ELSEVIER

Operative Techniques in
Sports Medicine

Management of Scapular Dyskinesis in Overhead Athletes

W. Ben Kibler, MD,[*] Austin V. Stone, MD, PhD,[†] Anthony Zacharias, MD,[†] W. Jeffrey Grantham, MD,[*] and Aaron D. Sciascia, PhD, ATC, PES, SMTC, FNAP[‡]

Optimal scapular function is integral to optimal shoulder function. Multiple roles of the scapula in arm function and throwing have been identified while scapular dysfunction continues to be associated with various shoulder pathologies. Although scapular motion alterations may be common in overhead athletes, various reports have shown that identification and management of the alterations can result in improved rehabilitation and performance outcomes. Considering that baseball throwing occurs as the result of integrated, multi-segmented, sequential joint motion and muscle activation within the kinetic chain, function and dysfunction within the kinetic chain needs to be understood. Furthermore, the scapula is a key component link within the chain through its function to maximize scapulohumeral rhythm and efficient throwing mechanics. Therefore, evaluation and management beginning with the scapula can produce improved outcomes related to shoulder pathology in overhead athletes. Although rehabilitation programs follow a core set of principles, they should be individualized based on the presentation of the patient and the needs for return to sport. This paper will describe scapular function in throwing, normal and abnormal scapular kinematics and muscle activations in throwing, discuss scapular dyskinesis as an impairment of function that can be associated with throwing injuries and altered performance, and how to detect impairments in order to establish proper treatment programs.
Oper Tech Sports Med 29:150797

KEYWORDS scapula, scapular dyskinesis, kinetic chain, overhead athlete

The Roles of the Scapula in the Overhead Throwing Motion

The scapula plays key roles in facilitating mechanics to accomplish the tasks required in the repetitive, high load, and rapid actions for successful overhead throwing. They include:

1. Dynamic stability to provide force transfer through the kinetic chain

Effective scapular stabilization allows the highest efficiency of force transfer from the core and legs to the hand in arm acceleration.[1] In arm deceleration the stabilized scapula provides 40% of the resistance to eccentric tensile loads in follow through.[2] Loss of stability increases joint loads and decreases "energy flow" from the engine (the core) to the delivery mechanism (the hand).

2. Stable base for optimal shoulder muscle activation and force generation

Maximum arm flexion, abduction, and external rotation force generation is achieved off a stabilized retracted scapula, in both symptomatic and asymptomatic athletes.[3,4] This position optimizes the function of

*Shoulder Center of Kentucky, Lexington Clinic, Lexington, KY.
†Division of Sports Medicine, Department of Orthopaedic Surgery and Sports Medicine, University of Kentucky, Lexington, KY.
‡Department of Exercise and Sport Science, Eastern Kentucky University, Richmond, KY.
Conflict of Interest: The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.
Address reprint requests to Aaron D. Sciascia, PhD, ATC, PES, SMTC, Department of Exercise and Sport Science, Eastern Kentucky University, Richmond, KY 40475 E-mail: aaron.sciascia@eku.edu

https://doi.org/10.1016/j.otsm.2021.150797
1060-1872/

the rotator cuff as a compressor cuff of the humerus into the glenoid socket.

3. Dynamic 3 dimensional motion

Scapular motion in reference to the thorax is deconstructed into 3 distinct motions: internal-external rotation about a superior axis, upward-downward rotation in the plane of the scapula, and anterior-posterior tilt around a horizontal axis.[5] Dynamic scapular motion is coupled with humeral motion to create scapulohumeral rhythm (SHR). SHR results in motions and positions that create precise ball and socket kinematics to maximize concavity compression mechanics, with minimal shear on the joint and anatomic structures, throughout the entire throwing motion.[6] This precision decreases internal impingement and posterior labral shear and injury[7] and maximizes labral function as a washer to spread joint loads evenly.[8] In addition, correct scapular motion moves the acromion upward and posteriorly, maximizing the acromio-humeral distance and the height of the subacromial space, decreasing external impingement and rotator cuff tendinopathy.[9-11]

These roles require coordinated patterns of muscle activations, which produce the specific forces and motions necessary to accomplish the tasks of throwing.

Scapular Motions and Muscle Activations

During the typical throwing motion, the healthy scapula follows a defined sequence of motions. The scapula upwardly rotates, tilts posteriorly, and externally rotates as the humerus is brought into maximal abduction.[12] From this point, while the humerus externally rotates during acceleration, the scapula further upwardly rotates, externally rotates, and posteriorly tilts, creating maximal scapular retraction at late cocking phase.[13] During stride foot contact, the scapula retracts, upwardly rotates and anteriorly tilts.[14,15] Progression to ball release results in anterior tilting and internal rotation. Following ball release the humerus continues to internally rotate with maximal internal rotation, downward rotation, and anterior tilting of the scapula.[12] This position dissipates the remaining force generated during ball acceleration and represents the opposite extreme of scapular motion during humeral maximal external rotation.[15]

