humeral head and prevention of superior impaction of the posterior capsule stretching may be helpful in treatment of impingement syndrome.
humeral head into the acromion. The subscapularis is an internal rotator of the shoulder, and the infraspinatus and teres minor externally rotate the shoulder. The supraspinatus muscle assists the deltoid in abduction and helps stabilize the glenohumeral joint with the force of gravity (28).

The rotator cuff stabilizes the shoulder against the action of the prime movers to prevent excessive anterior, posterior, superior, or inferior humeral head translation. Additionally, the rotator cuff adds power to glenohumeral elevation and rotation (28).

Function of the Scapulothoracic Muscles: The scapulothoracic muscles function as synergists and antagonists and also combine to form force couples. A force couple has been described as divergent pulls of forces creating a pure rotation (36). In addition, a force couple has been defined as the effect of equal, parallel forces acting in opposite directions that leads to rotatory movement (26).

The trapezius muscle is functionally divided into upper, middle, and lower portions. The upper trapezius elevates and upwardly rotates the scapula. The middle trapezius retracts the scapula. The lower trapezius upwardly rotates the scapula and depresses it. The levator scapulae elevates and downwardly rotates the scapula. The serratus anterior protracts and upwardly rotates the scapula. The serratus anterior has been divided into upper and lower portions. The upper portion of the serratus anterior assists in elevation of the scapula, and the lower part depresses the scapula (41, 49). According to Dvir and Berme (8), the upper portion of the serratus anterior stabilizes the scapula along with other scapular muscles, while the lower portion of the serratus anterior provides scapular motion. The pectoralis minor protracts the scapula. The rhomboid major and minor retract, elevate, and downwardly rotate the scapula (Figures 5 and 6) (21).

The upper and lower fibers of the serratus anterior and the trapezius form one of the force couples that acts upon the scapulothoracic joint. The converging actions of these fibers produce upward rotation of the scapula during elevation of the arm (14, 40, 44, 49). The force couple of the serratus anterior and the trapezius also serves as a stabilizing synergist for the deltoid muscle, which acts on the glenohumeral joint. In humeral elevation, the action of the deltoid will lead to downward rotation of the scapula, subsequently leading to active insufficiency of the deltoid. Upward rotation of the scapula produced by the serratus anterior and trapezius force couple will prevent this downward rotation and maintain an optimal length/tension ratio for the deltoid (36). The lower segments of the pectoralis major, pectoralis minor, levator scapulae, rhomboidei major and minor, and latissimus dorsi form a synergistic group of muscles that downwardly rotates the scapula (44). The lower fibers of the pectoralis major, pectoralis minor, latissimus dorsi, and lower trapezius combine to depress the scapula (Figures 5 and 6) (44).

The sternoclavicular joint is the only skeletal attachment of the shoulder–arm complex to the thorax. This singular attachment does not provide adequate stability for the shoulder–arm complex, and, thus, this responsibility is delegated to the muscles connecting the clavicle and scapula to the trunk (45). The proper movement and positioning of the shoulder comes not only from the muscles that provide the movement or position but also from the action of the antagonistic muscles, which provide stability (45). For example, elevation of the acromion by the upper trapezius and serratus anterior is imprecise without the guidance and control of the rhomboids and pectoralis minor (45). According to Steindler (45), loss of any scapulothoracic muscle will affect movement at the glenohumeral joint.

In isolated paralysis of the serratus anterior, shoulder flexion and abduction are drastically affected. Shoulder flexion and abduction are weakened, and the range of motion for these movements is decreased. In complete paralysis of the serratus anterior, 110° of shoulder abduction is the maximal range of motion (ROM) that can be achieved (9). Discoordination of the scapulothoracic rhythm and shoulder pain have been observed as well as shoulder pain following repeated use of the arm (9, 24). Similar signs and symptoms have been observed following injury to the spinal accessory nerve, resulting in paralysis of the trapezius (30).
In paralysis of the rhomboids, serratus anterior and pectoralis minor functions are unopposed, producing excessive upward rotation and protraction of the scapula. The excessive protraction of the scapula interferes with shoulder abduction due to needed scapular retraction in this movement (45).

