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CLINICAL COMMENTARY

REHABILITATION FOLLOWING SUBSCAPULARIS TENDON REPAIR

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ABSTRACT

Subscapularis (SSC) tendon tears are less common than tears of the remaining rotator cuff tendons, but one with serious consequences given its function as one of the main internal rotators and anterior stabilizers. Mild fraying involving the upper third of the tendon can be treated non-operatively; however, more substantive tears usually require repair in cases of pain or functional impairment. Given the importance of the subscapularis tendon in maintaining stability of the glenohumeral joint and performing internal rotation of the arm, surgical intervention with emphasis on repair may be recommended to eliminate pain and restore strength. Postoperative rehabilitation through phased progression is utilized to avoid premature stress on the healing tissue while enabling early return to daily activities. The purpose of this clinical commentary is to provide an evidence-based description of postoperative rehabilitation following SSC tendon repair with guidance for safe and effective return to activity and sports.

Level of Evidence: 5

Key words: Repair, Return to sport, Shoulder, Subscapularis tear

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INTRODUCTION

The subscapularis (SSC) tendon forms the anterior section of the rotator cuff (RC) and its muscle is the largest and most powerful rotator cuff muscle. The upper 60% of the insertion is tendinous and the lower 40% consists of muscle. The SSC is one of the most important anterior stabilizers of the glenohumeral joint. It balances the force couple in the horizontal and frontal planes. Moreover, SSC functions mainly as an internal rotator, whereas its superior fibers assist in abducting the arm and its inferior fibers help in adducting it.[1] Tears of the SSC tendon are less common than tears of the remaining rotator cuff tendons. The prevalence of SSC tears was reported to range from 31.4%[2] to 37%[3] in patients who underwent arthroscopic rotator cuff surgery. The majority of subscapularis tendon tears are degenerative in origin, however some result from trauma following an anterior shoulder dislocation or more commonly following violent external rotation force such as in a motor vehicle accident. Tear and dislocation of the long head of the biceps is very common in conjunction with subscapularis tendon rupture because of the loss of its medial constraint as the pulley tears.[4] Classification of SSC tendon lesions has been described by Fox and Romeo[5] along with Lafosse et al.[6] Surgical repair is often advocated for full-thickness tendon lesions. The size of the tear, tendon tissue quality, muscle fatty degeneration and chronicity of the condition can have drastic effects on the outcome of these repairs. Moreover, subcoracoid impingement can cause a "roller-wringer effect" on the SSC tendon and contribute to the pathogenesis of SSC tears.[7] Thus, the senior author performs a subcoracoid decompression simultaneously with SSC repair.

Literature focusing on rehabilitation following SSC tendon repairs with attention to return to sport is limited. This paper will discuss the recommended rehabilitation guidelines following repair of full-thickness upper 1/3 SSC tears versus extensive SSC tears all the way down to the direct muscular insertion. The purpose of this clinical commentary is to provide an evidence-based description of postoperative rehabilitation following SSC tendon repair with guidance for safe and effective return to activity and sports.

Biomechanics

As the most powerful rotator cuff muscle, the SSC contributes to 53% of the cuff moment. The force-generating capacity is equal to that of the other three muscles combined.[8] A tear or rupture of the subscapularis muscle may manifest as pain, weakness with internal rotation (IR) and increased passive motion with external rotation (ER) or anterior glenohumeral instability. Superior and midsuperior portions of the SSC were shown to have significantly higher stiffness compared to the inferior region both in hanging arm and 60° of abduction. They concluded that higher stiffness and ultimate load in the superior tendon region may explain the extension of rotator cuff tears into the SSC tendon.[1]

Clinical examination

The integrity of the SSC can be assessed with the belly-press, lift-off, modified lift-off, bear-hug tests and belly off sign.[9–11] The belly-press test was described by Gerber et al. and is performed with the arm at the side with elbow flexed to 90° and the palm held against the stomach.[12,13] Next, the patient is asked to push their palm toward their abdomen while the examiner pulls in the opposite direction. A positive test is denoted by an inability of the patient to resist or by compensation through wrist flexion and/or arm extension. Moreover, a combination of shoulder extension and adduction due to compensation through latissimus and pectoralis major activation may be seen. The lift-off test is performed with the dorsal surface of the hand being positioned on the lumbar spine.[12] The patient is asked to internally rotate the shoulder by lifting their hand off the lumbar spine. A positive test is denoted by inability to lift the dorsum of the hand or by compensation through elbow and/or shoulder extension. The modified lift-off test is performed with the patient's arm maximally internally rotated and extended behind the back with the hand 5 to 10 cm from the skin, followed by the release of the arm. The test is considered positive when the hand lands on the back.[11] This is also considered the IR lag sign. The bear-hug test utilizes resisted IR as the palm is held on the opposite shoulder while the elbow is held in a position of maximal anterior translation.[10] With the belly off sign, the arm of the patient is passively brought into flexion and maximum IR with 90° of elbow flexion. The belly off sign occurs if the patient cannot maintain this position and flexes the wrist or a lag occurs.[9]