Upward rotation of the scapula is largely the result of the upper trapezius elevating the clavicle, the middle trapezius elevating the acromion, and lower trapezius stabilizing the medial scapula.[16] In addition to this, the serratus anterior functions to stabilize the medial border and inferior angle of the scapula to facilitate the upward rotation, effectively prevents medial scapular winging and anterior tilt, and functions as a scapula external rotator as the arm is elevated.[17] Maintenance of upward scapular rotation with arm elevation >90° is a function of the lower trapezius.[18] Medial translation of the scapula is mainly a function of the middle trapezius and rhomboid muscles.[19] With its insertion on the coracoid, the pectoralis minor functions to anteriorly tilt the scapula as well as internally rotate.[20]

Scapular motion and muscle activations play a major role in the kinetic chain of the throwing motion as lower extremity energy is used to generate acceleration of the upper extremity.[21] Scapula muscle activation occurs in conjunction with strong ipsilateral gluteus medius activity followed by simultaneous activity of ipsilateral and contralateral gluteus medius activation; this pattern emphasizes the importance of trunk and scapula stability for energy transfer to the arm.[22] The energy then continues distally about the arm as Hirashima et al showed proximal shoulder muscles were activated before distal muscles.[23,24] This creates a stable base for arm motion and an efficient transfer of energy.

Alterations to the normal firing pattern of these muscles may lead to poor performance and increased injury risk. For example, decreased lower trapezius activation reduces the amount of subacromial space present while throwing.[25] Clinically, impingement symptoms are associated with altered lower trapezius recruitment.[26] These issues may be most apparent with muscular fatigue, as shoulder external rotation fatigue is associated with decreased lower trapezius activation.[27] Fatigue of the trapezius and serratus anterior will also create less efficient energy dissipation during deceleration putting increased stress on the other structures of the shoulder and elbow.

Understanding of the muscle roles in the throwing motion has implications on improving performance, preventing injury, and guiding rehabilitation. According to a meta-analysis of randomized control studies isokinetic upper body strengthening, periodization, and kinetic chain training including lumbopelvic strengthening consistently improved overhead athletes' velocity.[28] Less beneficial was isolated upper body strengthening using only elastic bands and weight machines. These findings help illustrate the dynamic nature of throwing motion and the role of muscular activation in the kinetic chain. These principles are also used to help guide current rehabilitation recommendations to prepare patients to return to throwing as later described in this chapter.

Scapular Dyskinesis

Observed or measured alterations of scapular resting position and/or dynamic motion have been termed scapular dyskinesis (dys- altered, kinesis- motion).[29,30] Dyskinesis is the mechanical result of anatomic injury or altered muscle activation that creates an impairment of SHR and can affect shoulder function and injury risk.[30] Dyskinesis is very common in association with altered function and injury and is present in 67- 100% of patients with shoulder injury.[31] The altered mechanics results in varying amounts of increased scapular anterior tilt, increased scapular internal rotation, and altered scapular upward rotation, which can have effects on joint loads, muscle activations, and arm motions. These effects include: increasing the glenohumeral (GH) arm angle in arm horizontal abduction; increasing anterior capsule and biceps tendon tension and shear[32]; increased posterior GH compression, creating increased compression and shear internal impingement loads on the posterior labrum; decreased rotator cuff activation and compressor cuff function; decreased sub acromial space dimensions, creating external impingement[33]; and alteration of optimal scapular external rotation as the first of the coupled scapular motions in cocking.

Dyskinesis may be associated with many symptoms and has multiple causative factors, which can be demonstrated by appropriate history, exam, imaging, and special testing. An algorithm has been developed to assist in the delineation of clinically significant dyskinesis and to evaluate the causative factors (Fig. 1). The 3 steps in this algorithm establish the presence or absence of dyskinesis, determine the clinical relationship of the dyskinesis to symptoms and dysfunction, and provide guidelines to assess the causative factors.

1. Qualitative methods of assessment of scapular kinematics- presence or absence of scapular dyskinesis. Current best practice for evaluation of scapular position at rest and motion upon arm motion is based on clinical observation of the medial scapular border.[29,30] It has been clinically used to detect and classify alterations of motion from the "normal" pattern of motion. The observation method has been termed the Scapular Dyskinesis Test. The exam is conducted by having the patients raise the arms in forward flexion to maximum elevation, and then lower them 3-5 times, with a 3-5 pound weight in each hand.[34,35] Prominence of any aspect of the medial scapular border on the symptomatic side is recorded as "yes" (prominence detected) (Fig. 2) or "no" (prominence not detected).[36]
2. Determining a possible association of the observed dyskinesis and throwing shoulder symptoms can be accomplished using corrective maneuvers, the scapular assistance test and the scapular retraction test. Modification of the symptoms by these manual maneuvers can demonstrate the role of the dyskinesis in the symptoms and dysfunction, and can suggest how treatment of the dyskinesis can help improve function. In the scapular assistance test, one hand on the clavicle and the other on the inferior angle of the scapula create posterior tilt and upward rotation (Fig. 3).[37,38] A positive result occurs when the painful external impingement symptoms are relieved, the arc of motion is increased, and/or the symptoms of GH instability are decreased. In the scapular retraction test (Fig. 4a and b), the examiner first grades the strength in forward flexion at 90 degrees or external rotation with the arm at the side, following standard manual muscle testing procedures or evaluates the labrum by the modified dynamic labral shear (M-DLS) test.[39] The examiner then places and manually stabilizes the scapula in a retracted position. A positive test occurs when the demonstrated strength is increased or the symptoms of internal impingement in the labral injury are relieved in the retracted position.
3. Causative factors for dyskinesis may be grouped into soft tissue, bone/joint, or neurological factors. Soft tissue factors include hip/core weakness with altered facilitation of muscle activation[26]; altered periscapular