Phases of Throwing Motion Understanding biomechanics of throwing leads to better understanding of the mechanisms of injury to the shoulder during throwing. The throwing motion has been divided into five phases, which are summarized in Table 1.

Classification

In normal shoulder movement, the rotator cuff mechanism is intimately related to the coracoacromial arch and is only separated by the subacromial-subdeltoid bursa (Figures 1 and 2) (28). Several factors minimize impingement of the rotator cuff. These factors include adequate shape of the coracoacromial arch to allow safe passage of the cuff tendons without encroachment; normal inferior surface of the acromioclavicular joint; normal subacromial bursa; normal function of the humeral head depressor mechanism, including the rotator cuff muscles and the biceps tendon; normal capsular laxity; a smooth gliding upper surface of the cuff tendons (28); and proper function of the scapulothoracic joint (22).

A number of abnormal processes may influence these mechanisms and cause friction, impingement, and increased wear of the cuff tendons. Matsen and Arntz (28) described structural and functional factors that could potentially increase rotator cuff impingement. These factors are summarized in Tables 2 and 3.

Traditionally, impingement of the rotator cuff underneath the coracoacromial arch has been attributed to repeated mechanical impingement (33). Currently, this mechanical impingement is termed primary impingement (10). Primary impingement may result from subacromial crowding, posterior capsular tightness, or excessive superior migration of the humeral head due to weakness of the humeral head depressors (Figure 7) (11, 28, 33, 38). Secondary impingement is defined as a relative decrease of the subacromial space due to instability of the glenohumeral joint (10) or functional scapulothoracic instability (Figures 7 and 8) (22).

Differentiating primary impingement from secondary impingement is crucial in the proper management of these two syndromes (10). If secondary impingement is managed as a classical case of primary impingement (ie., repeated subacromial injections and acromioplasty), the underlying problem may not be corrected (10). The end result of both syndromes is rotator cuff tendon inflammation and potential rupture. Similar signs and symptoms may be present in both syndromes; however, the mechanism of injury is different (10).

Primary Impingement Primary mechanical impingement has been described (28, 33) as “impingement of the rotator cuff beneath the coracoacromial arch.” Neer (33) observed that shoulder flexion with internal rotation leads to passage of the critical avascular zone of the rotator cuff under the coracoacromial arch. Neer (33) also noted bony changes and spur formation on the undersurface of the anterior acromion. Neer (33) proposed that these bony changes were due to repeated impingement of the rotator cuff between the coracoacromial ligament and the humeral head.

Impingement lesions have been divided by Neer (34) into three progressive stages. Signs that may assist in differentiating the stages of impingement lesions have been described by Neer (34) and by Hawkins and Abrams (12). A summary of these stages is provided in Table 4.

A positive impingement sign is present in primary impingement syndrome (12, 34). The impingement sign, as described by Neer (34), is elicited by performing passive shoulder flexion while preventing upward scapular rotation, which leads to encroachment of the greater tuberosity against the acromion. Hawkins and Abrams (12) describe a similar impingement sign in which the shoulder is flexed to approximately 90° and is forcibly internally rotated to

---

<table>
<thead>
<tr>
<th>Phase</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind-up</td>
<td>Preparatory activity that is mostly upper extremity flexion and ends when the ball leaves the glove</td>
</tr>
<tr>
<td>Early cocking</td>
<td>Begins with ball release from the glove as the shoulder obtains abduction and external rotation and ends with contact of the forward foot on the ground</td>
</tr>
<tr>
<td>Late cocking</td>
<td>Characterized by maximum shoulder external rotation</td>
</tr>
<tr>
<td>Acceleration</td>
<td>Begins with derotation of the maximally externally rotated shoulder and ends with ball release</td>
</tr>
<tr>
<td>Follow-through</td>
<td>Begins with ball release and ends when the throwing motion ceases</td>
</tr>
</tbody>
</table>

TABLE 1. Phases of throwing motion (17, 19).
produce a similar effect. Pain elicited with these signs may indicate impingement (12, 34).

