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Rehabilitation for Subacromial Impingement Starts at the Scapula
肩峰下撞擊綜合症的康復治療始於肩胛骨

Houglum Peggy A.

Duquesne University, 600 Forbes Avenue, Pittsburgh, USA

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ABSTRACT

Subacromial impingement, especially secondary subacromial impingement, is a common malady of athletes and non-athletes alike. Although several pathologies may lead to impingement, they all relate back to poor posture. Over time, postural changes increase stress to soft tissue structures to change both alignment and performance. Injury results as low-level stresses impact weakening tissues to the point of overload. Crucial to effective treatment of secondary subacromial impingement is the identification and correction of all causes. Basic to successful treatment is correction of posture, including scapular posture and muscles which control, stabilize, and move the scapula. An evidence-based approach to not only identifying the causes but also creating a treatment regimen to effectively resolve secondary subacromial impingement is presented.

中 文 摘 要

肩峰下撞擊症，特別是繼發性肩峰下撞擊，是運動員和非運動員的通病。雖然有一些病理可能造成撞擊，但全部都與姿勢不良有關。長期的體位改變能增加軟組織結構的壓力，影響其正常之排列和功能。創傷引起的低量應力能減弱組織的結構並到達其超載點。繼發性肩峰下撞擊綜合症的有效治療方法之關鍵是識別和糾正各種病因。成功的治療基礎是矯正姿勢，包括肩胛骨姿勢和控制、穩定及移動肩胛骨的肌肉羣組。我們以證據為基礎，不僅能查明病因，並創造了一個治療方案，有效地舒緩繼發性肩峰下撞擊症。

Introduction

Shoulder injuries are common, especially among athletes participating in either competitive or recreational sports or individuals whose work or tasks involve overhead activities. Of these shoulder injuries, secondary impingement is one of the shoulder pathologies most frequently treated by physicians and clinicians.[1–3] Since there are several reasons impingement occurs, clinicians must identify not only the sources of pathology, but also the best and most reliable means of rehabilitating them if treatment programs are going to be most effective. The goals of this study are to identify the most common pathology causing secondary subacromial impingement and present suggestions for rehabilitation of the problem.

Pathology

Although acute injury to glenohumeral structures may certainly lead to subacromial impingement, there are four more common and primary causes for this malady of the shoulder complex. These causes include pathological posture, overuse and fatigue of the scapular and glenohumeral muscles, neuromuscular adaptations, and muscle imbalances. All of these causes are inter-related and share the same root source, pathological posture.[4–6] How these problems relate back to poor posture is explained in this section.

Pathological Posture

When the body is in proper alignment, each upper body segment balances with minimal muscle activity on the adjacent segments below it. Proper standing or sitting posture includes the alignment of the head and neck directly under the shoulders so that a vertical line drawn along a lateral view of the body goes through the auditory meatus, the acromion, and the bodies of the cervical vertebrae (Figure 1). From a posterior perspective, the scapulae are approximately 5 cm from the thoracic spinous processes and lie flat along the posterior thoracic cage. In this alignment, the arms are resting at the sides with the hands on the lateral thighs.

As we develop improper postural habits, this alignment is gradually lost. Most often, individuals develop malalignments,

E-mail: houglum@duq.edu.

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Figure 1. Proper posture from a lateral view. From Houglum PA. *Therapeutic Exercises for Musculoskeletal Injuries*. 3rd ed. Champaign, IL: Human Kinetics, 2010. Reprinted with permission.

which place the auditory meatus forward of the acromion and the scapulae protract to lie more than 10 cm from the thoracic spine and tilted forward, causing the glenohumeral joints to lie in an anterior tilt and medially rotated to their normal position.[7,8] This malalignment is reflected during standing with the hands positioned on the anterior rather than the lateral thighs (Figure 2). The most obvious source of secondary impingement resulting from this malalignment is the narrowing of the subacromial space with the greater tubercle positioned under the acromion. Scapular protraction also results in reduced available motion of the glenohumeral joint during elevation activities.[9] In this pathological posture, the