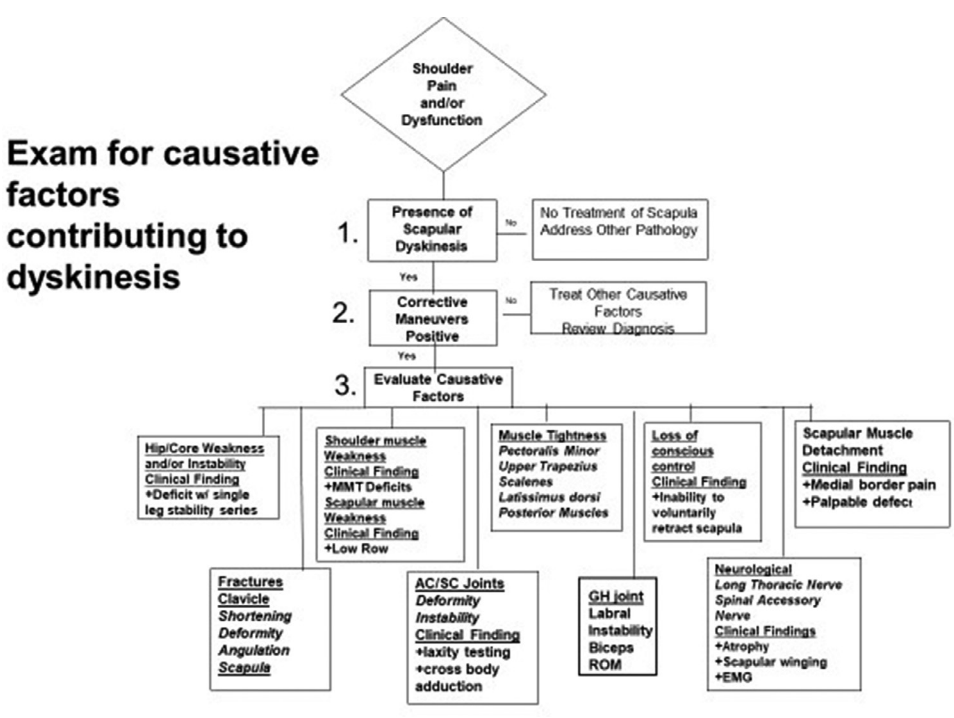

Figure 1 Clinical examination algorithm to determine scapular involvement in shoulder injury.

Figure 2 Example of scapular dyskinesis with medial border prominence.

and shoulder muscle activation, coordination, or balance due to pain derived muscle inhibition or fatigue; muscle stiffness and tightness[40]; loss of voluntary control of muscle activation[41]; or post traumatic periscapular muscle injury. Bone/joint causes include clavicle shortening, angulation, or malrotation; Acromioclavicular (AC) and/or sternoclavicular (SC) joint arthritis or instability; or GH joint internal derangement. Neurological causes include long thoracic, spinal accessory, or dorsal scapular nerve injuries or cervical radiculopathy. Routine history and clinical evaluation testing can be employed to assess each factor. A general sequential guide for the evaluation sequence would include: (1) screening evaluation for hip/core stability and strength, using one leg stance and one leg squat evaluation; (2) observation and palpation for medial scapula border tenderness and/or muscle defect; (3) testing for periscapular and shoulder muscle voluntary activation and strength and ability to fully retract the scapula, using standard clinical tests; (4) flexibility testing for commonly tight muscles including pectoralis minor, upper trapezius, and latissimus dorsi; (5) GH joint testing, including alteration of internal and external and horizontal adduction/abduction range of motion, anterior and posterior instability, labral injury, biceps injury, and rotator cuff disease, using standard exam techniques; (6) clavicle and AC/SC joint evaluation for joint stability and bone shortening, angulation, or malrotation; and (7) neurological evaluation.

Figure 3 Scapular assistance test (SAT) – The scapula is stabilized with one hand and the other hand 'assists' the scapula through its correct motion plane. Increased elevation and relief of impingement symptoms is a positive test.

Dyskinesis and Throwing Shoulder Injury

Dyskinesis has been found in association with every pathology in the throwing athlete's arm, most commonly labral injury,[42] impingement,[43] rotator cuff disease,[44] and elbow injury.[45] The incidence varies, but dyskinesis can be identified in between 50% and 100% of throwers with injuries. It may be either a cause or a result of the pathology but needs to be treated as part of the comprehensive program.