Deficits in range of motion (ROM) may exist in patients with shoulder impingement. These include deficits in internal rotation and cross-chest adduction ranges due to tightness of the posterior capsule (28). Tightness of the posterior portion of the glenohumeral joint capsule has been proposed to contribute to impingement syndrome by causing abnormal superior translation of the humeral head (28). This has been shown by operative tightening of the posterior capsule in cadavers (11). Harryman et al (11) found that operative tightening of the posterior capsule led to increased anterior and posterior translation of the humeral head during shoulder flexion and cross-chest adduction.

**Secondary Impingement** Secondary impingement is a relative decrease in the subacromial space due to glenohumeral instability or functional scapulothoracic instability (Figure 8) (10, 16, 17, 22). Secondary shoulder impingement due to glenohumeral instability may be triggered by weakness of the rotator cuff mechanism and the biceps tendon. This weakness leads to overload of the passive restraints of the glenohumeral joint during throwing activities, which results in glenohumeral laxity. The active restraints of the glenohumeral joint (ie., the rotator cuff and biceps tendon) attempt to stabilize the humeral head; however, fatigue and weakness of this mechanism result in abnormal translation of the humeral head with secondary mechanical impingement of the rotator cuff by the coracoacromial arch. The result of secondary impingement is inflammation of the rotator cuff tendons (Figure 8) (10, 16, 17). An overlap has been observed between the impingement syndrome and glenohumeral instability (48). Warner et al (48) have found that 68% of the patients with anterior shoulder instability studied showed signs of impingement. In addition to a positive impingement sign, a positive apprehension sign and relocat-
Secondary shoulder impingement sign may be present in this group, indicating anterior glenohumeral instability (16, 17).

Subacromial impingement secondary to functional scapular instability is another proposed mechanism of secondary impingement in throwing athletes (Figure 8) (10, 22). In this case, weakness of the scapulothoracic muscles leads to abnormal positioning of the scapula. Disruption of scapulohumeral rhythm may occur, leading to impingement of the rotator cuff underneath the coracoacromial arch if humeral elevation is not synchronized with scapular elevation and upward rotation. With disruption of the scapulohumeral rhythm, the acromion may not be elevated sufficiently to allow passage of the rotator cuff underneath the coracoacromial arch, leading to impingement (22). If weakness or fatigue of the serratus anterior muscle is present, the scapula may not be held against the thorax and may show excessive winging of the vertebral border and tipping of the inferior angle of the scapula (47). This excessive winging and tipping of the scapula will lead to a relative decrease in the subacromial space, causing impingement (47). A positive impingement sign will also be present in patients with secondary shoulder impingement (10, 22).

An electromyography (EMG) study showed that the serratus anterior shows high levels of activity during the late cocking, acceleration, and follow-through phases of pitching (19). The activation of the serratus anterior during late cocking is needed to eccentrically decelerate the retracting scapula. During acceleration, the serratus anterior concentrically protracts the scapula as the arm is adducted and internally rotated. In addition to controlling protraction and retraction of the scapula, the serratus anterior is a component of a force couple that upwardly rotates the scapula during elevation of the arm. This upward rotation is vital to clear the abducting humeral head from impinging against the acromion. The serratus anterior, along with the other scapulothoracic muscles, also contributes to stabilization of the scapula. Positioning of the scapula keeps the glenoid fossa underneath the humerus, which leads to improved glenohumeral stability (19). Thus, scapulothoracic stability contributes to dynamic glenohumeral stability. The scapular stabilization provided by the serratus anterior and other scapulothoracic muscles provides a stable base for scapulohumeral muscles to act upon the humerus, which improves efficiency of the muscles and dynamic glenohumeral stability.

In an effort to identify patients...
with functional scapular instability, Kibler (22) has described a lateral scapular slide test. In this test, the distance between the inferior scapular angle and the spinous process of the closest vertebral body is measured in three positions. The measurements are taken with the subject in a relaxed position with the arms at the sides, with the hands on their iliac crests with the thumbs pointed posteriorly, and with the arm abducted to 90° with maximal internal rotation and elbow extension. Measurements are taken bilaterally, and side-to-side comparisons are made. It is suggested that with weakness of the trapezius, serratus anterior, and rhomboids, the scapula will slide laterally, leading to an increase in the distance measured in the involved limb (22). In a study of symptomatic throwing athletes and an activity-matched control group, Kibler (22) found that the symptomatic group showed a significant increase (>1 cm side-to-side difference) in the lateral scapular slide distance in the second and third positions compared with the control group. Kibler (22) concluded that the increased lateral scapular slide distance in the throwing athletes indicated functional scapulothoracic instability.

