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Rehabilitation of rotator cuff tendinopathy

W. Ben Kibler, MD*

Lexington Clinic Sports Medicine Center, 700 Bob-O-Link Drive, Lexington, KY 40504, USA

Rehabilitation of the dysfunction associated with rotator cuff tendinopathy rests on several bases that have been discovered as part of the investigations into the pathoetiology of the clinical injury, and on observations into the clinical presentation associated with the dysfunction. The first base is that the tendinopathy is the result of a process of injury [1,2]. This implies a failed healing response to a set of still incompletely characterized tensile or compressive stress loads, and that the failure occurred over a period of time, rather than as an acute event. The second base is that at the time of clinical presentation, alterations in physiology and biomechanics of the rotator cuff and associated structures exist and can be clinically evaluated [1]. These alterations are in flexibility, motion, strength, or strength balance, and may be causative in the rotator cuff dysfunction, or may be the result of the rotator cuff injury and increase the dysfunction. The third base is that due to these alterations, symptoms of external or classical rotator cuff impingement under the coraco-acromial arch are common, but are most frequently secondary to the underlying alterations. Fourth, rehabilitation should start with optimized anatomy of the rotator cuff and then seek to restore the altered physiology and biomechanics to allow optimal rotator cuff function. Finally, rehabilitation should shade into "prehabilitation," or functional exercises designed to minimize reinjury risk. This article addresses each of these bases to develop a scientifically-based rehabilitation program.

Physiological and biomechanical alterations in patients with rotator cuff tendinopathy

Flexibility

Glenohumeral internal rotation deficit (GIRD) is the most commonly associated alteration in flexibility [3–5]. This alteration creates an anterior/superior humeral translation with arm forward flexion [3] that has been associated with

* 1221 S. Broadway, Lexington, KY 40504.
E-mail address: Wkibler@aol.com

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external impingement-based rotator cuff tendinopathy [4]. In addition, GIRD creates a posterior/superiorly-directed, humeral-head translation in arm-external-rotation at 90° of abduction, which can cause internal impingement-based undersurface rotator cuff tendinopathy [5]. Also, tightness of internal rotation at the glenohumeral joint results in excessive scapular protraction in arm-forward flexion or the follow-through motion to allow the arm a complete arc of motion in throwing or serving. The excessive protraction may result in external impingement due to decreased acromial elevation [4–7].

Inflexibility of the muscles that insert on the coracoid process, the pectoralis minor, and the short head of the biceps is also common. Tightness in these muscles also leads to scapular protraction, decrease in scapular posterior tilt, and a decrease in the subacromial space height, which is associated with external impingement [6,7].

These alterations may be evaluated in the clinical examination. GIRD should be evaluated measuring true glenohumeral rotation by goniometric means in both shoulders with the scapulae stabilized. Side-to-side differences greater than 25° are considered significant for GIRD [5]. The "spinal level" estimation technique for arm internal rotation has at least 6° of freedom, only one of which is glenohumeral motion, and does not correlate with goniometric measurements [8]. Coracoid-based tightness is more difficult to quantitate, but can be established by palpating the tight muscles and feeling the tautness along the course of the tendons. This test is usually painful due to the tightness.

Strength

One of the clinical hallmarks of rotator cuff tendinopathy is alteration in rotator cuff strength, especially in "empty can" isolated supraspinatus testing, or in resisted external rotation, either at the side or at 90° abduction. Isolated testing of each of the individual rotator cuff muscles by the standard techniques is used diagnostically in the clinical examination, and they invariably demonstrate the weakness. Some of the demonstrated weakness may be more apparent than real. Rotator cuff muscle activation, and the resultant force production, may be decreased up to 23% in the presence of excessive scapular protraction [9]. Rotator cuff strength will often test normal or improved if the scapula is positioned in retraction [9]. It is best to test isolated rotator cuff strength with the scapula in a stabilized retracted position.

Rotator cuff strength balance is also frequently altered in tendinopathy. External rotation strength deficit, both at 0° and at 90° of abduction, is the most common finding [4,5]. This alters the force couple for humeral head stabilization and depression.

