NONOPERATIVE TREATMENT FOR INJURIES TO THE IN-SEASON THROWING SHOULDER: A CURRENT CONCEPTS REVIEW WITH CLINICAL COMMENTARY

Michael A. Stone, MD¹

Omid Jalali, BS¹

Ram K. Alluri, MD¹

Paul R. Diaz, MA, ATC²

Reza Omid, MD¹

Seth C. Gamradt, MD¹

James E. Tibone, MD¹

Erik N. Mayer, MD¹

Alexander Weber, MD¹

ABSTRACT

Repetitive overhead throwing generates tremendous demands on the shoulder joint of the overhead athlete. Clinicians, therapists, and medical staff are charged with optimizing a throwing athlete's shoulder mobility and stability to maximize performance and prevent injury. Modifiable risk factors such as strength asymmetry, glenohumeral range of motion deficits, and scapulothoracic joint abnormalities contribute to the overhead athlete's predisposition to shoulder injury. Most shoulder injuries in the overhead thrower can be successfully treated nonoperatively to allow in-season return to sport. The optimal rehabilitation program must be based on an accurate evaluation of historical and physical information as well as diagnostic imaging. Return to play decisions should be individualized and should weigh subjective assessments along with objective measurements of range of motion, strength, and function. The purpose of this clinical commentary is to summarize the current literature regarding the nonoperative treatment options for these common injuries, and to present a treatment plan to safely return these athletes to the field of play.

Level of evidence: 5

Key words: Internal impingement syndrome, plyometric exercise, rehabilitation, shoulder, throwing shoulder

¹ Department of Orthopaedic Surgery, Keck School of Medicine of the University of Southern California, Los Angeles, CA, USA

² Department of Athletic Medicine, University of Southern California, Los Angeles, CA, USA

Disclosures: conflict of interest statement

None of the authors have any relevant financial disclosures related to the content of this work.

CORRESPONDING AUTHOR

Michael A. Stone, MD

1200 N. State St

CT-A7D

Phone: (323) 226-7204

E-mail: michaelstone55@gmail.com

BACKGROUND AND PURPOSE

Repetitive overhead throwing generates tremendous demands on the glenohumeral joint at extremely high angular velocities. Shoulder torque during pitching movements can result in moments in excess of 7500 degrees/sec.¹ These extreme stresses must be balanced by adequate stability in the shoulder girdle to allow an athlete to compete throughout the course of a season. Increased incidence of shoulder pathology has been well documented in overhead athletes as compared to non-throwing athletes.² Conte et al. reported that 28% of all injuries sustained to professional baseball pitchers occur within the shoulder.³ The most frequently encountered shoulder injuries relate to pathology of the rotator cuff, the biceps-labral complex, and the shoulder capsule.⁴ Most of these injuries can be treated nonoperatively, and an optimal rehabilitation protocol should seek to balance minimizing time lost to injury while preserving long-term healing and preventing reinjury or compensatory pathology. In professional athletics especially, successfully returning to sport participation while still in season can have enormous effects on player salaries, contracts, and organizational/team success. The purpose of this clinical commentary is to summarize the current literature regarding the nonoperative treatment options for these common injuries, and to present a treatment plan to safely return these athletes to the field of play.

PRINCIPLES OF TREATMENT

The optimal rehabilitation program must be based on findings from the medical history, physical examination, and diagnostic imaging when appropriate. Optimally, the medical professional should also evaluate the isokinetic profile and throwing mechanics to discern the cause of decreased performance and pain.⁵ To achieve this, Wilk et al. described the evaluation broken down into the osseous structures, capsular structures, and muscular structures of the shoulder joint complex.⁶ For example, there may be osseous adaptations (increased retroversion), posterior musculature tightness, posterior capsular tightness, and even altered scapular position. The complex interplay of these three elements in overhead throwing athletes can lead to motion adaptations that may differ from the normal population. Once the offending pathology is identified, the rehabilitation program must be multi-phased

and sequential. Each phase becomes more aggressive and demanding, gradually re-introducing the functional demands of the overhead athlete's sport requirements. A successful rehabilitation program focuses on intermuscular balance, strength, endurance, neuromuscular control, and dynamic stability. Furthermore, a successful program should include attention to all elements of the kinetic chain, from lower body and core strengthening to hip and knee range of motion (ROM).⁷ Successful return to sport relies upon completion of a comprehensive, supervised rehabilitation program with an emphasis on constant communication between the athlete, coaches, and clinicians. Return to play (RTP) decisions should be weighted heavily on subjective measures discerned from this communication, as well as objective measures of ROM, muscular strength, balance, and function.⁸ As always, individual clinical judgment and understanding of the athletic context (demands, time of season, etc.) are encouraged.

PHYSICAL EXAMINATION

A thorough physical examination is an essential component of the evaluation of the thrower's shoulder. If a complete physical examination of the shoulder cannot be performed due to pain and inflammation associated with injury, the examination should be deferred until adequate control of pain and acute inflammation is achieved. Once pain has improved, a thorough physical examination should be conducted focusing on areas of tenderness, ROM deficits, and strength limitations.⁹ Further, the physician, physical therapist, or athletic trainer should look for concomitant pathologies and functional deficits in all segments of the kinetic chain.⁸

Nonoperative Rehabilitation

After a thorough history and physical examination are completed, rehabilitation programs should pay special attention to: (1) rotator cuff strength and endurance abnormalities (isolated and intermuscular balance), (2) correcting ROM deficits, (3) optimizing scapulothoracic joint stabilization and shoulder flexibility, and (4) progressively and systematically re-introducing functional sport-specific stresses on the overhead athlete.⁸ The four phases of nonoperative treatment will be addressed in the following pages, and are summarized in Table 1.