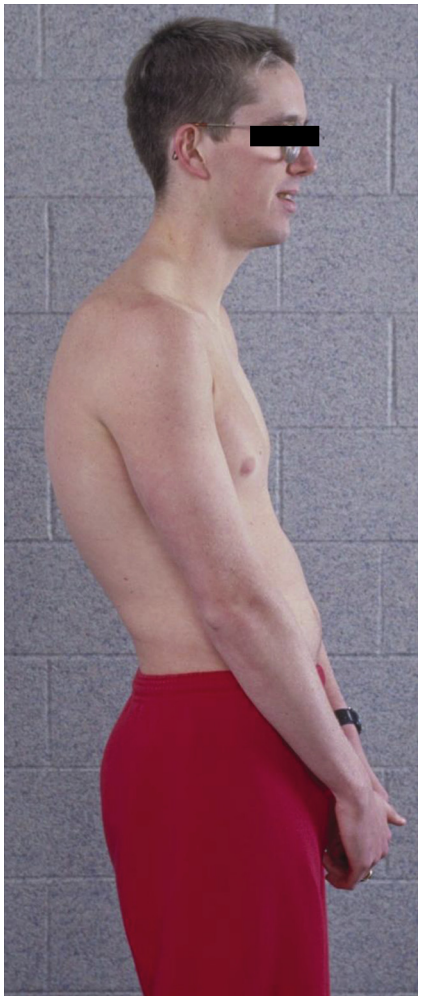

Figure 2. Pathological posture leading to secondary impingement. From Houglum PA. *Therapeutic Exercises for Musculoskeletal Injuries*. 3rd ed. Champaign, IL: Human Kinetics, 2010. Reprinted with permission.

humeral head's medially rotated position narrows the subacromial space when the arm elevates so as it moves into the higher degrees of elevation, compression of the shoulder's subacromial soft tissue structures increases.[10]

Pathological Adaptation

As this pathological posture develops, muscles adapt to these changes by adjusting their motor and neurological responses. When the head is positioned forward of normal alignment and the scapulae protract, there is a continual low-level stress of muscles supporting these structures; muscles on the elongated side lengthen while their opposing muscles shorten.[11] In the case of posture with a forward head and scapular protraction with glenohumeral medial rotation, muscles including the scalenes, rhomboids, and infraspinatus lengthen, while their opposing muscles such as the upper cervical muscles, pectoralis minor, and subscapularis shorten. Based on the length-tension principle, muscle strength diminishes as a muscle either shortens or lengthens from its optimal length, these affected muscles lose their ability to produce optimum strength.[12] To further complicate matters, this change in muscle length also creates imbalances in muscle function.[10,13] Muscle recruitment is altered, not only in their sequence of recruitment, but muscles' response time to stimulation increases as

the strength decreases.[14,15] Owing to these changes in response time, muscle recruitment patterns, and strength along with postural changes, the shoulder complex is forced to modify how it functions.[16] Since the shoulder complex now functions with less than optimal physical and neurological conditions, the result is inefficient performance.

When a body or its segment is inefficient during activities, potential problems arise. One problem is that muscles must work much harder to perform the same task a normal shoulder executes without nearly as much difficulty. Since they must work harder and are inefficient in their performance, these muscles fatigue more quickly. As they fatigue, their performance further degrades, increasing the risk for shoulder injury.[16–20] Another problem is that with our body segments malaligned, increased structural stresses on soft tissue and joints occur.[21]

Along with changes in the recruitment of muscles because of poor posture and fatigue, we also see other alterations in neuromuscular performance. Poor posture is developed over time and gradually enough that we do not realize the changes until we experience discomfort because of it. As many of us sit at desks or computers, our heads move forward on our trunk, our scapulae protract on the thorax, and our glenohumeral joints medially rotate.[21] Since these changes are gradual, our neuromuscular system adapts to them,[22] readjusting our engram of what we feel is comfortable so the pathological posture feels "normal". Once we are in this pathological posture, our muscles adapt to performing activities in this altered posture. With repetition of these activities, the altered patterns through which these muscles perform become more engrained in our performance memory, making them harder to alter as repeated performances continue.[23,24]