Surgical Management

The repair of the torn SSC tendon involves reattachment to the anatomical footprint on the lesser tuberosity with suture anchors, which can be done arthroscopically or via an open surgical approach. The technique utilized by the senior author has been previously published by Katthagen et al.[14] All procedures are performed with the patient in the beach-chair position under general anesthesia with an interscalene nerve block. Following standard diagnostic arthroscopy and confirming the size of the SSC tear, subcoracoid soft tissue decompression is performed along with release of any adhesions around the torn tendon. For partial tears, a knotless repair technique is preferred. To facilitate this, a spinal needle is placed percutaneously through the tear and a polydioxanone suture (PDS) is shuttled out through an anterior-superior portal. Next, a suture tape (FiberTape, Arthrex) is passed through the tear. After preparing the anatomic SSC footprint with a shaver to create a bleeding bone bed and tapping, the suture tape is passed through a bioabsorbable anchor (4.75 Bio SwiveLock, Arthrex). The anchor is then inserted in the lesser tuberosity and the tendon is secured back to the bone.[14]

In full-thickness SSC tears that involve the tendinous portion, the senior author prefers to perform an arthroscopic repair in a double-row, linked, knotless, bridging technique (SpeedBridge, Arthrex, Naples, FL). The SSC is visualized arthroscopically after a subcoracoid decompression. After mobilization of the tendon stump and debridement of the tendon footprint on the humerus to a bleeding surface, medial anchors are placed approximately 1 mm from the articular margin. The suture tapes are then passed through the SSC tendon. The SSC tendon is compressed onto the footprint and the lateral anchors are secured.[14] The arm is then taken through a range of motion to confirm that the SSC is secure and stable, and has appropriate tension. For massive tears that involve the direct muscular insertion or for chronic retracted tears, an open deltopectoral approach can be used.

In all cases of SSC tear and whenever the biceps pulley is disrupted, a biceps tenodesis is performed. The biceps is released arthroscopically and a subpectoral biceps tenodesis is performed with an interference screw.[15] Concomitant pathology of the long head of the biceps (LHB) is common in SSC tendon lesions.[16] Tahal et al. demonstrated that subpectoral biceps tenodesis is an excellent treatment option for active patients with LHB tenosynovitis and chronic anterior shoulder pain, resulting in decreased pain, improved function, high satisfaction, and improved quality of life.[17] Thus this is our preferred treatment option for LHB pathology. Immediately after the operation, the shoulder is immobilized in a sling. Early passive ROM is started with a limitation of 30° ER. Since a concomitant LHB tenodesis is performed whenever the SSC is repaired, resisted elbow flexion should be avoided for 6 weeks.[15] Moreover, resisted supination should also be avoided to minimize overall stress to the biceps.

Clinical outcome

Seppel et al. investigated the long-term results of arthroscopic repair of isolated SSC tears, reporting significant clinical improvements and enduring tendon integrity. The SSC strength remains reduced in the long term, however, 88.2% of patients were "very satisfied" or "satisfied" with their results.[18] In an earlier study, Adams and colleagues reported results of arthroscopic SSC repairs at a median follow-up of five years, finding 80% (32 of 40) of patients had a good or excellent result after an arthroscopic STR.[19] Recently, Katthagen et al. reviewed the senior author's (PJM) patient outcomes and demonstrated improved outcomes with high patient satisfaction following arthroscopic single-anchor repair of upper third SSC tears in 31 patients with a mean follow-up of 4.1 years. They reported more favorable outcomes following repair of full-thickness upper third SSC tears compared with high grade partial-thickness upper third SSC tears.[14]

GUIDELINES FOR REHABILITATION

A successful outcome following SSC repair surgery is a pain-free and stable shoulder that has sufficient mobility, stability and strength for a patient's desired level of activity and participation. Postoperative rehabilitation is tailored to the individual according to a criteria and functional based progression taking into account healing time lines, the attainment of specific clinical goals and in conjunction with the recommendations of the referring physician. Healing phases include the inflammatory phase, proliferation (repair) phase and remodeling phase. The overall aim of rehabilitation is centered on the principle of gradual application of controlled stresses to the shoulder with consideration of the healing phases in order to optimize patient outcome.[20]

Literature to support the efficacy of a specific rehabilitation protocol for SSC repair is limited. Rehabilitation following SSC repair is dependent on the extent of the lesion and will vary regarding whether the repair involves a full-thickness tear of the upper 1/3 of the tendon versus repair of the entire tendon all the way down to the direct muscular insertion. Clinicians, surgeons and physical therapists must have a working knowledge of the anatomy and kinematics of the shoulder complex, underlying pathophysiology, principles of tendon healing and the specific attributes and limitations of selected treatment interventions and need to select treatment strategies accordingly to achieve an optimal outcome. Time-based and performance-based criterions need to be united, with milestones for each being met prior to progression to the next phase. Millett et al. emphasized the importance of an evaluation-based rehabilitation protocol which takes into account not only healing time times but also the attainment of specific clinical goals.[21,22] Criterion to progress through each phase of rehabilitation are proposed by merging time-based and performance-based principles. This respects the biology and temporal aspects of healing while at the same time necessitate that functional goals be accomplished prior to progression to the next phase of rehabilitation. Such a program allows the patient to achieve a strong foundation in mobility, endurance and strength before returning to unrestricted activity or sport performance. Suggested guidelines for rehabilitation following repair of full-thickness upper 1/3 and extensive SSC tears were developed based on the current literature, best available evidence and professional expertise. This should provide clinicians who treat these injuries with guidelines to enhance rehabilitation following surgery.