Table 1. Return to throwing (4 phases)

Phases	Benchmark – When to Begin	Goals
Phase 1	Immediately after injury	1. Address acute inflammation/pain 2. Evaluate and normalize ROM deficits 3. Impede muscle atrophy 4. Restore proprioception 5. Begin kinetic chain exercises
Phase 2	Once pain and inflammation diminish, and neuromuscular control and static stability reach adequate levels	1. Re-establish inter-muscular balance in glenohumeral and scapulothoracic joints 2. Continue Phase 1 activities for range of motion, flexibility, and neuromuscular control 3. Further kinetic chain program and start a conditioning program
Phase 3	Athlete has achieved full active and passive ROM, at least 4/5 manual muscle test strength, minimal pain, and symmetrical capsular mobility	1. Initiate aggressive strengthening drills 2. Enhance power and endurance 3. Begin athlete specific functional drills 4. Initiate aggressive kinetic chain and conditioning programs
Phase 4	The athlete completes satisfactory clinical examination; non-painful ROM; satisfactory isokinetic test results; appropriate rehabilitation progress; and completed a successful plyometric program	1. Return functional sport and position specific demands on the athlete
ROM - range of motion		

Phase 1 - Acute Phase

The primary goal of Phase 1 is to address acute inflammation and pain if present. Once this is complete, stretching treatment for shoulder ROM deficits and scapulothoracic joint abnormalities (dyskinesis) can begin. Also, important at the early stages of rehabilitation is attention to the upstream components (legs, core, spine) of the kinetic chain. The key components of Phase 1 of rehabilitation will be outlined in this section.

PAIN/INFLAMMATION

Introduction of an acute subacromial pain stimulus demonstrated a 22.7% decreased infraspinatus electromyography (EMG) activity with a corresponding decrease in external rotation (ER) force of 32.8% in healthy patients.¹⁰ Stackhouse et al. found that experimental subacromial pain elicits a decline in force and activation of the infraspinatus.¹⁰ Although internal impingement is a much more common reason for pain compared to external (subacromial) impingement in the overhead throwing athlete, these findings suggest a relationship between pain and proper

recruitment of rotator cuff muscles. Management of pain is necessary to obtain optimal performance in the throwing motion. During the initial stage of treatment, an athlete may be prescribed oral nonsteroidal anti-inflammatories drugs (NSAIDs) and/or corticosteroid injections.¹¹ For the high-level throwing athlete, steroid injections have demonstrated greater improvement in shoulder function and decreased pain levels, without increased risk of complications at four to six weeks as compared to NSAIDs.¹² Adjuvant treatments for pain relief can be accomplished using ice, low-level laser therapy,¹³ ultrasound, and iontophoresis,^{13,14} however the long-term efficacy of these modalities in the acute phase of rehabilitation has yet to be defined.⁶ There is Level-1 evidence supporting use of continuous cryotherapy as an adjunct to decrease inflammation by reducing intra-articular temperatures, however these studies were performed in the shoulders of patients who had undergone arthroscopic shoulder surgery.^{15,16} After resolution of acute inflammation, moist heat, warm whirlpool, and ultrasound can be used to increase local circulation and soft tissue extensibility of the shoulder joint

complex.¹⁷ Functional stresses and strains placed on the shoulder must be minimized by decreasing sport-specific and non-sport specific workloads.

GLENOHUMERAL INTERNAL ROTATION DEFICIT (GIRD) CORRECTION

Normal internal range of motion in overhead throwing athletes averages anywhere from 36 to 62° in the dominant shoulder and from 42 to 71° in the non-throwing shoulder.^{2,18-23} Several studies have demonstrated that the dominant arm in throwing athletes, as compared to the non-dominant arm, has a significant decrease in internal rotation (IR) at the glenohumeral joint.^{2,3,6} One pathophysiological explanation for the decreased IR is that a compensatory increase in ER is believed to aid in creating maximum velocity during the pitching motion.^{24,25} The resultant increase in ER results in stretching of the anterior capsule and tightening of the posterior capsule, resulting in loss of IR. The significant loss of IR is referred to as glenohumeral internal rotation deficit (GIRD), and is defined as a loss of IR of the throwing shoulder compared to the contralateral non-injured shoulder, and generally is greater than 17°.^{6,26} A study of professional pitchers over three seasons demonstrated higher risk of injury in pitchers with GIRD, as compared to pitchers without GIRD.²⁷ GIRD is associated with glenohumeral instability, internal impingement, articular-sided partial rotator cuff tears, and SLAP lesions.

Alterations in osseous structures as well as posterior shoulder muscular and capsular tightness are hypothesized to contribute to changes in glenohumeral ROM.²⁸ Significant increase in humeral retroversion in the throwing arm is often seen in overhead athletes.¹⁷ The average side-to-side difference is 10 to 15°.²⁹ In an examination of 225 professional pitchers, Noonan et al. demonstrated that pitchers who sustained shoulder injuries had 4° less dominant humeral retrotorsion compared with pitchers without injury, and that pitchers with an elbow injury displayed 5° greater humeral retrotorsion compared with noninjured pitchers. These results suggest that increased adaptive humeral retrotorsion is protective against shoulder injuries, but a harmful contributor for elbow injuries in the overhead athlete.²⁹

The mechanism of posterior shoulder tightness (PST) is not completely clear, though it is speculated

that it is derived from tight posterior muscles, such as posterior deltoid, infraspinatus, and teres minor muscles.²⁸ These muscles experience high eccentric contractions during the IR of the throwing motion to allow for deceleration and follow-through of the arm.²⁰ Some authors suggest that the inflammation and scar formation from repetitive eccentric contractions lead to a rise in passive muscle tension and loss of ROM.³⁰ Many studies have demonstrated the efficacy of stretching to improve PST.^{31,32} A systematic review of randomized controlled trials of stretching techniques suggests the use of active, passive, or muscle energy techniques (MET) in the form of cross-body stretch with or without joint mobilization (Figure 1A), improves PST and GIRD for overhead athletes.^{33,34} Patients without access to the tool depicted in Figure 1A (The Rotater, Joint Mechanix LLC, Salem, AL) or in cases where pain or provocation is caused by this stretch, may accomplish the same stretch using the sleeper stretch (Figure 1B).^{33,35}

Pathogenesis of posterior capsular contracture of the shoulder in the overhead athlete is associated with the follow-through motion in throwing.³⁶ These repetitive forces on the posterior capsule are believed to cause capsular hypertrophy, which limits IR. Further, there is a strong association between GIRD and posterior capsule tightness in patients with internal impingement of the shoulder. If posterior capsular tightness is present, there is also evidence to support the use of sleeper stretches with joint mobilization.^{8,36-38}

The overall treatment of GIRD in Phase 1 includes examining the following deficits: decreased IR, increased ER, posterior muscle and capsular tightness, and determining osseous adaptations. This is followed by aggressive employment of active-assisted ROM, passive ROM, manual stretches, and mobilization techniques to normalize motion. In the author's experience, acceptable levels of IR can be expected to be obtained within about two weeks.