Scapular position and motion

Weakness in the muscles that stabilize scapular motion and position is also a common finding in rotator cuff tendinopathy. The serratus anterior and lower trapezius are the most commonly altered [10–12]. This may result from a true deficit in strength [9], an inhibition of activation [11], and an alteration in activation sequencing [10,12,13]. These muscles are particularly involved with horizontal and vertical stabilization of the scapula [13–15]. Deficiencies in activation in these muscles decrease posterior tilting and elevation of the acromion, contributing to external impingement [7,10,14], and increase scapular protraction.

The combination of glenohumeral rotation inflexibility, coracoid based anterior muscle tightness, and posterior muscle weakness results in alterations in scapular position at rest and motion-upon-arm motion that are collectively called scapular dyskinesis [14]. These alterations can be evaluated by observing scapular posture from behind with the patient in a resting position, and then by having the patient elevate his arms in the scapular planes three to five times. Attention should be paid to the symmetry of the medial scapular border to look for unilateral prominence along the border. Specific patterns of dyskinesis in single planes have been described [16]. Excessive acromial anterior tilt and protraction producing inferior medial border prominence—type I, and excessive superior scapular translation producing superior medial border prominence—type III, are both associated with external impingement and rotator cuff tendinopathy. Occasionally, these patterns may be seen in combination, and create an extra degree of acromial depression.

Clinical application—anatomically intact rotator cuff tendinopathy

Flexibility

Tight coracoid based muscles may be stretched by the "open book" stretch (Fig. 1). Arms should be placed at the side to reduce the risk of provoking thoracic outlet symptoms. Internal rotation deficit should be corrected by specific rotation exercises with the scapula stabilized (Fig. 2). The classical horizontal

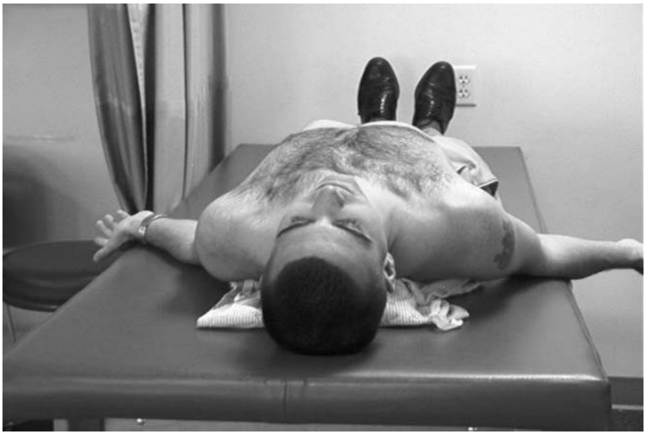

Fig. 1. The "open book" stretch for tight anterior coracoid muscles.

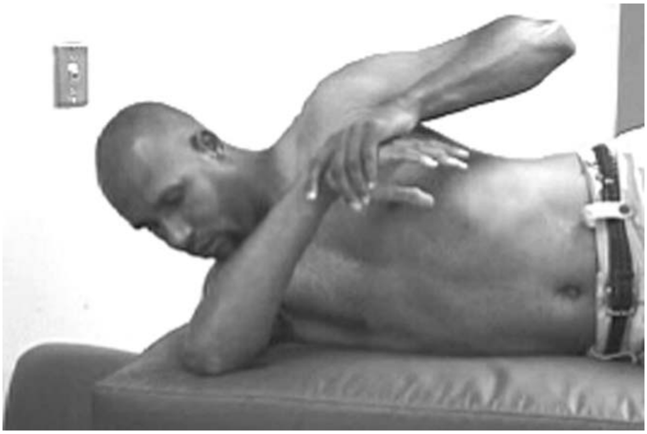

Fig. 2. Stretch to specifically address internal rotation deficit.

adduction stretch creates an impingement position, does not stretch rotation, and increases scapular protraction.