The rehabilitation program is divided into five phases. The underlying pathology, integrity of the repair and the biology of healing along with the desired level of activity will determine the speed of progression through all five phases.

Phase I is the maximal protection phase involving immobilization with only passive exercises that minimize loads across the repair. The muscular endurance phase, Phase II, consists of the introduction of active exercises, which gradually apply load to the repair and begin to transfer loads back onto the healing tissues. Phase III focuses on muscular strength, incorporating resistive exercises to further apply controlled stress to the tissues. If the individual does not require advanced or power movements for their activities of daily living (ADL), occupational or sport preferences, meeting Phase III goals could result in the completion of rehabilitation. If the individual has high physical demands from their occupational or sport needs progressing through the power Phase IV and/or Phase V return to sport may be necessary.

PHASE I: PROTECTION PHASE

The goals of this phase of rehabilitation are to maximally protect the surgical reconstruction, optimize the environment for tissue healing, decrease pain and inflammation, restore passive mobility to minimize stiffness (being mindful to not exceed ER limits), and pain free restricted ADL with use of a sling. These goals must be addressed without causing inappropriate stress to the healing structures.

Good communication between the physical therapist, patient, and surgeon is essential at this phase and helps direct the course of rehabilitation. Patient related factors, such as prior surgery, smoking and comorbidities negatively influence tendon healing, rehabilitation and ultimately clinical outcomes. Each variable should be considered when formulating a postoperative therapy plan, which should be tailored to each individual case. Patient education to convey the rationale of the outlined rehabilitation protocol and the importance of protecting the healing tissues from excessive stress is critical to ensure compliance.

Protection

In order to reduce strain on the repair, the shoulder is protected for four weeks. This is achieved by using an abduction sling during the day and at night. The authors suggest protecting the arm in slight abduction to promote optimal blood flow and minimize tension to the repair.[22] Patients are allowed waist level activity in the sling (i.e. keyboarding) as tolerated. Gurney et al. evaluated electromyographic (EMG) activity of the shoulder during commonly performed tasks such as ambulation, donning/doffing a sling and other movements. The authors demonstrated that rehabilitation tasks such as pendulum exercises, passive range of motion performed by a physical therapist, and self-ranging motion with a dowel showed low EMG activity, whereas ambulation without a sling, donning/doffing a sling and pulleys in the sagittal and scapular plane showed greater activity.[23] These findings indicate caution is needed following STR when donning/doffing a sling and highlights the importance of wearing the sling during ambulation.

Cryotherapy

Continuous cryotherapy has been shown to cause a significant reduction of both glenohumeral joint and subacromial space temperatures in the shoulder at variable times during the first 23 postoperative hours.[24] Cryotherapy should be used during this phase to control pain, decrease swelling and muscle spasm, suppress the inflammatory response and improve sleep patterns.

Range of motion

Active hand, wrist and elbow range of motion should be part of a home exercise program. The authors encourage early passive ROM exercises for the glenohumeral joint. Keener et al. could not show an apparent advantage or disadvantage of early passive range of motion (PROM) compared with immobilization in a prospective randomized trial following arthroscopic rotator cuff repair.[25] It has been shown that continuous passive motion properly applied (at the knee and elbow) during the first two stages of stiffness (bleeding and edema) following surgery acts to pump blood and edema fluid away from the joint and periarticular tissues. This allows maintenance of normal periarticular soft tissue compliance.[26] Early ROM prevents adhesions and when the repair is secure and tissue quality is good, early PROM is allowed. ER is typically limited to avoid undue loading on the nascent SSC repair.

Immediately following surgery, the repair is reliant on the mechanical strength of the sutures and anchors. Therefore, active motion of the shoulder joint at this time would overly stress the healing tissues. In these cases, a gradual progression of PROM over four weeks is recommended. However, with the shoulder at 0° abduction, passive glenohumeral ER movement past 30° stresses the anterior capsule as well as the SSC muscle and is not recommended following repair of a SSC tendon tear for three weeks. For a massive tear, with very poor quality tissue or undue tension on the repair, the authors sometimes limit ER to neutral for several weeks to avoid stressing the repair. Following SSC repair, passive internal rotation should be restricted to belt line for the first four weeks.