Labral Injury

Scapular dyskinesis has a high association with labral injury with up to 94% of injured athletes demonstrating dyskinesis.[46] The altered position and motion of internal rotation and anterior tilt plus loss of upward rotation changes GH alignment, placing increased tensile strain on the anterior ligaments,[32] increases "peel-back" of the biceps/labral complex on the glenoid,[47] increases posterior humeral head translation against the posterior labrum, and creates pathological internal impingement resulting in labral compression, tearing, and intrasubstance shearing.[48,49] Only a 10 degree loss of scapular upward rotation increases the area and amount of compressive impingement, while a 10 degree increase in internal rotation increases the amount of compressive impingement.[50] A scapular based rehabilitation program has been found to be successful to modify symptoms and improve performance so that surgery is not required in 41% of professional athletes[51] and 50%-60% of non-professional but recreationally active athletes[52].

External Impingement

Scapular dyskinesis in external impingement is characterized by loss of acromial upward rotation, excessive scapular internal rotation, and excessive scapular anterior tilt.[43] These positions and motions create a loss of scapular external rotation and upward rotation and create scapular protraction, which may decrease the subacromial space,[33] increase

Figure 4 Scapular retraction test (SRT) — The examiner first performs a traditional flexion manual strength test (a). The examiner stabilizes the medial border of the scapula and repeats the test; if the impingement symptoms are relieved and strength improved, the test is positive (b).

contact on the glenoid,[53] and decrease demonstrated rotator cuff strength.[3]

Alterations in scapular muscle activity to produce the altered positions and motions include increased upper trapezius activity, imbalance of upper trapezius/lower trapezius activation, decreased serratus anterior activation, and inflexibility of the pectoralis minor have been reported in patients with impingement.[26,43] Most cases of external impingement symptoms in throwing athletes that are not associated with GH internal derangement injury can be resolved by including restoration of scapular kinematics in the rehabilitation program.[54]

Rotator Cuff Injury

Dyskinesis can result from the actual rotator cuff injury. A compensatory excessive scapular upward rotation develops following rotator cuff injury and is thought to decrease contact pressure.[9] Dyskinesis can also be causative for rotator cuff injury. The protracted position that increases the internal impingement on the posterior superior glenoid with arm external rotation and increases the torsional twisting of the rotator cuff, which may create the undersurface rotator cuff injuries seen in throwers.[55] In addition, scapular protraction creates superior compression loads on the rotator cuff. With continued activity, these loads result in histological and mechanical changes in the tendon seen in clinical tendinopathy.[9]

Rehabilitation programs that address restoration of scapular mechanics have been shown to decrease rotator cuff symptoms and decrease the possibility of surgery, both in partial thickness and full thickness tears.[56]

Scapula and the Elbow

Dyskinesis can have several effects that can alter elbow motion, result in increased valgus load, and play a role in the etiology of elbow injuries, especially ulnar collateral ligament injuries.[57] Scapular muscle fatigue from repetitive overhead motions with resulting dyskinesis produces negative compensatory motions at the elbow and inability to reproduce effective elbow position,[58] which lead to increased elbow loads. Scapula protraction can result in altered GH angulation and potentiates the possibility of throwing with the arm behind the scapular plane, in a motion of relative humeral horizontal hyperabduction termed “slow arm” by pitching coaches, which increases the centripedal forces at the elbow. Dyskinesis and scapular protraction can also produce a lowered arm position relative to the thorax, resulting in the “dropped elbow” in which the elbow is lower than the shoulder throughout a large part of the throwing motion, and in which the elbow is in flexion for a longer time during cocking and acceleration, thus increasing valgus stress and increasing the amount of time the medial ligaments experience loads.

Rehabilitation

Traditional strengthening and conditioning maneuvers/programs have focused on the reacquisition of strength and flexibility however; dynamic movement patterns for the purposes of motor control and efficient task performance should be incorporated . It is possible that a movement-based impairment identification system that extends beyond traditional pathoanatomical clinical constructs could be employed as part of the evaluation which in turn would allow for treatments to be directed at addressing any identified deficiencies.[59]

The algorithm illustrated in Figure 1 is the basis for a classification system for discerning the cause of shoulder pain between humeral and scapular origins.[60] If scapular causes are suspected, they can be subclassified further based on identified impairments. Using baseball as a guide, this type of classification system could have more clinical usefulness compared to traditional pathoanatomical classifications considering the known reports of asymptomatic tissue lesions existing in baseball players.[61,62] For example, there are three groupings of impairment classification and subsequent treatment that could exist for baseball athletes: (1) Classification: Identified impairments or verified pathological diagnoses/ Treatment: No activity with formal rehabilitation; (2)

Table 1 Multifaceted Rehabilitation Possibilities Based on Diagnosis Classification