SCAPULAR FLEXIBILITY AND SOFT TISSUE MOBILIZATION

Scapular dyskinesis, or abnormal scapular control due to imbalances of scapular musculature, is associated with shoulder pathology.^{39,40} It is of particular

Figure 1. Cross-body stretch (A) and modified sleeper stretch (B) used to correct GIRD and/or posterior capsular contracture.

concern in the overhead athlete, as scapular dyskinesis was found to have a 28% greater reported prevalence in overhead athletes compared to non-overhead athletes.⁴¹ In overhead athletes, the scapula often appears protracted, depressed, and anteriorly tilted in relation to the contralateral scapula.⁶ An anteriorly tilted scapula with decreased upward rotation is strongly associated with a loss of IR.⁴² Proper scapular muscle balance and flexibility is important to couple movements into upward rotation, posterior tilting, and adequate internal or ER (depending on motion).⁸ This is important to avoid impingement and enhance proximal stability of the shoulder joint complex to allow for greater distal control, avoid instability, and thus prevent injury.

Management of the scapulothoracic joint focuses on restoring flexibility of musculature of the scapula, including the pectoralis minor, levator scapulae, rhomboids, and the posterior capsular structures.⁸ Range of motion of the scapulothoracic joint should

be examined with scapular elevation–depression, upward–downward rotation, anterior–posterior tilting, protraction–retraction, and medial–lateral rotation. Evaluation of scapular muscles and pectoralis minor length should also be performed.⁴³ Specific stretches for the pectoralis minor may be performed with the unilateral corner stretch, or alternatively with the assistance of a physical therapist/athletic trainer (Figure 2). Soft tissue mobilization techniques are also recommended to treat scapulothoracic pathology (Figure 3A-C).⁸

Overall Phase 1 management of scapulothoracic pathology includes addressing the following: correcting posture, improving muscle strength of the lower and middle trapezius, serratus anterior, and managing soft tissue tightness or pain.

IMPEDE MUSCLE ATROPHY

Isometric exercises of the internal and external rotators of the shoulder should be initiated during phase

Figure 2. Stretching of *pectoralis minor* with assistance of a physical therapist/athletic trainer.

one to impede muscle atrophy, and improve proprioception and dynamic stabilization.²³ Isotonic exercises can be started if there is minimal muscle soreness during phase 1 to impede muscle atrophy. However, if the athlete is extremely sore or painful, then submaximal isometric exercises are done instead, and later progressed to aggressive isotonic exercises during phase two. This requires a focus on improving the strength of the weak muscles, such as the external rotators and scapular retractor, protractor, and depressor muscles.

PROPRIOCEPTION RESTORATION OF INVOLVED SHOULDER

Neuromuscular feedback mechanisms, specifically proprioception, become interrupted secondary to trauma and microtrauma.⁴⁴ The repetitive forces of the throwing motion predispose the overhead athlete to losses in proprioception.⁴⁵ Proprioception is important in rehabilitation and restoration of pre-injury levels of performance for the overhead athlete as it allows for awareness of body position and movement to be performed without continuous reference to consciousness.⁴⁴ This allows for a level of control which is necessary for later strengthening, performance, and a reduced chance of reinjury.

Proprioception of both the glenohumeral joint and scapular stabilizers are the focus of Phase 1 management. Agonist/antagonist muscle coactivation of the rotator cuff is emphasized through rhythmic stabilization exercises, and proprioceptive neuromuscular facilitation (PNF) patterns with rhythmic stabilization.⁶ For the scapular stabilizers, Mottram et al. described the “scapular orientation exercise”, which involves sustained holds of the scapula in ideal postural positions for 10 seconds, repeated 10 times.⁴⁶

Figure 3. Scapulothoracic soft tissue mobilization techniques (A-C). A and B: Prone position. The left hand of the physical therapist/athletic trainer lifts the scapula to distract from the thoracic wall while the right hand mobilizes and stretches the inferior musculature attachments to the scapula C: Lateral position. The left hand pushes the coracoid process posteriorly to displace the scapula from the thoracic wall while the right hand is distracting the inferior border of the scapula to stretch the inferior musculature attachments

KINETIC CHAIN DEFICIT EVALUATION AND EARLY EXERCISE

Early implementation of kinetic chain exercises helps prepare the body for later incorporation of intensive shoulder and full body exercises.⁸ Exercises should be designed with the movement of the overhead-throwing athlete in mind. Common potential deficits to examine include: (1) inflexibilities of the hamstrings, hip, and/or trunk, and (2) core musculature weakness. Lightweight isotonic exercises should be first attempted (e.g. active straight leg raise, oblique crunch, and side lying hip abduction), but if soreness is present, then submaximal isometric exercises should be employed (e.g. side plank, gluteal bridge, and dynamic stability tasks in quadruped and prone using the arms and legs as levers). Kinetic chain exercises include core, lower body, and axial loading exercises, which are also beneficial in restoring proprioception. Gait and stance adaptations have been shown to exist in overhead throwing athletes with upper extremity injury as evaluated by the Y Balance Test.⁴⁷ In theory, poor balance could negatively affect throwing mechanics and lead to injury. Fortunately, correction of upper extremity deficits has also shown to improve lower extremity balance.⁴⁸

Phase 2 – Intermediate Phase

Goals of Phase 2 are to begin isotonic strengthening activities focused on restoration of shoulder joint muscle balance if unable to do so in Phase 1, and to continue to increase flexibility, mobility, ROM and neuromuscular control of the shoulder complex.¹⁷ These strengthening activities should focus on correcting

the individual pathology determined during Phase 1 evaluation. Continued exercises for the entire kinetic chain, and an introduction of shoulder endurance programs are recommended. Phase 2 can begin once pain and inflammation diminish, and neuromuscular control and static stability reach adequate levels (Table 2). The rehabilitation program for the overhead athlete must pay special attention to the strength, stability, and inter-muscular balance of the muscles of the rotator cuff and scapulothoracic joint.

Glenohumeral joint musculature (rotator cuff muscles)

Overhead athletes often exhibit sport-specific adaptations leading to a relative decrease in the strength of the external rotators and thus muscular imbalance in the rotator cuff.³⁰ Eccentric muscle strength of the external rotators is very important in the deceleration of the arm, and weakness predisposes the athlete to increased destabilization of the humeral head in the glenoid fossa, and potential injury. Muscular balance goals for external and internal rotator strength are provided in Appendix A.