Scapula

For the first two weeks following repair of a large full thickness tear of the SSC, excessive scapular mobility can stress the repair and should be avoided. After two weeks or initially following upper 1/3 SSC repairs, scapular mobility exercises can be incorporated. Normal active scapular movement (protraction, retraction, elevation and depression) helps to facilitate early neuromuscular control of the scapula. The side-lying scapular clock exercise is a great starting point for this with progression to sitting or standing with the sling on.

Isometrics

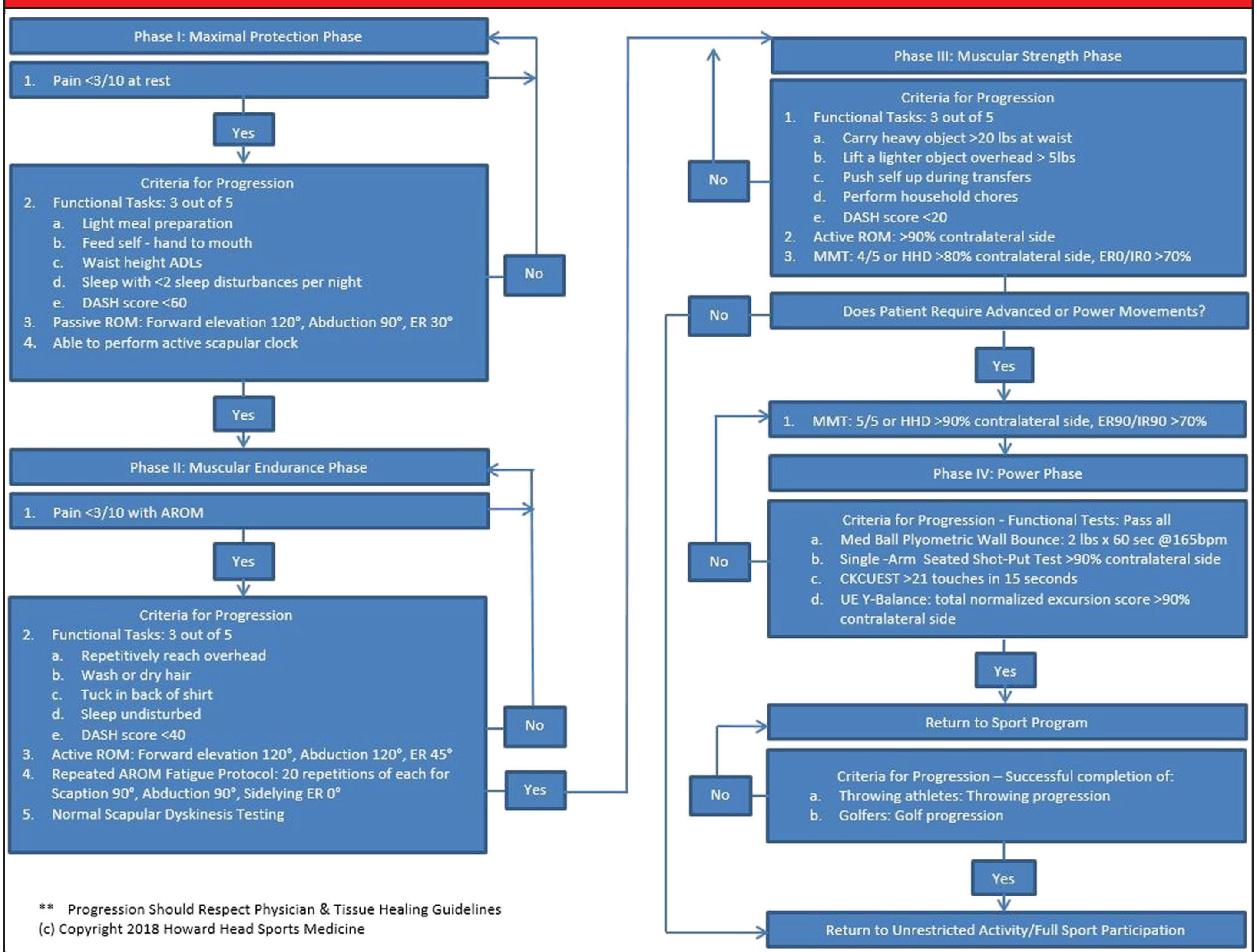
To protect the repair from shear or compressive forces, no isometric exercises should be performed during weeks 0-3 following repair of extensive SSC tears and weeks 0-2 following upper 1/3 SSC repair. After this time isometric exercises of the muscles surrounding the shoulder girdle can be initiated. These should be submaximal and non-painful, with the shoulder in a neutral position. Rhythmic stabilization, involving gentle manual resistance to the proximal forearm using oscillating perturbation in a neutral shoulder position, is appropriate to facilitate low contraction of the scapular and rotator cuff musculature and can be beneficial for early neuromuscular re-education.