Scapular control

Improvement in strength of the lower trapezius and serratus anterior is based not only on increasing strength production, but also on decreasing inhibition and restoring normal muscle activation patterns. Early exercises should be prescribed at submaximal activation levels with the arm below 90° abduction, to avoid impingement-related pain and inhibition, and should use facilitation of activation by trunk-muscle activation [17]. Examples of exercises include scapular pinches, "low rows" (an isometric exercise combining hip/trunk extension), scapular retraction, and arm extension (Fig. 3), and integrated diagonal trunk rotation/scapular retraction (Fig. 4) or trunk extension/scapular retraction. As the arm can be moved toward 90° elevation, closed chain exercises like the "scapular clock" may be added (Fig. 5). Further progressions in scapular control exercises will involve integration with rotator cuff activation.

Rotator cuff activation

Rotator cuff rehabilitation should be emphasized when the cuff is anatomically intact or strong enough to withstand the applied loads, and when a stable scapular base has been established for activation and for acromial clearance. The clinical evidence for scapular stability includes resolution of scapular dyskinesis, with control of scapular retraction. Rotator cuff activation is most efficient when it is done in an integrated manner with other potent facilitators of rotator cuff activation such as the lower trapezius and latissimus dorsi [17].

Rotator cuff rehabilitation must be graded in intensity of activation and position of activation, so as to not place undue strains on the injured cuff and thus to avoid reinjury. One method of estimating the strain load is to evaluate the percentage of

Fig. 3. The “low row” exercise to activate the serratus anterior and the lower trapezius.

maximal voluntary contraction (MVC) that a muscle is generating in an exercise. A spectrum of activation can then be demonstrated (Table 1). Early passive and active assisted range-of-motion exercises develop only 5% MVC [18]. These exercises include supported positions of the hand and emphasized humeral head depressions. The transition to more challenging types of exercises is a crucial part of the rehabilitation protocol. Studies in our lab (Wise et al, submitted for publication) show that changing type of exercise (closed- versus open-chain), hand position (horizontal versus vertical versus diagonal), and arm velocity (slow versus fast) can affect percent MVC activation. This study documented a progressive increase in MVC activation from 11% to 18% in horizontal closed-chain exercises (Fig. 6) through vertical closed-chain exercises (Fig. 7), horizontal open-chain exercises, and diagonal closed-chain exercises (Fig. 8). Horizontal closed- or open-chain

Fig. 4. Integrated diagonal trunk rotation/scapular retraction.

exercises at faster speeds increased the activation to 27% and 34% MVC respectively. This progression may be used as a template to structure exercises that gradually increase the demand on the healing cuff. Final progressions can be open-chain plyometric type exercises. Isolated rotator cuff exercises using rubber tubing or other resistance in specific arm positions may be done at the end of the rehabilitation sequence.

Clinical application—surgically repaired rotator cuff tendinopathy

Protection of the healing tendon from excessive tensile or shear load is the prominent factor in the early rehabilitation stages. The length of time for