Exercises begin with light weight but should be gradually increased as tolerated. Wilk et al. used EMG research of numerous investigators to design the Thrower's 10 Program, which attempts to address the vital muscles involved in the throwing motion.⁴⁹ Exercises in the program used to address ER deficits include prone rowing into ER and side lying ER. Specifically, these exercises target the infraspinatus and teres minor muscles. For the supraspinatus, Reinold et al. reported that the best exercise was the "full

Table 2. Phase 1 – Acute phase

Goal	Treatment Plan
<ol style="list-style-type: none"> 1. Address acute inflammation/pain 2. Evaluate and normalize ROM deficits 3. Impede muscle atrophy 4. Restore proprioception 5. Begin kinetic chain exercises 	<ol style="list-style-type: none"> 1. NSAIDs/steroid administration, ice, laser therapy, and iontophoresis 2. Assisted active range of motion, passive range of motion, and manual stretches; correct posture, and employ the unilateral corner stretch for pectoralis minor tightness; soft tissue mobilization 3. Isometric shoulder exercises 4. Rhythmic stabilization with and without PNF patterns: facilitates agonist/antagonist muscle coactivation 5. Lumbopelvic strengthening (likely isometrics)
ROM – range of motion, NSAID – nonsteroidal anti-inflammatory drug, PNF - proprioceptive neuromuscular facilitation	

can" exercise, or elevation in the scapular plane with full ER (thumb up).⁵⁰ Boettcher et al. found that pendant ER and prone ER may maximize supraspinatus strengthening while minimizing deltoid activity.⁵¹ Malanga et al. found that selective isolation of the supraspinatus is difficult and that both prone exercises and exercises in the scapular plane result in recruitment of the posterior and anterior deltoid fibers, respectively.⁵²

SCAPULAR STABILIZERS

Peri-scapular muscles are extremely important in maintaining the proper position, and stability of the scapula at rest and during the throwing motion.⁵³ Proper scapular function is also key in facilitating the transfer of energy from the main force generators of the kinetic chain – the legs and trunk – to the hand.¹ Re-establishing inter-muscular balance of the scapular musculature is important in preventing injury as well as optimizing performance.

Exercises should target potential weakness in serratus anterior strength, hyperactivity and early activation of the upper trapezius, decreased activity and late activation of the lower trapezius, neuromuscular control, and synchronized movement.⁵⁴ Kibler et al. identified specific exercises for scapular control including the low row, lawnmower (the arm is brought to the contralateral knee and retracted back through with full retraction of the scapula to the ipsilateral side and extension of the hips and trunk), and robbery (the trunk is flexed 40-50° with the arms forward flexed, then scapular retraction is performed, with elbows bent and arms externally rotated and held for five seconds while extending the hip and trunk) exercises.⁵⁵ Wilk et al. developed specific exercise drills to enhance scapulothoracic neuromuscular control.⁵⁶ For the serratus anterior, supine protraction and wall push-ups are recommended.⁵⁷ To target middle and lower trapezius activation while minimizing upper trapezius activation, side lying ER, prone forward flexion, prone horizontal abduction with ER, and prone extension are recommended.⁵⁸

CONTINUE ROM, FLEXIBILITY, AND IMPROVE NEUROMUSCULAR CONTROL

Phase 1 stretches and exercises for ROM, flexibility, and neuromuscular control should be continued during this phase. To increase neuromuscular control, stabilization drills at end ROM, including PNF

exercises performed in a full arc of patient's available ROM should be added.⁶

STRENGTHENING OF KINETIC CHAIN AND CONDITIONING

Proper management of the kinetic chain in a rehabilitation program allows for efficient and consistent transfer of energy from proximal to distal components. This allows the overhead athlete to: (1) reduce kinetic stress on the shoulder to prevent injury, and (2) generate added force to increase maximum velocity and increase performance.¹ For the overhead athlete, the activities of the shoulder work within a diagonal pattern kinetic chain, spanning from the ground through to the trunk. Exercises should be designed from diagonal patterns as this has shown to increase scapular muscle activity.⁸ In Phase 2, exercises should advance to isotonic strengthening of the lumbopelvic musculature (Table 3). A sport and position-specific cardiovascular conditioning program should begin during this phase.⁶

Phase 3 – Advanced Strengthening Phase

Phase 3 can begin once the athlete has achieved full ROM, at least 4/5 manual muscle test strength, and minimal pain.¹⁷ The goals are to initiate progressive strengthening drills, enhance power and endurance, and perform functional drills (Table 4).⁶ In Phase 2, inter-muscular imbalances should have been corrected and more protective muscle balance should now be seen. The focus of Phase 3 is to actively advance strength and control during sport and position-specific movements through integration of the kinetic chain throughout the shoulder exercise program.

Phase 3 requires introduction of fatiguing activities for the shoulder joint complex and rest of the kinetic chain. A study examining EMG activity of the muscles of the rotator cuff and scapula during a diagonal movement task demonstrated that fatiguing protocols led to decreased lower trapezius activity and a compensatory increase in infraspinatus activity, predisposing the infraspinatus to injury during functional tasks.⁵⁹ Fatigue has been associated with a decrease in neuromuscular control,⁶⁰ ER and ball velocity, lead lower extremity knee flexion and shoulder adduction torque,⁶¹ and an increase in humeral head superior translation during the

Table 3. Phase 2 – Intermediate phase

Goal	Treatment Plan
<ol style="list-style-type: none">1. Re-establish inter-muscular balance in glenohumeral and scapulothoracic joints2. Continue phase 1 activities for range of motion, flexibility, and neuromuscular control3. Further kinetic chain program and start a conditioning program.	<ol style="list-style-type: none">1. Thrower's 10 Program (prone rowing into ER, side lying ER, "full can" exercise) For scapulothoracic articulation employ low row, row with external rotation ("lawnmower"), and external rotation with abduction ("robbery" position) for scapular control; supine protractions and wall push-ups for serratus anterior strength; side lying ER, lying forward flexion, prone horizontal abduction with ER and prone extension for middle and lower trapezius2. Phase 1 stretches and add on stabilization drills at end range of motion3. Isotonic strengthening of lumbopelvic region and a sport and position specific conditioning program
ER – external rotation	

