

Electromyographically Based ■ Rehabilitation Exercises for the Scapula

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Overhead athletes including those in racket sports, throwers, volleyball players, and swimmers require full, unrestricted use of their upper extremity to compete at optimal levels. Scapulothoracic and scapulohumeral (rotator-cuff) muscle function are critical for normal overhead activities of the shoulder and play an important role in normal shoulder function.

KEY POINTS

- ▶ Scapular-muscle function is critical for full unrestricted activity in overhead athletes.
- ▶ Scapular function requires control of both the scapulothoracic and scapulohumeral muscle groups.
- ▶ There is sufficient EMG evidence regarding favorable exercise techniques to elicit high muscle-firing patterns for both the scapulothoracic and scapulohumeral muscle groups.
- ▶ Key Words: muscle strength, muscle endurance, scapulohumeral

EMG in order to determine to what level specific scapulothoracic and scapulohumeral muscles are activated. Electromyographic studies will be used in this article to provide a rationale for exercise recommendations to strengthen scapulothoracic and scapulohumeral muscles.

Furthermore, weakness of scapulothoracic and scapulohumeral muscles is a common cause of shoulder pathology.

The primary purpose of this article is to describe therapeutic exercises that activate scapulothoracic and scapulohumeral muscles that are derived from literature examining the electromyographical (EMG) activation of the scapular muscles. Therapeutic exercises have been investigated using surface and indwelling

Scapulothoracic Muscles and Pathology

Because of the overt mobility present at the human glenohumeral joint, overhead athletes require a stable base of operation at the scapulothoracic joint. To maintain stability, the scapula relies very heavily on the muscles of the scapulothoracic region. If scapulothoracic muscles are not functioning properly because of aberrant motion or asynchrony of the firing patterns, overhead athletes are at great risk for injuries such as impingement and other forms of overuse syndromes.

Moseley et al.¹ assessed scapular-muscle activity with indwelling EMG electrodes. In their study, an exercise was considered a significant challenge if it generated at least 50 % of the muscles maximum contraction. The researchers focused on the scapulothoracic muscles: the serratus anterior, the trapezius, the rhomboid muscles, and the pectoralis minor. Four scapular-muscle exercises were determined to generate the most activity in healthy subjects. These exercises included scaption (scapular-plane elevation; Figure 1), rowing (Figure 2), push-up with a plus (Figure 3), and press-up exercises (Figure 4). These exercises are commonly known as the Moseley scapular core exercises. These and others are used in a thorough program to address scapulothoracic-muscle impairments.



Figure 1 Scapular-plane elevation (thumb up).



Figure 4 Press-up.



Figure 2 Rowing exercise.



Figure 3 Push-up with a plus.

Serratus Anterior

The outer superior borders of first 7–10 ribs and the intercostal muscles are the point of origin for the serratus anterior muscle, and the lower medial scapula

border is the insertion. The serratus anterior forms an important force couple with the trapezius muscles that allows upward rotation of the scapula—a motion critical for overhead movements. Decker et al.² demonstrated that several exercises sufficiently activated the serratus anterior; these included the forward punch (Figure 5), scaption (Figure 1), dynamic hug (Figure 6), and push-ups plus (Figure 3). Ekstrom et al.³ agreed that the push-up plus was a very high-level serratus exercise. They also found that the combined glenohumeral motions of flexion, adduction, and external rotation (Figure 7), as well as glenohumeral abduction to 125° in the plane of the scapula (Figure 8) and glenohumeral flexion to 125° with protraction, elicited high levels of EMG activity.

Trapezius Muscles

The trapezius is a very broad triangular muscle originating from the occiput to the lower thoracic spine. It inserts on the clavicle, the acromion, and the spine of the scapula. The upper and lower trapezius and the serratus anterior are thought to be the primary upward scapular rotators during overhead motions.⁴ Ekstrom et al.⁵ evaluated EMG trapezius muscle activity and found that the unilateral shoulder-shrug exercise produced the greatest EMG activity in the upper trapezius, whereas shoulder horizontal abduction with external rotation and the prone overhead arm raise in line with the lower trapezius muscle activated the middle trapezius to the fullest extent (Figure 9). The prone overhead arm raise in line with the lower trapezius fibers activated the lower trapezius the most.

Rhomboid Muscles

The rhomboid muscles are a set of muscles that lie on the posterior thorax, originate on the thoracic spine,



Figure 5 Forward punch.



Figure 8 Shoulder abduction to 125° in the plane of the scapula.



Figure 6 Dynamic hug.



Figure 9 Prone lower trapezius.



Figure 7 Shoulder horizontal adduction/extension with external rotation.

and attach to the medial scapular border. Activation of the rhomboid muscles will cause a concentric downward scapular rotation, or they will help eccentrically control scapular upward rotation. Moseley et al.¹ evaluated activation of the rhomboid muscles in their previously cited study. Four exercises were found to activate the rhomboid major and minor muscles to the greatest extent: horizontal abduction in neutral, scaption, shoulder abduction, and rowing.

Intervention for Scapulothoracic-Muscle Impairment

When devising any therapeutic-exercise program, one should determine the primary goals to be addressed. Simply stated, are the goals of the program to increase local muscle strength, endurance, or power? Using the mode of exercise that best fits the functional demands of the athlete is known as specificity of training. It is

outside this article's scope to describe specific training programs in detail, but the reader is directed to the work of Baechle and Erale⁶ to gain further insights regarding specific training methods. Once a patient's exercise goals have been determined, the clinician can apply techniques that more appropriately affect the given muscles.