Component	Classification I*	Classification II	Classification III
Activity status	Restricted activity	Limited/modified activity	Activity to tolerance
Rehabilitation	Establish proper postural alignment and proper motion Facilitation of scapular motion via exaggeration of lower extremity/trunk movement Exaggeration of scapular retraction in controlling excessive protraction Utilize closed chain exercise early Work in multiple planes	Apply interventions as guided by identified impairments (items from Classification I may apply)	May incorporate items from Classification I and II as needed
Strength and conditioning	Once athlete can perform maximum sets and repetitions of supervised rehabilitation maneuvers, transition to weight room for strength and conditioning programming	Modify strength training and conditioning in collaboration with strength coaches to decrease exacerbation of symptoms and reduce areas of deficiency	Assess and monitor technique during strength and conditioning maneuvers; review off-season programming
Biomechanical assessment	Not until sports-specific activities are permitted	Analyze throwing or hitting mechanics with position coaches	Assess, monitor, and adjust (as needed) mechanics during throwing, fielding, and hitting; manage volume and frequency of sporting drills for proper progression

*See Table 2 for specific examples for each portion of the kinetic-chain based rehabilitation framework.

Classification: Symptoms reported but cause not verified/ Treatment: Limited/modified activity with supplemental rehabilitation; and (3) Classification: No symptoms reported but impairments/deficiencies identified that may lead to injurious events/Treatment: Full activity with supplemental conditioning. The key points for each level are described below while a summary of treatment possibilities has been provided in Table 1.

Classification I: Identified Impairments or Verified Pathological Diagnoses (Formal Rehabilitation)

When clinical examinations reveal obvious physical impairments (weakness, inflexibility, early fatigue with motion, compensatory movements, etc.) or pathology, activity restriction and the development of a formal rehabilitation program are often employed. Removing the high load activity (throwing) can help re-establish the normal activations that create scapulohumeral rhythm. This phase concentrates on addressing the causative factors for the scapular dysfunction or dyskinesis and also re-establishes the proximal to distal kinetic chain activations that allow rehabilitation of the body to function as a unit in order to perform a multitude of tasks.[46,63]

A kinetic chain rehabilitation framework focuses on 3 critical characteristics.[64] First, patients are upright during exercise performance rather than be positioned supine or prone (when possible) to simulate functional demands.[64] The primary reasons for this include increased scapular (ie, serratus anterior and lower trapezius) and lower extremity (ie, gluteal and hamstring) muscle activation in standing positions[65,66] and decreased joint position sense errors which tend to occur more often in non-standing positions.[67] Second, the lever arm on the shoulder and trunk is shortened to reduce the load on the injured arm. Finally, arm motions should be initiated using the legs and trunk to facilitate activation of the scapula and shoulder muscles, which is a typical neurological pattern of motion.[23,68] Also, the scapula is a link within the kinetic chain responsible for transferring energy from the lower extremity and trunk to the arm. Thus, identifying and targeting deficiencies within the linked system that could deleteriously affect the energy transfer is a primary goal of this concept. This kinetic chain rehabilitation framework was later expanded to include a set of progressive goals that includes[63]: (1) establishing proper postural alignment; (2) establishing proper motion at all involved segments; (3) facilitating of scapular motion via exaggeration of lower extremity/trunk movement; (4) exaggerating scapular retraction while controlling excessive protraction; (5) utilizing the closed chain exercise early; and (6) working in multiple planes. A sample program has been provided illustrating the application of the framework (Table 2).

Table 2 Classification I Rehabilitation Exercise Examples

Guidelines	Goal(s)	Examples
Establish proper postural alignment and proper motion	Eliminate postural deficiencies such as rounded shoulders, forward head, thoracic kyphosis, and lumbar lordosis Improve motion deficiencies in glenohumeral, scapula, spine, and lower extremity segments	Programs designed to target all kinetic chain segments using manual therapy such as joint mobilization, passive stretching, and/or massage as well as home-based patient programs
Facilitation of scapular motion via exaggeration of lower extremity/trunk movement	Use the legs and trunk to perform trunk rotation or move from flexion to extension in order to gain scapular retraction	Lawnmower with arm close to body (Fig. 5a,b) Sternal lift
Exaggeration of scapular retraction in controlling excessive protraction	Assure the scapula is retracted or able to be easily retracted when performing arm movements Limit the amount of protraction that occurs early which can decrease the function of the rotator cuff muscles.	Conscious correction of scapula Rhythmic stabilization with the arms close to the body
Utilize closed chain exercise early	Decrease the forces acting on the arm and increase sensory feedback by utilizing closed chain exercise	Low row (Fig. 6a,b) Active inferior glide
Work in multiple planes	Utilize the previously established motion and strength to work on advanced motor control using open chain exercise in multiple plans of motion Progress to long lever open chain maneuvers	Lawnmower Fencing Power Position Step Back (Fig. 7a,b) Reverse Throwing Eccentric Training T's, I's Y's Horizontal abduction Thrower's Ten

Note: Exercises within the table serve as examples and do not represent an exhaustive list.