Table 4. Phase 3 – Advanced strengthening phase

Goal	Treatment Plan
<ol style="list-style-type: none">1. Initiate aggressive strengthening drills2. Enhance power and endurance3. Begin athlete specific functional drills4. Initiate aggressive kinetic chain and conditioning programs	<ol style="list-style-type: none">1. Advanced thrower's 10 program2. Plyometric exercise program (chest pass, overhead soccer throw, side-to-side throws, side throws); wall dribbling with playball, wall arm circles, underweight ball throws, and overweight ball throws3. Manual resistance stabilization, dynamic stabilization, and rhythmic stabilization at maximal ER with added perturbations4. Functional, aggressive lumbopelvic strengthening
ER – external rotation	

throwing motion.⁶² All these factors contribute to diminished performance, and a greater likelihood of injury. Proprioception exercises that focus on strength, dynamic stability, and neuromuscular control exercises at end-range ER should also be introduced during Phase 3. Some examples of proprioceptive exercises which focus on axial loading include planks, shoulder ER in plank position, and hand on wall stabilization drills.⁶

SPORT-SPECIFIC ADVANCED STRENGTHENING

To maintain focus on the vital muscles of the throwing motion, and implement increasing sport-specific demands, Wilk et al. created the Advanced Thrower's 10 Program, which adds alternating movement patterns, and alternating dynamic and sustained

hold sequencing.⁴⁹ The introduction of sustained isometric holds has been shown to increase motor recruitment. Evidence supports that sustained isometric contractions can lead to increased muscular hypertrophy.⁶³ These ideas led to the suggestion that incorporating sustained isometric holds, as done in the Advanced Thrower's 10 Program, will increase muscle activation and lead to added muscular strength, endurance, and dynamic stabilization. Further, sustained contraction increases the demand on the shoulder, preparing the athlete for return to sport. In a recent randomized clinical trial, Myers et al. demonstrated improved upper extremity torque and angular impulse during scaption exercises after completing six-weeks of the Advanced Throwers 10 Program, though there were no significant differences compared to a traditional exercise

program.⁶³ All exercises in the Advanced Thrower's 10 Program are designed to be performed in 3 sets of 10 repetitions.⁴⁹

PLYOMETRICS

Plyometric exercises have three stages: (1) high velocity eccentric contraction (pre-stretch), (2) storage of the elastic energy (amortization), and (3) release of the kinetic energy in a powerful concentric contraction.⁶⁴ This type of exercise is believed to encourage neuromechanical adaptations to allow the muscle to tolerate a higher rate of pre-stretch and transition more quickly to concentric contractions.⁶⁵ These adaptations to the muscle alter the kinematic risk factors for injury, while leading to added performance by increasing the transfer of energy from the lower extremities and trunk to the upper extremity.

Because of the added risk of injury found in weak eccentric activity of the rotator cuff musculature, plyometric exercises target eccentric contractions of the posterior musculature and are believed to provide added protective benefit to the overhead athlete.⁵⁴ Wilk and colleagues established a plyometric exercise program for the overhead thrower.⁶⁶ Some of these exercises include two-handed exercise drills like chest pass, overhead soccer throws, side-to-side throws, and side throws. A recent study demonstrated decreases in eccentric, amortization, and concentric phase times for both plyometric and strength training groups and increases in scapular upward rotation for both groups, providing objective evidence for the effectiveness of these strengthening exercises in producing upper extremity protective and performance benefits.⁶⁴ Further, the addition of plyometrics demonstrated an increase in shoulder passive IR ROM.⁶⁴ The shortened amortization phase is believed to increase power development by increasing stored elastic energy and subsequent kinetic energy released, and reduces shoulder injury by limiting the amount of

time that the shoulder is in potentially harmful positions – abduction and maximum ER.⁶⁷

Fatigue is a major risk factor for injury in the overhead athlete. Studies have shown that muscle fatigue is the leading factor predisposing the Little League pitcher to shoulder injury while pitching.⁶⁸ Additional non-plyometric exercises than can aid in improving endurance include exercise drills which include wall dribbling with a plyometric ball, wall arm circles, and underweighted and overweighted ball throws.⁶

Increases in maximal ER are believed to have performance benefits in the form of increased velocity.⁵⁴ In Phase 3, manual resistance stabilization, dynamic stabilization, and rhythmic stabilizations should continue to be performed, but now at maximal ER, and with added perturbations. Kinetic chain consideration focused on lower body, core, and axial loading exercises should continue to be prescribed as well. The conditioning program should be increased, with the continued understanding of fitness demands required for a particular position and sport in mind.

Phase 4 – Return to Throwing Phase

Phase 4, the interval-throwing program, is initiated once the athlete completes: (1) satisfactory clinical examination; (2) non-painful ROM; (3) satisfactory isokinetic test results if such testing is available; (4) appropriate rehabilitation progress; and (5) successful completion of a plyometric program.⁶ The interval-throwing program is broken into two stages, with strict adherence to proper throwing mechanics and fundamentals necessary to progress within each phase and between each phase (Table 5). Improper use of throwing mechanics or the kinetic chain may result in delays in recovery or re-injury.⁷ Throughout Phase 4, open communication is key to ensure that there is no pain or stiffness during the throwing

Table 5. Phase 4 – Return to throwing phase	
Goal	Treatment Plan
Return functional and sport specific demands on the athlete	1. Interval throwing program 2. Stage 1 → pre-mound throwing 3. Stage 2 (pitchers) → Mound throwing 4. Stage 2 (position players) → Distance throwing

Table 6. Stages of return to throwing		
	Initial objectives	Goals
Stage 1 – Pre-Mound Throwing	Day 1: 25 throws max at 20-45'	Long-toss program; progress distance 45, 60, 90, and 120' 150' goal for pitchers
Stage 2 (Pitchers) – Mound Throwing	Start at 45' on mound; fastballs 50% max velocity; continue to increase number of pitches and distance	Modulating pitch velocity 75%-100%, breaking balls only once fastballs and changeups can be thrown
Stage 2 (Position Players) – Distance Throwing Phase	Focus on mechanics with progression to accuracy	Interval distance progression: 120, 150, 180'
Rest/Off-Day	Engage in activities similar in difficulty and intensity to exercises in phase 2	Keep shoulder loose, minimize soreness; 10-minute toss session

motion, and only minimal soreness exists after a throwing session. Any significant pain, or pain deep in the shoulder during the throwing motion warrants halting of all exercises for that day and reassessment on a later date for return to the throwing program.