### Traditional Nonoperative Treatment of Shoulder Impingement Syndrome

Several protocols have been designed for the rehabilitation of the injured shoulder (Table 5). Most of these protocols focus on strengthening the rotator cuff muscles (13, 18, 28, 32) in addition to the restoration of normal ROM, endurance, and pain control (13, 16, 28, 32, 35, 38, 42). Physical modalities such as ultrasound, heat, and cold have been suggested for control of pain and inflammation (13, 35, 42). Jobe and Bradley (16) described a program of kinesiologic repair, which involves a specific training program for the rotator cuff and the scapular rotators to establish proper scapulohumeral rhythm. The emphasis placed on restoring scapulohumeral rhythm and strengthening the rotator cuff and the scapular rotators is crucial. The proper scapulohumeral rhythm acts to lessen the risk of impingement by synchronizing scapulothoracic motion with glenohumeral motion. Adequate strength of the rotator cuff decreases impingement by depressing the humeral head and preventing excessive superior migration of the humeral head during elevation of the arm. Additionally, strengthening the rotator cuff provides dynamic stability to the glenohumeral joint by controlling excessive humeral head migration. Proper strengthening of the scapular rotators assures that the scapula follows the humerus, providing dynamic stability and assuring synchrony of scapulohumeral rhythm.

### DISCUSSION

After reviewing the biomechanics of shoulder elevation, it becomes apparent that this complex movement is carried out by a delicate mechanism. Scapulohumeral rhythm is critical for normal arm elevation. The force couple of the deltoid and the rotator cuff and the force couple of the serratus anterior and the trapezius are of great importance during elevation of the arm. The functions of these force couples are to achieve smooth arm elevation without impinging the humeral head against the coracoacromial arch and to enhance dynamic stability of the glenohumeral joint. The force couple of the trapezius and serratus anterior achieves upward rotation of the scapula by acting concentrically during humeral elevation. During lowering of the arm, this force couple acts eccentrically to control downward rotation of the scapula. If strong downward rotation of the scapula is needed (eg., forced lowering of the arm), it will be performed by concentric contraction of the lower segment of the pectoralis major, pectoralis minor, levator scapulae, rhomboids, and latissimus dorsi (44).

Weakness of the scapulothoracic muscles may cause or aggravate impingement. If humeral elevation is not synchronized with upward scapular rotation or lowering of the arm is not synchronized with downward scapular rotation, impingement may occur.

The throwing athlete performs repetitive overhead movements at high velocities and with explosive forces (39). Weakness or fatigue of the scapular muscles after repeated use may lead to impingement due to

### TABLE 5. Nonoperative treatment of shoulder impingement syndrome.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Suggested Treatment Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pappas et al (38)</td>
<td>Return of normal passive and active ROM, synchrony of motion,</td>
</tr>
<tr>
<td></td>
<td>strength, endurance, and integrated muscle action, and prospective return to pitching.</td>
</tr>
<tr>
<td>Hawkins and Kennedy (13)</td>
<td>Rest, ice/heat, ultrasound, anti-inflammatory medications,</td>
</tr>
<tr>
<td></td>
<td>stretching and strengthening program for the rotator cuff and</td>
</tr>
<tr>
<td></td>
<td>large shoulder girdle muscles.</td>
</tr>
<tr>
<td>Moynes (32)</td>
<td>Relative rest, stretching and strengthening exercises with</td>
</tr>
<tr>
<td></td>
<td>emphasis on the rotator cuff muscles, and gradual return to</td>
</tr>
<tr>
<td>Matsen and Arntz (28)</td>
<td>Avoidance of repeated injury, restoration of normal flexibility,</td>
</tr>
<tr>
<td></td>
<td>restoration of normal strenthen strength, aerobic conditioning,</td>
</tr>
<tr>
<td></td>
<td>and gradual return to work or sports.</td>
</tr>
<tr>
<td>Neviaser et al (35)</td>
<td>Anti-inflammatory medications, moist heat, restricted exercises,</td>
</tr>
<tr>
<td></td>
<td>and avoidance of overhead activities.</td>
</tr>
<tr>
<td>Richardson et al (42)</td>
<td>Stretching, anti-inflammatory medications, ice, rest,</td>
</tr>
<tr>
<td></td>
<td>and injectable steroids.</td>
</tr>
</tbody>
</table>
Muscle Suggested Exercises