Classification II: Symptoms Reported But Cause Not Apparent (Modified Activity and Rehabilitation)

In this category, clinicians may be unintentionally led to believe that any and all impairments identified may be contributing to the dysfunction but the culprit is something more involved and/or outside of traditional impairment testing. For example, a baseball player with questionable throwing mechanics has been playing with scapular and shoulder pain for 3 months. To avoid pain during throwing, he begins to subconsciously alter his mechanics even further but not correctly. The compounding effect of beginning with questionable mechanics and then continuing with additional negative alterations resulted in exacerbated pain and tightness at the shoulder and scapula. The clinician detects the tightness on examination and, assuming the player's issues stem from the lack of flexibility the clinician employs a manual therapy-based mobility program. Although the program alleviates the tightness and pain, the player's symptoms return once throwing commences because the root cause (poor mechanics) was not addressed. This is an example that illustrates how the movement system classification could be useful, but also highlights a possible pitfall. The system helped identify an apparent impairment that improved with the selected treatment. However, once treatment ceased, the symptoms returned suggesting an underlying cause beyond the clinical presentation. This suggests that a multifaceted approach that extends beyond the clinical examination and supervised rehabilitation may be useful.

(a) (a)

Figure 5 The lawnmower with the arm close to body requires the patient to begin with the hips and trunk flexed and the arm held secure to the body (a). The patient is instructed to extend the hips and trunk, maintain the arm position next to the body, and followed by rotation of the trunk to facilitate scapular retraction (b).

(a) (b)

Figure 6 For the low row, the patient is positioned standing with the hand of the involved arm against the side of a firm surface and legs slightly flexed (a). The patient should be instructed to extend the hips and trunk to facilitate scapular retraction and hold the contraction for 5 seconds (b).

Multifaceted rehabilitation would involve clinician-supervised or home-based exercises and/or stretches that target specific muscles and tissues directly affecting scapular function along with modified strength training and conditioning and possible mechanical coaching. Similar to the exercise progression described within the verified impairments or pathology level, the kinetic chain-based approach would be implemented to address scapular control and integration of all kinetic chain links. The strength-training program would also be modified so the athlete receives the training benefit, but the injured or irritated tissue would not be overly stress or taxed. Examples would include modifying arm maneuvers to avoid hyperextension, horizontal abduction, or overhead positions. At this classification level, clinicians tend to address underlying kinetic chain concerns and inflexibilities of local stabilizing muscles while strength and conditioning specialists target muscle hypertrophy and endurance of larger global muscles responsible for movement. Furthermore, because of this less severe presentation, allowing the athlete to participate in some team activities while simultaneously performing the modified rehabilitation and training regimens is permissible and often tolerable. The activity modifications would include limited throwing volume, participation in field drills that only require gathering a ball, and batting. Mechanical concerns could be addressed with coaches who are well versed in biomechanical demands and requirements of the sport. It is important to note that clinicians, strength specialists, and position coaches need to communicate early and often to avoid overlap between training and supervised rehabilitation that could negatively influence the outcome.

(a) (b)

Figure 7 The power position step back begins with the athlete positioned standing similar to the initial phase of throwing (a). The athlete then steps back onto a platform moving the dominant arm into a 90/90 position and forearm pronated (b). The athlete is also instructed to rotate the trunk and balance on the back leg while maintaining the 90/90 position of the arm (b).

Classification III: No Symptoms Reported But Impairments/Deficiencies Identified That May Lead to Injurious Events (Prevention and Maintenance)

This classification tends to arise on pre-season screening examinations. Although numerous risk factors have been identified within specific cohorts, the ones that appear across most studies relate to restricted rotational range of motion and throwing volume across a single season.[69] Thus, clinicians who detect underlying deficiencies ranging from soft tissue inflexibility to muscle weakness or imbalance, tend to implement injury reduction programs in order to stave off habitual soreness or possible injury. Mobility has often been a point of investigative and clinical focus for overhead athletes. However, a recent comprehensive review of commonly seen rotational range of motion deficits noted that there is no clear "best" method for addressing soft tissue inflexibilities in overhead athletes.[70] Using the literature and clinical experience as a guide, the authors of that review suggested the following: (1) clinicians should employ low load, long duration stretching, but not as a part of pre-throwing warm-up regimens; (2) static stretching, self-stretching, and plyometric-based stretching is encouraged to perform as part of the pre-activity (warm-up) regimens; (3) joint mobilizations are permissible but the clinician needs to account for joint position, load applied, technique (oscillations, tractions, or both), and number of bouts; and (4) objective range of motion and subjective end-feels should be assessed prior to employing joint mobilizations to determine if this type of manual therapy technique is applicable to the individual patient.[70] Using these principles as a guide, clinicians have the autonomy to develop mobility programs that are specific to each patient's needs, but in most cases, the latissimus dorsi, pectoralis major and minor, posterior rotator cuff muscles, and biceps brachii muscles in addition to the shoulder capsule will be the point of focus.