These factors of poor posture, neurological changes, and muscle overuse combine to produce muscle imbalances. These imbalances result in additional problems. Specifically regarding the scapula's protracted position and muscular adaptations, weakness in these muscles leads to loss of glenohumeral control.[19] Since the scapular-stabilizing muscles are unable to perform their responsibility of positioning the scapula so that the rotator cuff muscles can perform their own stabilizing function, glenohumeral stability is detrimentally affected. This lack of control then leads generally to glenohumeral injuries,[25–27] and specifically to secondary subacromial impingement.[28–30]

In summary, although secondary subacromial impingement may occur acutely, it is most often the result of four pathologies, poor posture, overuse fatigue, neuromuscular alterations, and muscle imbalances. Of these four pathologies, poor posture is the primary pathology, which leads to the other three. With a posture of forward head, scapular protraction, and medially rotated glenohumeral joints, the body adjusts its expectations of "normal" posture to coincide with gradual postural changes. These changes, in turn, cause muscle imbalances, increased stresses and fatigue, and decreased tolerance to meet these stresses. Eventually, the body segment succumbs to these progressive pathological influences, resulting in secondary subacromial impingement.

Rehabilitation

When many health care professionals treat subacromial impingement, they emphasize the rotator cuff muscles in their rehabilitation programs. However, it is the scapular muscles that are often overlooked and are, in fact, a key to secondary subacromial impingement. Although the patients with subacromial impingement often have weak rotator cuff muscles, this factor is likely the result of pain rather than the cause of the impingement.

The scapula and its muscles provide the foundational structure for the glenohumeral joint, allowing the joint to move from a stable base. The scapular muscles which provide this stability include the serratus anterior, trapezius, rhomboids, and pectoralis minor.[28,31] When these muscles become dysfunctional, the glenohumeral joint is affected. Of this muscle group, the muscle that appears to be the most influential in causing secondary subacromial impingement is the serratus anterior.[28,31,32] The serratus anterior is both a primary scapular stabilizer and is active throughout a significant portion of shoulder elevation activities. For example, it is continually active throughout the freestyle swim stroke, firing at more than 20% of its maximum throughout the stroke[33]; Keep in mind that any muscle that performs sustained activity at 15–20% of its maximal output is susceptible to fatigue.[34] It has been determined that during functional activities, the serratus anterior and trapezius are most susceptible to fatigue and inhibition following fatigue.[35–37] As these muscles become fatigued, their activity and timing are altered.[38] Specific to patients with subacromial impingement, it has been demonstrated that serratus anterior activity is delayed more than three times normal response time and significantly later than the upper trapezius, with the lower trapezius firing even later than the serratus anterior.[38] This sequence is atypical of the normal sequential firing which has the lower trapezius activating before the upper trapezius.[14,39]

When these muscles do not function as they should, the scapula becomes unstable, establishing conditions that make the glenohumeral joint susceptible to injury. Scapular instability has been found in 100% of individuals with glenohumeral instability.[40] Scapular deficiencies in areas of posture, weakness, and timing, then lead to various glenohumeral dysfunctions, especially subacromial impingement.[41]

Effective treatment of subacromial impingement must go to the root of the problem, the scapula. Following the clinician's identification of pathologies, efforts must be made to correct causative factors. Once pain is relieved through the use of various modalities and manual techniques, advocating for and instructing in proper posture, improving flexibility and mobility of restricted structures and strength of weakened muscles, and restoring proper muscle firing patterns are goals of the clinician.

Optimal flexibility, mobility of joints, and soft tissue are sought for all the involved regions. This may require joint mobilization for joints within the shoulder complex as well as at the costovertebral and thoracic joints if they are restricting normal shoulder motion. It is common for individuals with posture-related shoulder pathology to have soft tissue restrictions that require manual techniques such as myofascial release, trigger point release, or strain-counterstrain applications to correct soft tissue alignment. These manual therapies accompany active and passive range of motion exercises.