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Suggested Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serratus anterior</td>
<td>Scapular plane abduction$ (31), push up$ (31), end range shoulder flexion in prone$ (14), serratus anterior punch$ (21)</td>
</tr>
<tr>
<td>Upper trapezius</td>
<td>Shoulder shrug$ (1, 4, 50), scapular plane abduction$ (31)</td>
</tr>
<tr>
<td>Middle trapezius</td>
<td>Rowing$ (31), shoulder elevation and hyperextension in standing$ (1, 50), shoulder abduction and flexion in prone$ (1, 50), scapular retraction with horizontal abduction of the externally rotated shoulder in prone$ (21)</td>
</tr>
<tr>
<td>Lower trapezius</td>
<td>Scapular plane abduction and rowing$ (31), shoulder depression and retraction in sitting$ (50), elevation of the externally rotated arm which is positioned diagonally between flexion and abduction$ (21)</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Shoulder elevation, abduction, flexion$ (2, 7), rowing$ (31)</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>Rowing$ (31), shoulder retraction, elevation, and abduction$ (7), scapular retraction with horizontal abduction of the internally rotated shoulder in prone$ (21)</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Press ups$ (46), lat pull down$ (16)</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>Press ups$ (46)</td>
</tr>
<tr>
<td>Pectoralis minor</td>
<td>Press ups$ (31)</td>
</tr>
</tbody>
</table>

\$ Exercises based upon EMG studies.
† Exercises based upon anatomomechanical studies.

TABLE 6. Suggested exercises for the scapulothoracic muscles.

failure of the scapular rotators to achieve the required scapular rotation with humeral elevation. Also, shoulder pain from impingement may lead to inhibition of the scapular muscles, causing further impingement (Figure 8). If the scapulothoracic muscles are not properly retrained following acute shoulder injury, these muscles may suffer disuse atrophy or may not function in proper sequence.

The validity of the lateral scapular slide test (22), which was designed to identify patients with functional scapulothoracic instability, is yet to be proven and should be viewed cautiously. Hypertrophy of the upper back and medial scapular musculature of the dominant arm of throwers may introduce error to the measurement. In addition, functional scapular instability is a dynamic deficiency, which may not be apparent in static conditions that this test utilizes (arm held isometrically in different degrees of abduction).

Several rehabilitation protocols have been designed for the treatment of impingement syndrome and rotator cuff injuries. The shoulder rehabilitation protocols seem to focus on the proper function of the rotator cuff, with little emphasis on function of the scapulothoracic musculature. Jobe and Bradley (16) have included strengthening of the scapular rotators in their protocol for treatment of shoulder injuries and stress the upper trapezius, serratus anterior, and latissimus dorsi. Electromyography has been used to study the activity of various shoulder muscles in different sports activities. Jobe et al (19), Nuber et al (37), and Ryu et al (43) emphasize the function of the serratus anterior in providing a stable base for articulation of the humeral head and stress that the strength and endurance of the serratus anterior should be addressed as part of treatment of shoulder impingement syndrome. Although the researchers are commended for their efforts, these studies have not included all of the scapular muscles responsible for scapular motion and stabilization. In addition to the serratus anterior, the trapezius, levator scapulae, rhomboids, pectoralis minor, latissimus dorsi, and pectoralis major muscles control scapular motion and contribute to its stabilization during movement of the arm. Stability of the scapulothoracic joint could not be achieved by one muscle alone. Proper function of all of the scapulothoracic muscles is nec-
Clinical Commentary

It is necessary to achieve dynamic stability of the scapula. Isolated strengthening of one of the scapulothoracic muscles will create a muscular imbalance, which could aggravate the condition. The authors believe that a comprehensive protocol for treatment of secondary shoulder impingement should take into consideration the proper function of all of the scapulothoracic musculature as well as the rotator cuff muscles. Proper function includes strength, endurance, and synchrony of activation during movement. Proper function of the scapulothoracic muscles promotes synchrony of the scapulohumeral rhythm and may lessen the risk of impingement.