Manual therapy
Manual therapy during this phase should consist of soft-tissue techniques and PROM. Soft tissue techniques initially include lymphatic drainage to assist with swelling reduction and later include myofascial release techniques of the upper quarter and portal scar mobilization techniques. Glenohumeral mobility is not assessed due to healing structures and post-surgical precautions since anterior humeral glide could put excessive strain on the repaired SSC.

Kinetic chain exercises
Addressing the kinetic chain early in rehabilitation will benefit the patient long term, therefore breathing and basic core exercises should be incorporated at this stage of rehabilitation. Core exercises in a hook-lying position with the sling on, with focus on lower extremity movement will ensure the surgical reconstruction is safe and not stressed. Stationary recumbent bike should be encouraged in order for the patient to maintain cardiovascular conditioning, enhance blood flow to healing tissues and for mental health benefits.[27]

The criterion to progress to the next phase of rehabilitation is outlined in Table 1. The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire may be used as a criterion to progression as well.[28] In addition to this, it is important to work with the individual surgeon to elicit their preferred time frames for progression and to understand their rationale in deciding ROM restrictions.

Table 1. *Subscapularis Tendon Repair Progression Criteria Algorithm.*



PHASE II: MUSCULAR ENDURANCE

The primary goals of this phase are careful progression to full active ROM (AROM), improvement of muscular endurance and neuromuscular control of the shoulder complex. In addition, normal use of the involved extremity for ADLs should be achieved by the end of this phase with the exception of no overhead lifting, fast-jerking motions or repetitive activities.

During this phase the sling is discontinued and ROM progressed to include active-assisted ROM (AAROM) and AROM. PROM and light stretching should be continued as needed until full PROM is achieved. If deficits remain, low load, long duration stretching and joint mobilization can be utilized at 5-6 weeks postoperatively. Isotonic exercises should focus on high repetitions with low to no resistance. Gravity alone for resistance is often sufficient at this time. Individuals following repairs of smaller upper 1/3 SSC tears will usually move into this phase a week sooner than those with larger or more extensive tears due to the earlier timeframe for initiating AROM.

AAROM is initiated one week prior to commencing AROM, as it is important to gradually apply load without overstressing the healing structures during this phase. Equipment such as a foam roller and stability ball can be utilized to allow patient to progress AAROM, as maintaining low muscle activation of the SSC following repair is important. Previous literature have used EMG studies to guide postoperative rehabilitation progression in the RC following surgery with 15% MVIC considered as an upper limit of a safe loading range during exercises in the early motion stages following repair. Table slides, pulley-assisted elevation, seated row, wall-assisted ER have all been shown to have a MVIC of 15% or less.[29] Patients may have significant deficits in ER mobility due to post-operative restrictions; utilizing a bar to progress ER AAROM in supine is encouraged.

Once the patient exhibits effective isometric muscle contraction as well as fair muscle activation with AAROM, the initiation of AROM can commence. ROM can be performed in supine, side-lying or prone positions to reduce the effects of gravity, progressing to a standing position as endurance improves. For example, progression of shoulder abduction would commence with supine, slide board AAROM with a bar (Figure 1), to side-lying shoulder abduction adding rhythmic stabilization to aid with neuromuscular control (Figure 2), advancing to prone T's (horizontal abduction) (Figure 3) and standing abduction/adduction against a wall with a focus on scapular control.

It is vital to incorporate ROM exercises that enhance scapular control during this phase. A synchronized contribution from scapular musculature is essential for optimal positioning, stability and functioning of the shoulder complex. The upper (UT), middle (MT) and lower trapezius (LT) muscles and the serratus anterior muscle are the greatest contributors to scapular stability and mobility.[30] It is clinically important to enhance the LT/UT and MT/UT activation ratios as a dominant UT has been linked to shoulder pathologies due to contributions of poor posture and muscle imbalances.[31] Particular exercises which have been shown via EMG studies to accentuate periscapular control while minimizing UT muscle activation are side-lying ER, side-lying

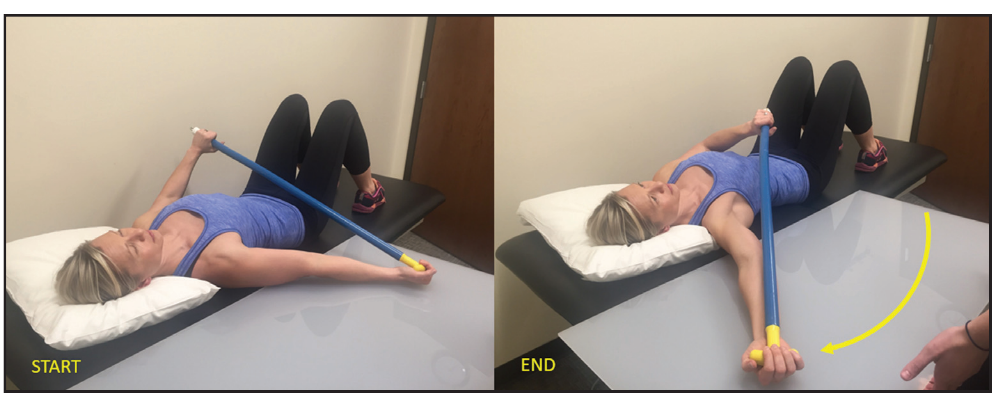


Figure 1. *Supine active-assisted range of motion abduction on slide board with bar.*