Motion loss is related to fascia and joint capsule restrictions as well as muscle tightness.[42] For example, it has been found that pectoralis minor shortening[43] and posterior capsular tightness[7] are both present in subjects with subacromial impingement. Therefore, the most deficient motions include glenohumeral medial rotation, horizontal adduction, and elevation. Stretches directed at relieving these deficient motions include those seen in Table 1. Since optimal time and repetitions for injured or pathological tissue has yet to be determined, many clinicians use what investigators have found to be optimal for normal tissue: one 30-second stretch.[44] Others use a variety of stretch applications such as a 15-second stretch for four repetitions since it may be difficult for a patient to maintain a 30-second stretch[45]; however, as mentioned, optimal stretch exercise parameters for pathological tissue has not yet been empirically identified.

Strength exercises included in rehabilitation of patients with secondary subacromial impingement are designed to correct deficiencies within the scapular stabilizers, glenohumeral stabilizers, and larger movers of the shoulder, as appropriate. Although rotator

Table 1
Flexibility and stretching exercises

Exercise	Motion	Purpose
Inferior capsule stretch	Place arm overhead with the elbow relaxed and flexed and next to the head. With opposite hand, grasp the elbow and pull backward.	Stretches inferior part of the glenohumeral capsule and pectoralis minor muscle.
Posterior capsule stretch	With the arm at the shoulder level, place the hand on the opposite shoulder. Pull the elbow with the contralateral hand towards the contralateral shoulder.	Stretches posterior part of the glenohumeral capsule.
Sleeper stretches	Lying on affected side, place the shoulder at ~70° of flexion with elbow at 90°. Place the contralateral hand on back of the wrist and push the affected shoulder into medial rotation until a stretch is felt. Repeat the motion at 90° of shoulder flexion and 120° of shoulder flexion.	Stretches the posterior part of the glenohumeral capsule at its inferior, middle and superior portions.
Corner stretch	Stand with one foot in front of the other, facing a corner. Place elbows at shoulder level with elbows flexed to 90°. Using your back leg, push your body into the corner until you feel a stretch in the anterior shoulders.	Stretches the anterior part of the glenohumeral capsule and pectoralis major muscle.

cuff muscles often become weak, painful and injured in subacromial impingement and must also be restored to their optimal function, deficiencies in the scapular muscles are addressed first since they are the basis from which a normal shoulder complex functions. Of the scapular stabilizers, the lower and middle trapezius, serratus anterior, and rhomboids are of most concern.[31] Although the upper trapezius is an upward scapular rotator, it overpowers the other scapular rotators and precedes them in their firing sequence, adding to subacromial impingement symptoms.[38,46] Therefore, early rehabilitation exercises are designed and incorporated to isolate and recruit the lower trapezius, serratus anterior, rhomboids, and middle trapezius. The scapular exercises are listed in Table 2.

Table 2
Evidence-based rehabilitation strengthening exercises for scapular muscles

Muscle	Exercise	References
Lower trapezius	Overhead shoulder flexion in prone (elbows extended)	Ekstrom[55]
Lower trapezius	Lateral rotation in 90° abduction in prone	Ekstrom,[55] Reinold[56]
Lower trapezius	Seated row or prone row	Ekstrom,[55] Moseley et al[57]
Lower trapezius	Horizontal abduction with lateral rotation	Ekstrom,[55] Moseley et al,[57] Reinold[56]
Lower trapezius Serratus anterior	Push-up plus	Moseley et al,[57] Ekstrom,[55] Reinold[56]
Serratus anterior	Dynamic hug	Decker et al,[58] Reinold[56]
Serratus anterior	Serratus punch at 120°	Reinold[56]
Serratus anterior	Shoulder elevation in scapular plane	Escamilla,[59] Decker et al,[58] Moseley et al,[57] Ekstrom[55]
Rhomboids Middle trapezius	Overhead shoulder flexion in prone (elbows extended)	Ekstrom,[55] Moseley et al[57]
Rhomboids Middle trapezius	Lateral rotation in 90° abduction in prone	Ekstrom[55]
Rhomboids Middle trapezius	Seated row or prone row	Ekstrom,[55] Moseley et al,[57] Reinold[56]