Scapulohumeral Muscles and Pathology

Any sport or recreational activity requiring overhead motions places high demands on the scapulohumeral muscles. Inman et al.⁷ described the importance of the force couple that occurs between the scapulohumeral muscles and the deltoid muscle during arm-elevation activities. Proper recruitment of the scapulohumeral muscles is imperative to provide dynamic compression to the humeral head to offset the superior translatory moment generated by deltoid activation during arm elevation.

Townsend et al.⁸ used dynamic fine-wire intramuscular EMG to study common shoulder exercises in healthy participant■. In their study an exercise was considered a significant challenge to the scapulohumeral muscles if it generated at least 50% of the scapulohumeral muscles' maximum contraction. Four exercises were consistently found to be challenging for the scapulohumeral muscles. The four exercises, commonly known as the Townsend core rotator-cuff exercises, include glenohumeral elevation in the scapular plane with thumbs down, glenohumeral flexion, glenohumeral horizontal abduction with the arms externally rotated (Figure 7), and the press-up (Figure 4). Townsend et al.⁸ found that scaption with thumbs down elicited high EMG activity above 90° of glenohumeral elevation. Clinically, this range of motion is not recommended because it can very easily place the glenohumeral joint in a position of impingement. The risk of impingement strongly outweighs the gains that would result from this exercise. In developing a comprehensive rehabilitation program, all of the scapulohumeral muscles must be addressed.

Supraspinatus

The supraspinatus origin is the supraspinatus fossa of the superior portion of the scapula, and it inserts onto the greater tuberosity of the humerus to form the superior portion of the rotator cuff. The supraspinatus and the deltoid muscle form one of the most important force couples in the glenohumeral joint. Both of these

muscles are activated early in beginning of shoulder elevation and reach maximal levels of firing at about 90°.⁹ Throughout the motion of elevation these two muscles contribute approximately equal shares of abduction torque.¹⁰ The supraspinatus is also thought to be important in maintaining dynamic shoulder stability.¹⁰,¹¹ Several studies have examined the EMG activity of the supraspinatus muscle. Kelly et al.¹² assessed such EMG activity and found that scaption with thumb up (full-can position) generates the most activity in the supraspinatus muscle (Figure 1), and Reinold et al.,¹³ Blackburn et al.,¹⁴ and Worrell et al.¹⁵ all determined that prone horizontal abduction with the elbow extended and the glenohumeral joint externally rotated and abducted to 100° maximally activated the supraspinatus. In contrast, Jobe and Moyes■¹⁶ found that the supraspinatus is maximally activated in scaption with thumb down (the empty-can position) at 90° of abduction, as well as 30° of horizontal adduction and full internal rotation. Recent evidence by Thigpen et al.¹⁷ revealed that there is an increased amount of scapular anterior tipping and internal rotation during elevation in the empty-can position, which might not be appropriate for patients with impingement-related conditions. It appears from this recent study that the empty-can position should be used very selectively, and, when possible, use of the full-can position might be more appropriate to activate the supraspinatus and not lessen the subacromial space.¹⁷

Subscapularis

Subscapularis-muscle activity is crucial for overhead athletes. The subscapularis muscle is the anterior component of the scapulohumeral force couple, along with its antagonist the infraspinatus muscle. It is imperative that all of the cuff muscles function properly to counteract the cephalad pull of the humerus by the deltoid muscle. There appear to be conflicting findings regarding functions, innervation, and activation of the subscapularis.¹⁸ There is evidence to suggest that the upper and lower portions of the subscapularis muscle function independently and have separate innervations.¹⁸,¹⁹ Decker et al.¹⁹ found that both upper and lower subscapularis-muscle activity was generated with amplitudes greater than 20% of maximal voluntary contraction in participants performing the dynamic hug (Figure 6), push-up plus (Figure 3), internal rotation with arm at side, internal rotation with arm abducted approximately 40°, and diagonal-adduction/internal-rotation exercise. Electromyographic amplitudes

did not reach levels greater than 20% for the lower subscapularis for internal rotation with arm abducted to 90° or the forward-punch exercise. The two exercises that activated the upper and lower portions to a greater level more consistently were the push-up plus (Figure 3) and the diagonal-adduction/internal-rotation exercise.

Infraspinatus and Teres Minor

The infraspinatus and teres minor arise from the concave posterior surface of the scapula and, along with the subscapularis, form an important force couple in the shoulder to maintain glenohumeral stability during overhead motions. This function is very critical during the throwing motion, when joint distraction forces approximate full body weight at the glenohumeral joint.²⁰ Therefore, strengthening these muscles is critical to have a normally functioning shoulder. The highest EMG activity in the infraspinatus was recorded by Ballantyne et al.,²¹ and Reinold et al.²² while participants performed side-lying external-rotation exercise (Figure 10).



Figure 10 Side-lying external rotation.

Summary

Both the scapulothoracic- and scapulohumeral-muscle complexes are critical to a fully functional and asymptomatic shoulder. Strengthening exercises for these essential muscle groups should not be done in a random pattern, without careful thought and consideration. There appears to be sufficient evidence from the literature to help clinicians develop a specific structured treatment approach to address deficits in each muscle group.

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