Figure 2. *a, b) Sidelying abduction c) Rhythmic stabilization.*

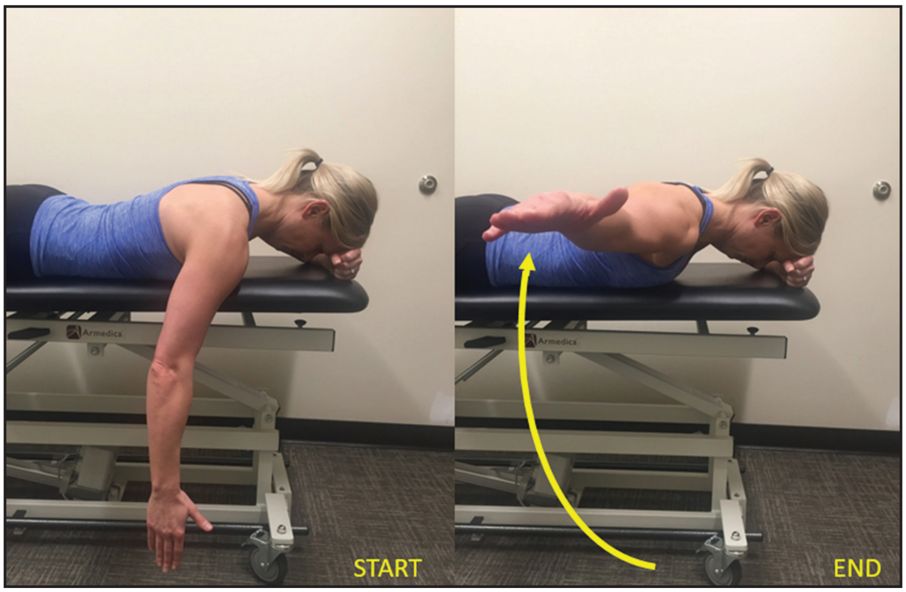


Figure 3. *Prone horizontal abduction (T's).*

forward flexion, prone horizontal abduction with ER, prone flexion and prone extension.[31–33] These activate key scapular stabilizing muscles without placing high demands on the shoulder joint.

Functional stability of the shoulder is accomplished through passive and active mechanisms. The passive mechanisms include the joint's geometric configuration and the integrated functions of the joint capsule, ligaments and the glenoid labrum. The active mechanisms include the dynamic stabilization of the surrounding musculature and the innervation of those muscles, particularly the rotator cuff musculature.[34] Additionally, the dynamic stabilizers provide stability through an active mechanism referred to as neuromuscular control. Dynamic stability is accomplished through proprioceptive and kinesthetic awareness and efficient muscular activity, which is achieved through the efficiency of several muscular force couples of the shoulder. The SSC and pectoralis musculature work in conjunction with the external rotators to establish the internal/external rotator force couple that functions in concert with the deltoid. Dynamic glenohumeral stability is accomplished by these force couples through joint compression, ligament tension and proficient neuromuscular control. An essential goal of therapeutic exercise should be directed towards enhancing neuromuscular control and thus improving dynamic functional stability of the glenohumeral joint.[35]

As ROM targets are met, the focus of rehabilitation can shift to neuromuscular retraining. The neuromuscular training must provide a stepwise increase in muscular demand in order to protect the healing structures and also prevent abnormal movement patterns from developing. Rhythmic stabilization at various angles and diagonal proprioceptive neuromuscular facilitation patterns can be initiated to help gain stability and control into functional patterns. Open chain scapular exercises, such as supine serratus punch/plus can help establish proper scapula-thoracic force couples and improve neuromuscular endurance with AROM. Loaded closed chain exercises are not appropriate during this phase as these can create too much compressive joint stress and negatively affect the surgical repair.[36] Unloaded closed kinetic chain scapular exercises such as wall slides (Figure 4) or wall plus, can be initiated cautiously at this time. Loaded closed chain scapular exercises should be initiated in Phase III in order to allow sufficient time to develop proper dynamic stability prior to initiation of compressive forces of the glenohumeral joint.

This phase of rehabilitation can potentially require a significant amount of time to properly retrain the rotator cuff and periscapular musculature. Before progressing into Phase III of rehabilitation the patient needs to achieve adequate PROM as well as non-compensated shoulder and scapulothoracic AROM (see Table 1).

PHASE III: MUSCULAR STRENGTH

Following establishment of good muscle activation and endurance in Phase II, the main goal of Phase III is to improve strength by increasing resistance and reducing repetitions, to advance muscular endurance and dynamic stability exercises. This can be done through a periodization format to load the repair and stimulate healthy remodeling. It is recommended initial strengthening does not commence prior to 6 weeks postoperatively and advanced strengthening is delayed until 10 weeks postoperatively. Iannotti et al. could show in a prospective imaging study that re-tears primarily occurred between six and twenty-six weeks after arthroscopic rotator cuff repair thus underlining the importance of this recovery phase.[37] As this is a criterion-based progression, individuals should not start this phase until Phase II goals are met, therefore a significant variability between when individuals start strengthening may exist.