Whenever the scapular muscles are strengthened, it must be remembered that in the lower ranges of scapular rotation, they work primarily to stabilize or "set" the scapula. As the humerus moves through its elevation range of motion, scapula muscles not only work to continue to stabilize the scapula but also contract to rotate it, so their activity level increases as the glenohumeral motion progresses upward.[47,48] This means that the clinician must first achieve scapular stabilizer strength in the lower ranges of glenohumeral motion and then progress to higher levels of elevation only as the scapular rotators gain sufficient strength to control the scapula appropriately at each level of elevation. It is important to restore scapular stability before scapular movement is permitted.[49] The division of glenohumeral elevation activities into three progressions, 0°-60°, 60°-120°, and 120°-180°, is recommended.[45]

As part of the rehabilitation process to regain scapular stability, the patient must be instructed to recruit the muscles that stabilize the scapula during activity. Before beginning a shoulder exercise, the patient is instructed to "set" the scapula in its proper position and maintain stability as the arm elevates.

As the patient's strength in these muscles improve to where the muscles are appropriately recruited and have sufficient strength to control the scapula in the lower ranges of motion, additional exercises may be added to the program. Rotator cuff strengthening exercises, then exercises to strengthen the larger glenohumeral movers such as the deltoid, pectoralis major, and latissimus dorsi are included. Rotator cuff exercises begin with the arm positioned at the side in the scapular plane. The exercises for the rotator cuff that are most effective for strengthening each muscle are listed in Table 3. As strength of each of these muscles improve along with

Table 3
Evidence-based rotator cuff exercises

Muscle	Exercise	References
Supraspinatus	Prone horizontal abduction in lateral rotation	Blackburn et al,[60] Reinold et al,[61] Townsend[49,50]
Supraspinatus	Elevation in the scapular plane with 90° of lateral rotation (Full can)	Escamilla et al,[59] Takeda et al[62]
Infraspinatus Teres minor	Sidelying lateral rotation with arm at side	Reinold et al,[61] Dark et al,[63] Townsend[50]
Infraspinatus Teres minor	Horizontal abduction with lateral rotation	Townsend,[50] Blackburn[60]
Subscapularis	Medial rotation at 0° or 90°	Decker,[64] Dark[63]

the scapular muscles, rotation and abduction exercises to strengthen the rotator cuff are performed at 90° of elevation in the scapular plane. Townsend et al[50] identified four exercises that best recruited the deltoid, two of which best recruited the pectoralis major, and one that provided optimal output from the latissimus dorsi. These exercises include shoulder abduction, shoulder flexion, military press, and rows for the deltoid; press-ups and push-ups for the pectoralis major; and press-ups for the latissimus dorsi.

A variety of exercises and exercise progressions are available for subacromial impingement rehabilitation. In addition to those already mentioned and listed in the tables, additional activities include rhythmic stabilization, manual resistance, and weight-bearing stabilization activities. A number of exercises using either resisted pulleys or rubber bands may also be incorporated for both scapular and glenohumeral muscle strengthening as well as for straight plane and tri-planar motions.

Additionally, a number of body-weight resisted exercises such as push-ups progressing from wall push-ups to incline to modified to regular to inverted push-ups can be used from early to later in the program. Seated push-ups or press-downs, machine resistance exercises, and weighted ball tosses are exercises that may be utilized in the later stages of strengthening.

Straight-plane exercises are used prior to tri-planar and functional activities to strengthen specifically weak muscles. The primary reason for this sequence is that weakened or deficient muscles are often substituted during multi-planar activities by stronger or more dominant muscles[51]; therefore, before multi-planar or functional activities can be added to the program, exercises to strengthen and re-establish appropriate recruitment patterns must first occur. Once tri-planar movements are incorporated into the rehabilitation program and the patient demonstrates both control and strength throughout the range of glenohumeral motion, functional activities are added.

To some extent, the type of functional activities selected is dependent upon the demands placed upon the patient during normal activities. For example, if the patient has to return to overhead athletic activities, then functional activities such as tri-planar motion with the arms overhead would be indicated, but if the patient was an assembly-line worker whose work station was at counter level, then that individual's functional activities may include tri-planar activities in mid-ranges of shoulder elevation.