During the throwing motion, proper employment of the kinetic chain in the form of a “gathering step” and conscious use of the legs and trunk should be enforced, especially early in the long-toss program.⁷ Throws should be made “on a line” rather than in a “high arc”, and a four-seam fastball grip should be used. Care should be taken early on to ensure throws are made with submaximal effort.^{7,69} Although historically a long-toss program is implemented, a recent survey study has shown there is a high level of variability in parameters used in professional athletes for the long-toss program.⁷⁰ Until completion of the program, throwing activities should be performed every other day, with successful completion of three throwing days warranting advance to the next level. Position considerations and an understanding of the context of the athlete’s season should be taken in the individual design of an athlete’s program.

See Table 6 for detailed stages of return to throwing.

RETURN TO PLAY (RTP)

Return to play (RTP) is an important decision for getting the athlete back to his/her sport. The decision should be made only after careful discussion between the physical therapist/athletic trainer, surgeon, and player. These decisions can be complicated by athlete and coaching preferences, as well

as external pressures.⁷¹ Previous injury is associated with up to four-fold increase in re-injury.⁷² RTP decisions should always be individualized, and require substantial clinical judgment, though there has been a trend in the literature to try and standardize some of these decisions.^{71,73}

Matheson et al. described the RTP model, which describes three steps that the clinician should take to systematically approach individual components and their sequence in RTP decisions.⁷¹ The first step is an evaluation of the athlete’s health status, which includes analytic and functional tests to determine medical factors. Appendix A outlines objective criteria to consider in assessing health status.⁸ The second step is a consideration of sport risk modifiers, with the goal of evaluating the athlete’s participation risk given the sport, position, and competitive level of the athlete. The third step involves a consideration of external modifiers, including social or economic pressures, and timing in the season. While this system helps to decrease controversy and provide a framework for consideration of all aspects of RTP, individual considerations and clinical judgment cannot be overemphasized in RTP decisions.

CONCLUSIONS

This clinical commentary presents the current hypotheses on pathophysiology of throwing injuries that occur in the overhead athlete and provides evidence-based guidelines for conservative treatment. Rotator cuff muscular abnormalities, glenohumeral internal rotation deficits, and scapulothoracic joint

pathology contribute to the distinct shoulder complex pathologies seen in these athletes. A thorough history and physical examination are important for the rehabilitation specialist to accurately recognize the underlying cause of the pathology of an individual. The rehabilitation program should be multi-phased, and sequential, with a gradual reintroduction of sport-specific demands. RTP decisions should weigh subjective assessment as well as objective measures of ROM, strength, and function.

REFERENCES

1. Seroyer ST, Nho SJ, Bach BR, et al. The kinetic chain in overhand pitching: its potential role for performance enhancement and injury prevention. *Sports Health*. 2010;2(2):135-146.
2. Shanley E, Rauh MJ, Michener LA, et al. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *Am J Sports Med*. 2011;39(9):1997-2006.
3. Conte S, Requa RK, Garrick JG. Disability days in major league baseball. *Am J Sports Med*. 2001;29(4):431-436.
4. Wilk KE, Obma P, Simpson CD, et al. Shoulder injuries in the overhead athlete. *J Orthop Sports Phys Ther*. 2009;39(2):38-54.
5. Weber AE, Kontaxis A, O'Brien SJ, et al. The biomechanics of throwing: simplified and cogent. *Sports Med Arthrosc*. 2014;22(2):72-79.
6. Wilk KE, Macrina LC. Nonoperative and postoperative rehabilitation for injuries of the throwing shoulder. *Sports Med Arthrosc*. 2014;22(2):137-150.
7. Makhni E, Weber A, Ball B, et al. Principles of Post-operative Shoulder Rehabilitation in Throwing Athletes. *Oper Techn Sport Med*. 2016;24(3):223-225.
8. Cools AM, Borms D, Castelein B, et al. Evidence-based rehabilitation of athletes with glenohumeral instability. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(2):382-389.
9. Manske R, Ellenbecker T. Current concepts in shoulder examination of the overhead athlete. *Int J Sports Phys Ther*. 2013;8(5):554-578.
10. Stackhouse SK, Eisennagel A, Eisennagel J, et al. Experimental pain inhibits infraspinatus activation during isometric external rotation. *J Shoulder Elbow Surg*. 2013;22(4):478-484.
11. Brockmeyer M, Tompkins M, Kohn DM, et al. SLAP lesions: a treatment algorithm. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(2):447-455.
12. Sun Y, Chen J, Li H, et al. Steroid Injection and Nonsteroidal Anti-inflammatory Agents for Shoulder Pain: A PRISMA Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Medicine (Baltimore)*. 2015;94(50):e2216.
13. Page MJ, Green S, Mrocki MA, et al. Electrotherapy modalities for rotator cuff disease. *Cochrane Database Syst Rev*. 2016(6):CD012225.
14. Perez-Merino L, Casajuana MC, Bernal G, et al. Evaluation of the effectiveness of three physiotherapeutic treatments for subacromial impingement syndrome: a randomised clinical trial. *Physiotherapy*. 2016;102(1):57-63.
15. Osbahr DC, Cawley PW, Speer KP. The effect of continuous cryotherapy on glenohumeral joint and subacromial space temperatures in the postoperative shoulder. *Arthroscopy*. 2002;18(7):748-754.
16. Singh H, Osbahr DC, Holovac TF, et al. The efficacy of continuous cryotherapy on the postoperative shoulder: a prospective, randomized investigation. *J Shoulder Elbow Surg*. 2001;10(6):522-525.
17. Wilk KE, Hooks TR. Rehabilitation of the throwing athlete: where we are in 2014. *Clin Sports Med*. 2015;34(2):247-261.
18. Picha KJ, Harding JL, Bliven KCH. Glenohumeral and Hip Range-of-Motion and Strength Measures in Youth Baseball Athletes. *Journal of Athletic Training*. 2016;51(6):466-473.
19. Reinold MM, Wilk KE, Macrina LC, et al. Changes in shoulder and elbow passive range of motion after pitching in professional baseball players. *The American journal of sports medicine*. 2008;36(3):523-527.
20. Crockett HC, Gross LB, Wilk KE, et al. Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *The American journal of sports medicine*. 2002;30(1):20-26.
21. Wilk KE, Macrina LC, Fleisig GS, et al. Deficits in glenohumeral passive range of motion increase risk of elbow injury in professional baseball pitchers: a prospective study. *The American journal of sports medicine*. 2014;42(9):2075-2081.
22. Reagan KM, Meister K, Horodyski MB, et al. Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med*. 2002;30(3):354-360.
23. Wilk KE, Meister K, Andrews JR. Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med*. 2002;30(1):136-151.
24. Park SS, Loebenberg ML, Rokito AS, et al. The shoulder in baseball pitching: biomechanics and