Since athletes at this level will be participating in all team activities without limitation, clinicians should diligently assess all aspects of the athlete's regimen – mechanics during throwing, fielding, and hitting; technique during strength and conditioning maneuvers; volume and frequency of sporting drills; and off-season programming – to determine if an adjustment to current training should be employed. Furthermore, an assessment of the athlete's pre-throwing regimen should occur. The adjustments could be a modification of training interventions (more endurance-focused exercises rather than power-focused exercises), an addition of exercises not currently being performed, or a change in mechanics during drills or throwing. Pre and post activity measurements of GH rotation and scapular position should be obtained because a significant percentage of throwing athletes will demonstrate large changes that can have implications for shoulder and arm kinematics.[71]

Conclusion

Optimal scapular function is integral to optimal shoulder function. Multiple roles of the scapula in arm function and throwing have been identified while scapular dysfunction continues to be associated with various shoulder pathologies. Although scapular motion alterations may be common in overhead athletes, various reports have shown that identification and management of the alterations can result in improved rehabilitation and performance outcomes. Considering that baseball throwing occurs as the result of integrated, multi-segmented, sequential joint motion and muscle activation within the kinetic chain, function and dysfunction within the kinetic chain needs to be understood. Furthermore, the scapula is a key component link within the chain through its function to maximize scapulohumeral rhythm and efficient throwing mechanics. Therefore, evaluation and management beginning with the scapula can produce improved outcomes related to shoulder pathology in overhead athletes. Although rehabilitation programs follow a core set of principles, they should be individualized based on the presentation of the patient and the needs for return to sport.

References

1. Martin C, Kulpa R, Delamarche P, et al: Professional tennis player's serve: Correlation between segmental angular momentums and ball velocity. Sports Biomech 12:2-14, 2013
2. Nieminen H, Niemi J, Takala EP, et al: Load-sharing patterns in the shoulder during isometric flexion tasks. J Biomech 28:555-566, 1995
3. Kibler WB, Sciascia AD, Dome DC: Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. Am J Sports Med 34:1643-1647, 2006
4. Smith J, Dietrich CT, Kotajarvi BR, et al: The effect of scapular protraction on isometric shoulder rotation strength in normal subjects. J Shoulder Elbow Surg 15:339-343, 2006
5. McClure PW, Michener LA, Sennett BJ, et al: Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. J Shoulder Elbow Surg 10:269-277, 2001
6. Ludewig PM, Phadke V, Braman JP, et al: Motion of the shoulder complex during multiplanar humeral elevation. J Bone Joint Surg Am 91A:378-389, 2009
7. Sheean AJ, Kibler WB, Conway J, et al: Posterior labral injury and glenohumeral instability in overhead athletes: current concepts for diagnosis and management. J Am Acad Orthop Surg 28:628-637, 2020
8. Kibler WB, Sciascia A: The role of the scapula in preventing and treating shoulder instability. Knee Surg Arthrosc Sport Traumatol 24:390-397, 2016
9. 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 32:1436-1443, 2014
10. Lawrence RL, Braman JP, LaPrade RF, et al: Comparison of 3-dimensional shoulder complex kinematics in individuals with and without shoulder pain, part 1: Sternoclavicular, acromioclavicular, and scapulothoracic joints. J Orthop Sports Phys Ther 44:636-645, 2014
11. Lawrence RL, Braman JP, Staker JL, et al: Comparison of 3-dimensional shoulder complex kinematics in individuals with and without shoulder pain, part 2: Glenohumeral joint. J Orthop Sports Phys Ther 44:646-655, 2014
12. Meyer KE, Saether EE, Soiney EK, et al: Three-dimensional scapular kinematics during the throwing motion. J Appl Biomech 24:24-34, 2008
13. Provencher MT, Makani A, McNeil JW, et al: The role of the scapula in throwing disorders. Sports Med Arthrosc Rev 22:80-87, 2014
14. Fleisig GS, Andrews JR, Dillman CJ, et al: Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med 23:233-239, 1995
15. Fleisig GS, Barrentine SW, Zheng N, et al: Kinematic and kinetic comparison of baseball pitching among various levels of development. J Biomech 32:1371-1375, 1999
16. Yoshizaki K, Hamada J, Tamai K, et al: Analysis of the scapulohumeral rhythm and electromyography of the shoulder muscles during elevation and lowering: Comparison of dominant and nondominant shoulders. J Shoulder Elbow Surg 18:756-763, 2009
17. Dvir Z, Berme N: The shoulder complex in elevation of the arm: A mechanism approach. J Biomech 11:219-225, 1978
18. Kibler WB, Sciascia A, Wilkes T: Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg 20:364-372, 2012
19. Ebaugh DD, McClure PW, Karduna AR: Three-dimensional scapulothoracic motion during active and passive arm elevation. Clin Biomech 20:700-709, 2005
20. Provencher MT, Kirby H, McDonald LS, et al: Surgical release of the pectoralis minor tendon for scapular dyskinesia and shoulder pain. Am J Sports Med 45:173-178, 2017
21. Kibler WB, Wilkes T, Sciascia A: Mechanics and pathomechanics in the overhead athlete. Clin Sports Med 32:637-651, 2013
22. Oliver GD, Weimar WH, Plummer HA: Gluteus medius and scapula muscle activations in youth baseball pitchers. J Strength Cond Res 29:1494-1499, 2015
23. Hirashima M, Kadota H, Sakurai S, et al: Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing. J Sport Sci 20:301-310, 2002
24. Hirashima M, Yamane K, Nakamura Y, et al: Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. J Biomech 41:2874-2883, 2008
25. Leong HT, Tsui SSM, Ng GYF, et al: Reduction of the subacromial space in athletes with and without rotator cuff tendinopathy and its association with the strength of scapular muscles. J Sci Med Sport 19:970-974, 2016