Suggested Exercises for the Scapulothoracic Muscles

Several exercises used to strengthen the scapulothoracic muscles are summarized in Table 6. Figures 9–16 illustrate some suggested exercises for the scapulothoracic muscles. Most of these exercises are based upon anatomomechanical or electrophysiological studies and should be viewed cautiously. Several EMG studies have been performed to examine the activity of different scapulothoracic muscles (1, 2, 4, 7, 14, 31, 46, 50). The results of these studies should be viewed carefully due to the presence of methodological flaws, including the use of surface electrodes (which may introduce error to the study due to "cross-talk") (50), the use of active motion only (4), and the lack of utilization of standardized resistance (31, 46, 50). A need exists to verify these positions electromyographically in well-controlled randomized studies.

The function of the scapulothoracic muscles is to provide mobility as well as stability for the scapula. Scapular positioning (mobility) synchronizes scapulothoracic joint motion with glenohumeral joint motion and decreases risk of impingement. Scapular stabilization by the scapulotho-

FIGURE 12. Rowing.

FIGURE 13. Scapular retraction with horizontal abduction of the externally rotated shoulder in prone.

FIGURE 14. Elevation of the externally rotated arm, which is positioned diagonally between flexion and abduction.

FIGURE 15. Scapular retraction with horizontal abduction of the internally rotated shoulder in prone.

FIGURE 16. Press up.

sized that the scapulothoracic muscles serve as primarily a postural function. Postural muscles should contain a larger proportion of type I fibers. Autopsy studies have shown that the lower and middle portions of the trapezius contain predominantly type I fibers (80 and 76%, respectively) (25). The upper portion of the trapezius also contains a higher percentage of type I fibers (67%) (25). These data would support the above hypothesis regarding the postural function of the scapulothoracic muscles. Thus, in rehabilitation of the scapulothoracic muscles, their postural function should be ad-
dressed and retrained (ie., endurance exercises). This is done by training the muscles with low weights and high repetitions. Although return of endurance of the scapulothoracic muscles should be emphasized, return of their strength should also be a goal.

Deficits in ROM, if present, should be addressed. Posterior capsular stretching may be helpful in treatment of impingement syndrome (16, 28, 38, 48). Posterior capsular tightness could be examined by assessing posterior glenohumeral motion as part of the accessory motion testing (dorsal glide of the humeral head) (20) as well as assessing internal rotation and cross-chest adduction of the shoulder (28). If posterior capsular tightness is present, it should be addressed by passive stretching techniques (16, 28, 38) and by dorsal glenohumeral joint mobilization techniques (20). Deficits of scapulothoracic joint motion, if present, should be addressed.

The patient's shoulder examination will dictate whether or not the above exercises are needed. In addition to strength and endurance of the scapulothoracic muscles, flexibility of the scapulothoracic muscles should be assessed and maintained. The authors believe that a protocol should serve only as a guide in planning a specific program that is individualized to meet the patient's needs. A comprehensive nonoperative management protocol for shoulder impingement syndrome should emphasize endurance and strength of the scapulothoracic musculature in addition to the traditional treatment goals of restoring normal range of motion, strength, and endurance of the rotator cuff muscles. Further research utilizing EMG is needed to find optimum testing and exercise positions for the scapulothoracic muscles.

CONCLUSION

Weakness of the scapulothoracic musculature could lead to secondary subacromial impingement through disruption of the scapulohumeral rhythm, abnormal scapular positioning, and functional scapulothoracic instability. The authors suggest that a comprehensive protocol for treatment of secondary shoulder impingement should include restoration of normal active and passive mobility of the shoulder, with special emphasis on restoring normal scapulohumeral rhythm. Additionally, exercises to develop strength and endurance of the shoulder muscles, with special emphasis on the rotator cuff and scapulothoracic muscles, should be included. Further research is needed to determine the function of the scapulothoracic muscles and to verify exercise positions traditionally employed for strengthening the scapulothoracic muscles.

REFERENCES

21. Kendall PF, McCreaey FK: Muscles:


47. Warner JP: Pittsburgh, PA (personal communication)