- related injuries-part 2. *Bull Hosp Jt Dis.* 2002;61(1-2):80-88.
25. Manske R, Wilk KE, Davies G, et al. Glenohumeral motion deficits: friend or foe? *Int J Sports Phys Ther.* 2013;8(5):537-553.
26. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. *Arthroscopy.* 2003;19(4):404-420.
27. Wilk KE, Macrina LC, Fleisig GS, et al. Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. *Am J Sports Med.* 2011;39(2):329-335.
28. Kibler WB, Sciascia A, Thomas SJ. Glenohumeral internal rotation deficit: pathogenesis and response to acute throwing. *Sports Med Arthrosc.* 2012;20(1):34-38.
29. Noonan TJ, Thigpen CA, Bailey LB, et al. Humeral Torsion as a Risk Factor for Shoulder and Elbow Injury in Professional Baseball Pitchers. *Am J Sports Med.* 2016;44(9):2214-2219.
30. Reisman S, Walsh LD, Proske U. Warm-up stretches reduce sensations of stiffness and soreness after eccentric exercise. *Med Sci Sports Exerc.* 2005;37(6):929-936.
31. Bailey LB, Thigpen CA, Hawkins RJ, et al. Effectiveness of Manual Therapy and Stretching for Baseball Players With Shoulder Range of Motion Deficits. *Sports Health.* 2017;9(3):230-237.
32. Chepeha JC, Magee DJ, Bouliane M, et al. Effectiveness of a Posterior Shoulder Stretching Program on University-Level Overhead Athletes: Randomized Controlled Trial. *Clin J Sport Med.* 2017.
33. Mine K, Nakayama T, Milanese S, et al. Effectiveness of Stretching on Posterior Shoulder Tightness and Glenohumeral Internal Rotation Deficit: A Systematic Review of Randomised Controlled Trials. *J Sport Rehabil.* 2016:1-28.
34. Manske RC, Meschke M, Porter A, et al. A randomized controlled single-blinded comparison of stretching versus stretching and joint mobilization for posterior shoulder tightness measured by internal rotation motion loss. *Sports Health.* 2010;2(2):94-100.
35. Wilk KE, Hooks TR, Macrina LC. The modified sleeper stretch and modified cross-body stretch to increase shoulder internal rotation range of motion in the overhead throwing athlete. *J Orthop Sports Phys Ther.* 2013;43(12):891-894.
36. Bach HG, Goldberg BA. Posterior capsular contracture of the shoulder. *J Am Acad Orthop Surg.* 2006;14(5):265-277.
37. Oliver GD, Plummer H, Brambeck A. HIP AND GLENOHUMERAL PASSIVE RANGE OF MOTION IN COLLEGIATE SOFTBALL PLAYERS. *International Journal of Sports Physical Therapy.* 2016;11(5):738-745.
38. Gillet B, Begon M, Sevrez V, et al. Adaptive Alterations in Shoulder Range of Motion and Strength in Young Tennis Players. *J Athl Train.* 2017;52(2):137-144.
39. Struyf F, Nijs J, Mottram S, et al. Clinical assessment of the scapula: a review of the literature. *Br J Sports Med.* 2014;48(11):883-890.
40. Reuther KE, Thomas SJ, Tucker JJ, et al. Scapular dyskinesis is detrimental to shoulder tendon properties and joint mechanics in a rat model. *J Orthop Res.* 2014;32(11):1436-1443.
41. Burn MB, McCulloch PC, Lintner DM, et al. Prevalence of Scapular Dyskinesis in Overhead and Nonoverhead Athletes: A Systematic Review. *Orthop J Sports Med.* 2016;4(2):2325967115627608.
42. Borich MR, Bright JM, Lorello DJ, et al. Scapular angular positioning at end range internal rotation in cases of glenohumeral internal rotation deficit. *J Orthop Sports Phys Ther.* 2006;36(12):926-934.
43. William Rondeau M, Padua D, Thigpen C, et al. *Precision and Validity of a Clinical Method for Pectoral Minor Length Assessment in Overhead-Throwing Athletes.* Vol 422012.
44. Lephart SM, Pincivero DM, Giraldo JL, et al. The role of proprioception in the management and rehabilitation of athletic injuries. *The American journal of sports medicine.* 1997;25(1):130-137.
45. Safran MR, Borsa PA, Lephart SM, et al. Shoulder proprioception in baseball pitchers. *J Shoulder Elbow Surg.* 2001;10(5):438-444.
46. Mottram SL, Woledge RC, Morrissey D. Motion analysis study of a scapular orientation exercise and subjects' ability to learn the exercise. *Man Ther.* 2009;14(1):13-18.
47. Garrison JC, Arnold A, Macko MJ, et al. Baseball players diagnosed with ulnar collateral ligament tears demonstrate decreased balance compared to healthy controls. *J Orthop Sports Phys Ther.* 2013;43(10):752-758.
48. Hannon J, Garrison JC, Conway J. Lower extremity balance is improved at time of return to throwing in baseball players after an ulnar collateral ligament reconstruction when compared to pre-operative measurements. *Int J Sports Phys Ther.* 2014;9(3):356-364.
49. Wilk KE, Yenchak AJ, Arrigo CA, et al. The Advanced Throwers Ten Exercise Program: a new exercise series for enhanced dynamic shoulder control in the overhead throwing athlete. *Phys Sportsmed.* 2011;39(4):90-97.