Table 4
Rehabilitation program outline for subacromial impingement

Phases	Phase I Inactive	Phase II Active	Phase III Resistive	Phase IV Aggressive
Intention, objectives, or purpose of each phase	If the injury is very irritable, goals are to reduce pain, oedema, spasm, and other irritable factors.	Once irritability is under control, motion and mobility are restored. Early proprioception, muscle endurance exercises, and strength gains occur.	By this time, motion is fully restored and the injury is not irritable. Emphasis is placed on restoring full strength and muscle endurance, and progress from lower to higher levels of glenohumeral elevation in exercises as scapulothoracic muscle strength gains are made.	Near the end of the program, functional and activity-specific exercises are included to prepare the patient for return to full and normal function.
Treatment program outline	Modalities. Soft tissue mobilization. Grades I & II joint mobilization. CV exercises PRN. Maintenance exercises for unaffected segments. Postural instruction and awareness; provide postural cues for correction.	AROM exercises. Grade III joint mobilization. Scapular resistance exercises in straight plane motions. Early proprioception exercises. Rotator cuff exercises in lower ranges of motion in single plane motions. Continue with CV and maintenance exercises for unaffected segments. Postural correction cues and activities.	Progression of resistive exercises for scapular and rotator cuff muscles with increases in resistance and arm elevation as muscle strength improves scapular control. Add large-muscle exercises to program. Incorporate diagonal, multiplanar and simple functional activities. Continue with CV and maintenance exercises for unaffected segments. Postural correction cues and activities.	Exercises are specific to the needs and demands of the individual's work or sport activities. Progression is made from more complex functional activities to activity-specific exercises which mimic normal activities.
Specific exercises (Without CV and maintenance exercises listed)		AROM: Sleeper stretches, capsular stretches, and corner stretch. Strength: Manual resistance to scapular protraction, retraction, and depression. Dynamic hug. Serratus punch. Prone row. Wall push-up plus. Glenohumeral medial rotation and lateral rotation at 0° elevation, abduction to 30° in sidelying. Horizontal abduction with lateral rotation. Proprioception: Weight-bearing activities in lower ranges of elevation.	UE strength exercises: Push-up plus progression to incline, modified, regular. Overhead shoulder flexion in prone. Lateral rotation in 90° abduction in prone. Seated row. Shoulder elevation in scapular plane (full can). Glenohumeral medial and lateral rotation at 90° abduction in standing. Military press. Press-ups. Press-downs. Multiplanar exercises: BodyBlade in diagonal motions in low and high ranges of motion. Tubing or pulley D1 and D2 exercises. Weighted ball tosses.	Dependent upon the individual's specific needs.

AROM = active range of motion; CV = cardiovascular; UE = upper extremity

The clinician, then, must be able to not only understand the demands and requirements of the patient's normal activities, but also provide activities that mimic those skills.

Throughout the subacromial impingement rehabilitation program, (Table 4), the clinician also addresses posture correction and core strengthening activities. Since poor posture is often the cause of subacromial impingement, it is necessary to correct the patient's posture to assure a long-lasting effect of the treatment program. Additionally, it has been demonstrated that core strength has a direct impact on shoulder performance and injury prevention.[52–54] Both posture correction and core exercises may be initiated early in the program and continue throughout the program until those goals are achieved. It should be considered, however, that the patient will be unable to maintain good posture for extended periods until flexibility and strength of postural muscles have progressed sufficiently to permit the patient to hold a correct posture. Since posture is habitual, it is important to also provide the patient with cues early in the rehabilitation program to remember to correct posture; frequent recall will assist the patient in changing postural habits when muscles are able to better maintain the desired posture.

Summary

Secondary subacromial impingement is one of the most common injuries seen in the shoulder. Although several reasons are to blame for this malady, at the base of these causes is poor posture. Poor posture leads to muscle weakness and fatigue, inappropriate muscle recruitment patterns, and changes in neurological control. If a patient is to achieve long-lasting results of a treatment program, these issues must be addressed. Posture correction and changes in muscle recruitment occur with alterations in muscle strength and muscle endurance along with conscious posture corrections. An appropriate rehabilitation program has been provided.

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