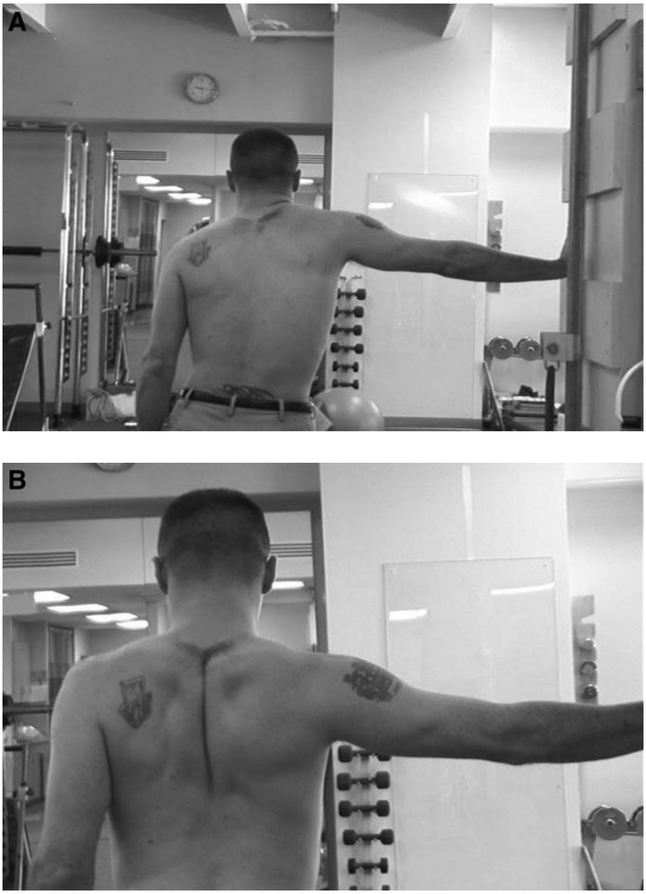

Fig. 5. “Scapular clock” exercises. The hand is stabilized and the scapula may be moved in a closed chain fashion to the points of the clock. (*A*) Elevation to 12:00. (*B*) Retraction to 9:00.

protection varies with the underlying tissue and the type of repair, but usually takes 6 to 10 weeks. Rehabilitation may be performed during this time, however. Emphasis is placed on proximal kinetic chain and scapular rehabilitation, and development of shoulder motion in safe planes.

Most of the kinetic chain and scapular exercises can be performed without inducing shear at the repair. All of the integrated trunk extension/scapular retraction or trunk rotation/scapular retraction exercises can be done while the arm is still in a sling.

Passive and active assisted range-of-motion can be started in the planes below 60° abduction/flexion early in the rehabilitation stages. Closed-chain based rotations, with the hand supported on a ball, allow motion without inducing shear (Fig. 9). An alternative method to achieve rotation is to move the body around the supported hand. The effect at the shoulder to increase motion is the same. Within

Table 1
Range-of-muscle activations for common exercises

Exercise	Activation —% MVC (SD)
Self-assisted elevation	3 (4)
Open-chain pendulum	9 (12)
Horizontal closed-chain, 45°/sec	11 (6)
Stick assisted vertical	13 (17)
Vertical closed-chain	13 (7)
Horizontal open-chain, 45°/sec	15 (9)
Diagonal closed-chain	18 (12)
Diagonal open-chain	22 (11)
Horizontal closed-chain, 100°/sec	27 (17)
Horizontal open-chain, 100°/sec	34 (18)
Scaption—weights	74 (33)

Abbreviations: MVC, maximal voluntary contractions; SD, standard deviation.

2 or 3 weeks, the same supported position at low levels of abduction/flexion can be used to initiate humeral head depression exercises, starting the rotator cuff progressions as previously outlined. Care must be maintained to keep the rotator cuff activation and strain load within the limits imposed by the healing tissue. Using the progression framework outlined in Table 1 can increase the margin of safety.

Prehabilitation

Completion of rehabilitation of rotator cuff tendinopathy requires fulfillment of specific criteria regarding healing, range-of-motion, strength, and kinetic chain restoration [15,19]. Frequently the patient will then return to the same activity or

Fig. 6. Horizontal closed-chain exercise. The arm slides along a board or other support.

Fig. 7. Vertical closed-chain exercise.

sport that created the injurious stresses, however, thereby placing himself at some increased risk for repeat injury. Because the exact nature of the stresses operating in rotator cuff tendinopathy is not completely known, the best strategies for prevention are based on empirical protocols that attempt to understand the inherent demands of the sport or activity, and then devise a maintenance exercise program to maximize the body's ability to withstand those demands [20]. The specific flexibility, strength, power, anaerobic, and aerobic demands can then be matched with specific exercise programs. Examples include trunk/hip strengthening and continued rotational flexibility exercises for baseball pitchers and tennis players, scapular stabilization exercises in workers who continually use

Fig. 8. Diagonal closed-chain exercise.

Fig. 9. Closed-chain “Codman” exercises, rotations with the hand supported.

their arms extended in front or overhead, and isolated mild rotator-cuff strength exercises in older patients.

Summary

Rehabilitation of the dysfunction that is associated with rotator cuff tendinopathy should be based on the evidence known about the pathoetiology of the tendinopathy, what is known about the extent of the local anatomic injury, the local and distant physiological and biomechanical alterations, and on the knowledge developed regarding progressive loading of the injured or altered structures. Prehabilitation, or prospective exercises to minimize future rotator cuff loading stresses, should be included at the end of rehabilitation as part of the return to function.

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