-
50. Reinold MM, Escamilla RF, Wilk KE. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther.* 2009;39(2):105-117.
 51. Boettcher CE, Ginn KA, Cathers I. Which is the optimal exercise to strengthen supraspinatus? *Med Sci Sports Exerc.* 2009;41(11):1979-1983.
 52. Malanga GA, Jenp YN, Growney ES, et al. EMG analysis of shoulder positioning in testing and strengthening the supraspinatus. *Med Sci Sports Exerc.* 1996;28(6):661-664.
 53. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26(2):325-337.
 54. Edwards P, Ebert J, Joss B, et al. Exercise Rehabilitation in the Non-Operative Management of Rotator Cuff Tears: A Review of the Literature. *Int J Sports Phys Ther.* 2016;11(2):279-301.
 55. Kibler WB, Sciascia AD, Uhl TL, et al. Electromyographic analysis of specific exercises for scapular control in early phases of shoulder rehabilitation. *Am J Sports Med.* 2008;36(9):1789-1798.
 56. Wilk K, Arrigo C, Andrews J. Closed and open kinetic chain exercises for the upper extremity. *J Sports Rehabil* 1996;5:88-102.
 57. Cools AM, Struyf F, De Mey K, et al. Rehabilitation of scapular dyskinesis: from the office worker to the elite overhead athlete. *Br J Sports Med.* 2014;48(8):692-697.
 58. Sciascia A, Kuschinsky N, Nitz AJ, et al. Electromyographical comparison of four common shoulder exercises in unstable and stable shoulders. *Rehabil Res Pract.* 2012;2012:783824.
 59. Joshi M, Thigpen CA, Bunn K, et al. Shoulder external rotation fatigue and scapular muscle activation and kinematics in overhead athletes. *J Athl Train.* 2011;46(4):349-357.
 60. Carpenter JE, Blasier RB, Pellizzon GG. The effects of muscle fatigue on shoulder joint position sense. *Am J Sports Med.* 1998;26(2):262-265.
 61. Murray TA, Cook TD, Werner SL, et al. The effects of extended play on professional baseball pitchers. *Am J Sports Med.* 2001;29(2):137-142.
 62. Chen S, Wickiewicz T, Otis J. Glenohumeral kinematics in a muscle fatigue model. *Orthop Trans.* 1995;18:1126.
 63. Myers NL, Toonstra JL, Smith JS, et al. Sustained Isometric Shoulder Contraction on Muscular Strength and Endurance: A Randomized Clinical Trial. *Int J Sports Phys Ther.* 2015;10(7):1015-1025.
 64. Swanik KA, Thomas SJ, Struminger AH, et al. The Effect of Shoulder Plyometric Training on Amortization Time and Upper-Extremity Kinematics. *J Sport Rehabil.* 2016;25(4):315-323.
 65. Davies G, Riemann BL, Manske R. Current Concepts of Plyometric Exercise. *Int J Sports Phys Ther.* 2015;10(6):760-786.
 66. Escamilla RF, Ionno M, deMahy MS, et al. Comparison of three baseball-specific 6-week training programs on throwing velocity in high school baseball players. *J Strength Cond Res.* 2012;26(7):1767-1781.
 67. Fleisig GS, Andrews JR, Dillman CJ, et al. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med.* 1995;23(2):233-239.
 68. Fleisig GS, Andrews JR, Cutter GR, et al. Risk of serious injury for young baseball pitchers: a 10-year prospective study. *Am J Sports Med.* 2011;39(2):253-257.
 69. Reinold MM, Wilk KE, Reed J, et al. Interval sport programs: guidelines for baseball, tennis, and golf. *J Orthop Sports Phys Ther.* 2002;32(6):293-298.
 70. Stone AV, Mannava S, Patel A, et al. Defining the Long-Toss: A Professional Baseball Epidemiological Study. *Orthop J Sports Med.* 2017;5(2):2325967116686773.
 71. Matheson GO, Shultz R, Bido J, et al. Return-to-play decisions: are they the team physician's responsibility? *Clin J Sport Med.* 2011;21(1):25-30.
 72. Fuller CW, Bahr R, Dick RW, et al. A framework for recording recurrences, reinjuries, and exacerbations in injury surveillance. *Clin J Sport Med.* 2007;17(3):197-200.
 73. Kovacic J, Bergfeld J. Return to play issues in upper extremity injuries. *Clin J Sport Med.* 2005;15(6):448-452.

Appendix A. Objective measures of ROM, muscular strength and balance, and function

Structural Consideration	Criteria
Glenohumeral Joint Range of Motion	IR ROM deficit of throwing arm < 18° (for maximal protection) NOTE: no consensus (values in the literature range from 18° to 25°)
Rotator Cuff Strength	1. Isokinetic ER/IR ratio of 66 % or an isometric ER/IR ratio of 75–100 % 2. General rotator cuff strength increase of 10 % of the dominant throwing side compared to the non-dominant side 3. Eccentric strength of the ER is equal to the isometric IR strength
Scapular Position and Muscle Strength	Position: 60° of upward rotation in full arm elevation Strength: 10 % increased strength of peri-scapular musculature on the dominant side in one-handed sports
Pectoralis Minor Tightness	PMI* > 7.65
IR – internal rotation, ER – external rotation, PMI - pectoralis minor length normalized based on body height. *PMI is calculated by dividing the resting length of the muscle in centimeters by subject height in centimeters and multiplying by 100.	

Appendix B. Physical examination

Subjective History Observation/inspection Palpation <ol style="list-style-type: none"> 1. Osseous structures (SC joint, AC joint, clavicle, acromion, coracoid, bicipital groove, scapula) 2. Assess musculature: RC, deltoid, rhomboids, trapezius, serratus anterior, pectoralis minor Range of Motion (Active and Passive) <ol style="list-style-type: none"> 1. Glenohumeral motion 2. Scapulothoracic motion 3. Crepitus Motor Strength <ol style="list-style-type: none"> 1. Glenohumeral 2. Scapular 3. Arm/Forearm 	Specific Maneuvers <ol style="list-style-type: none"> 1. Impingement signs (Neer/Hawkins, cross-chest adduction, internal impingement) 2. Stability Tests (Sulcus sign, relocation test, etc.) 3. Special Tests, Biceps (Speed's, Yergason's) 4. Special Tests, SLAP (Clunk, O'Brian's active compression, Biceps load, Lemak, Pronated biceps load, etc.) Neurologic Examination Cervical Spine Examination Performance Testing <ol style="list-style-type: none"> 1. Isokinetic and motion analysis testing
---	--