A strengthening program for the entire shoulder girdle is employed, with focus on rotator cuff and periscapular musculature. Initially the non-resisted exercises previously described in Phase II are implemented with the addition of resistance. Dumbbells, elastic cords (Figure 5), cable machines, barbell weights and manual resistance including perturbation can be incorporated to these exercises to make them more challenging. The focus should be on controlled concentric and eccentric contractions. Initial strengthening exercises should be chosen which have been shown to have EMG activation of 21-50% MVIC. Specifically for the SSC this includes upright bar assisted elevation, forward punch and IR at 0° abduction.[29]

During the late strengthening phase EMG activation of >50% MVIC can be initiated. These include IR at 45° abduction, ER at 0° and 90° abduction; dynamic hug; diagonal; IR at 90° abduction; low row, high row, resisted shoulder extension; resisted active elevation/flexion.[29] (Figure 6)

Figure 4. *Wall slides with foam roller (No load).*

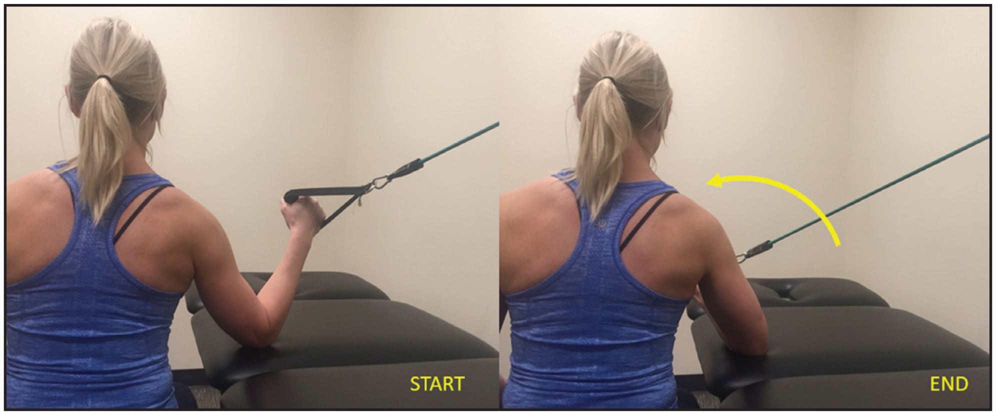


Figure 5. *Internal rotation at 45o with elbow supported on table using sport cord.*

Figure 6. *Dynamic hug with sport cord.*

The balance between external and internal rotation (ER/IR) strength is important to normal glenohumeral joint function. An adequate external-internal rotator muscle strength ratio has been emphasized in the literature with a minimum of 65% and optimally between 66% and 75%.[35,38] Increased EMG activity of the SSC with internal rotation at 90° abduction (IR90) has been reported compared to 0° abduction (IR0).[39] Previous studies have recommended SSC strengthening exercises in adducted positions;[40] conversely Alizadehkhaiyat et al. found significantly higher activation of SSC along with low-to-moderate activation of pectoralis major, latissimus dorsi and teres major in IR90, indicating a preference of this exercise for selective SSC activation.[39] This finding is in line with Decker et al. who demonstrated higher levels of pectoralis major and latissimus dorsi activation at IR0 compared to IR90, and suggested IR90 would be more beneficial in strengthening SSC due to minimizing the contributions of larger muscle groups.[41]

Initially, closed chain body weight exercises are performed as isometric or static exercises, which can be progressed to increase weight bearing through the upper extremities.[36] Advancing from wall to tabletop or to quadruped position creates a gradual increase in loading and is excellent for scapular control. Some examples include push up with a plus, which has demonstrated high EMG activity for SSC;[41] and quadruped upper extremity and lower extremity reaches, which additionally challenges core stability. Placing an unstable base under the upper limbs such as a stability ball or BOSU®, enhances neuromuscular control at a reflex level while the altering perturbation will challenge proprioception and improves joint position sense.[42] Light impact activities (jogging) can be included at the end of this phase.

Strength testing periodically throughout this phase is important in order to identify specific muscular deficits and focus exercise prescription accordingly. Handheld dynamometry (HHD) offers an accurate

Figure 7. *Handheld dynamometer (HHD) testing – Belly press.*

Figure 8. *Handheld dynamometer (HHD) testing – Internal rotation at 90˚.*

means of assessing muscle strength. Kokmeyer et al. promoted the use of a HHD to determine a Limb Symmetry Index (LSI).[43] (Figures 7 & 8) This study suggested a 90% strength index or greater being a good baseline goal, when evaluating an athlete's readiness to return to sport (RTS). The criteria to progress to Phase IV requires the athlete to have a LSI of 80% or greater with ER/IR ratio to be >70%. HHD tests isometric muscular strength and should be utilized in various positions in order to test all rotator cuff musculature, specifically testing at ER0, IR0, ER90, IR90, abduction and scaption at 90˚. For clinical evaluation, both the belly-press and lift-off tests are valid and specific for evaluation of the SSC. The belly-press test was found to activate the upper SSC muscle significantly more than the lift-off test, whereas the lift-off test was found to pose a significantly greater challenge to the lower SSC muscle than the belly-press test.[44] In addition to strength goals, individuals should have active ROM of >90% of contralateral side and achieve three out of the five tasks described in Table 1. If the individual has occupational or athletic demands that require power movements or overhead strength, they will advance to Phase IV of the rehabilitation program. Otherwise once these goals are achieved they can be discharged from therapy with a home exercise program.

PHASE IV: POWER PHASE

The main goals for this phase are to incorporate speed, explosive strength and introduce patterns of movement biased towards the individuals' specific sporting or occupational demands. It is the role of the physical therapist to continue to develop and individualize the patient's program. Repetition, speed and load may be varied in relation to the desired task, facilitating feed forward processing.[45]

Plyometric exercises are an excellent, functional method for an individual to increase power, endurance and stability of the RC and activation of the periscapular musculature.[46] Plyometric exercises should focus on the SSC muscle combined with trunk stabilization. Starting with double upper extremity plyometric exercises, such as slams to the ground, overhead throws against a wall and side throws against a wall (Figure 9). Progressing to single upper extremity plyometric exercises as power, strength and ability permit. These exercises can be performed with 90˚ of glenohumeral joint abduction which prepares the athlete for a return to the demands of overhead function and has been shown to improve IR/ER strength and throwing performance after 8 weeks of training.[47] During the cocking phase of throwing, the SSC contracts eccentrically to decelerate ER and protects the anterior and inferior structures of the glenohumeral joint. The acceleration phase is very explosive and requires the SSC to concentrically contract. Single arm plyometric exercises include IR wall dribbles, IR throws against a trampoline and supine 90/90 IR ball toss using a light handheld medicine ball).

Figure 9. *A) Side throw against wall with medicine ball (start) B) Side throw against wall with medicine ball (finish).*

Closed chain exercises are progressed in this phase to prepare the individual for return to sport requirements. Suspension training, such as the TRX® system has been shown to produce greater activation in both upper limb and anterior trunk muscles when performing a sling based push up versus a ground push up.[48] To progress weight bearing further and increase load through the shoulder complex, the feet can be suspended in the straps while performing a ground push up. Moving to Phase V of rehabilitation requires the athlete to have no pain, ROM deficits or scapular dyskinesis. A limited selection of functional tests has been identified in the literature for evaluating the readiness of an athlete to RTS. The most appropriate test, reflective of the demands of the athlete's specific sport should be utilized and successfully passed before progressing to Phase V. These tests include single-arm seated shot-put test, upper Extremity Y-Balance test (UEYBT), closed kinetic chain upper extremity stability test (CKCUEST) and plyometric medicine ball wall exercises.[49–51]

PHASE V: RETURN TO SPORT

The goal of this phase is to successfully return the athlete to full sports participation without compensation, risk of re-injury or dysfunctional movement patterns. Loading is progressed towards normal participation levels by increasing volume and intensity.

It is advised that clinical testing and sport-specific testing are undertaken prior to releasing athlete to full play. This includes meeting all mobility and strength based criteria in addition to sport specific tests, such as simulated sporting activity, performing in sport practice, playing at a lower level and the player feeling ready and confident.[52] Moreover, it should be considered that the SSC plays an important role during the late cocking and acceleration phase of throwing.[53] Thus, special attention should be paid to this phase of throwing during sport-specific rehabilitation. A slow re-introduction back into the sport, using irritability as a guide to his or her progression is also recommended.

CONCLUSION

The purpose of this clinical commentary was to present a detailed rehabilitation protocol for use following SSC repair. The success of SSC repair depends on appropriate rehabilitation, proper surgical technique and consideration of other procedures performed. The graded application of stress to the healing tissues guides the therapy. This rehabilitation program advances through five phases with objective criterion requirements in order to progress to the next phase. Phase I focuses on protection of the repair and initiation of passive ROM. Phase II advances active assisted and active ROM as tolerated with a focus on endurance and performance of movement without compensation. Phase III progresses muscular strength by incorporating bands, cords, dumbbells and manual resistance as necessary. Phase IV starts to prepare the individual for return to activity or occupational demands by addressing power, agility and speed. Phase V focuses on returning the athlete back to pre-injury sporting levels. The ultimate goal of rehabilitation is to maximize the patient's ability to return to full ADL, work and recreational activities. The criterion for progression through each phase is based on both functional and objective markers with consideration to tissue healing time frames. The current review has blended current literature and expert opinion to inform the development of the rehabilitation guidelines following SSC repair.

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