26. Cools AM, Witvrouw EE, DeClercq GA, et al: Scapular muscle recruitment pattern: Trapezius muscle latency with and without impingement symptoms. Am J Sports Med 31:542-549, 2003
27. Joshi M, Thigpen CA, Bunn K, et al: Shoulder external rotation fatigue and scapular muscle activation and kinematics in overhead athletes. J Ath Train 46:349-357, 2011
28. Myers N, Sciascia A, Westgate PM, et al: Increasing ball velocity in the overhead athlete: A meta-analysis of randomized controlled trials. J Strength Cond Res 29:2964-2979, 2015
29. Kibler WB, Ludewig PM, McClure PW, et al: Scapula summit 2009. J Orthop Sports Phys Ther 39:A1-A13, 2009
30. Kibler WB, Ludewig PM, McClure PW, et al: Clinical implications of scapular dyskinesis in shoulder injury: The 2013 consensus statement from the "scapula summit". Br J Sports Med 47:877-885, 2013
31. Warner JJP, Micheli LJ, Arslanian LE, et al: Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. Am J Sports Med 18:366-375, 1990
32. Weiser WM, Lee TQ, McQuade KJ: Effects of simulated scapular protraction on anterior glenohumeral stability. Am J Sports Med 27:801-805, 1999
33. Ludewig PM, Reynolds JF: The association of scapular kinematics and glenohumeral joint pathologies. J Orthop Sports Phys Ther 39:90-104, 2009
34. McClure PW, Tate AR, Kareha S, et al: A clinical method for identifying scapular dyskinesis: Part 1: Reliability. J Athl Train 44:160-164, 2009
35. Tate AR, McClure PW, Kareha S, et al: A clinical method for identifying scapular dyskinesis: Part 2: Validity. J Athl Train 44:165-173, 2009
36. Uhl TL, Kibler WB, Gecewich B, et al: Evaluation of clinical assessment methods for scapular dyskinesis. Arthroscopy 25:1240-1248, 2009
37. Kibler WB: The role of the scapula in athletic function. Am J Sports Med 26:325-337, 1998
38. Seitz AL, McClure PW, Lynch SS, et al: Effects of scapular dyskinesis and scapular assistance test on subacromial space during static arm elevation. J Shoulder Elbow Surg 21:631-640, 2012
39. Kibler WB, Sciascia AD, Dome DC, et al: Clinical utility of new and traditional exam tests for biceps and superior glenoid labral injuries. Am J Sports Med 37:1840-1847, 2009
40. Borstad JD, Ludewig PM: The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. J Orthop Sports Phys Ther 35:227-238, 2005
41. Huang TS, Du WY, Wang TG, et al: Progressive conscious control of scapular orientation with video feedback has improvement in muscle balance ratio in patients with scapular dyskinesis: A randomized controlled trial. J Shoulder Elbow Surg 27:1407-1414, 2018
42. Laudner KG, Stanek JM, Meister K: Differences in scapular upward rotation between baseball pitchers and position players. Am J Sports Med 35:2091-2095, 2007
43. Ludewig PM, Cook TM: Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Phys Ther 80:276-291, 2000
44. Paletta GA, Warner JJP, Warren RF, et al: Shoulder kinematics with two-plane x-ray evaluation in patients with anterior instability or rotator cuff tears. J Shoulder Elbow Surg 6:516-527, 1997
45. Kibler WB, Sciascia AD: Kinetic chain contributions to elbow function and dysfunction in sports. Clin Sports Med 23:545-552, 2004
46. Kibler WB, Kuhn JE, Wilk KE, et al: The disabled throwing shoulder—Spectrum of pathology: 10 year update. Arthroscopy 29:141-161, 2013
47. Burkhart SS, Morgan CD, Kibler WB: The disabled throwing shoulder: Spectrum of pathology Part I: Pathoanatomy and biomechanics. Arthroscopy 19:404-420, 2003
48. Myers JB, Laudner KG, Pasquale MR, et al: Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. Am J Sports Med 34:385-391, 2006
49. Laudner KG, Myers JB, Pasquale MR, et al: Scapular dysfunction in throwers with pathologic internal impingement. J Orthop Sports Phys Ther 36:485-494, 2006
50. Mihata T, Jun BJ, Bui CN, et al: Effect of scapular orientation on shoulder internal impingement in a cadaveric model of the cocking phase of throwing. J Bone Joint Surg Am 94:1576-1583, 2012
51. Fedoriw WW, Ramkumar P, McCulloch PC, et al: Return to play after treatment of superior labral tears in professional baseball players. Am J Sports Med 42:1155-1160, 2014
52. Edwards SL, Lee JA, Bell JE, et al: Nonoperative treatment of superior labrum anterior posterior tears: Improvements in pain, function, and quality of life. Am J Sports Med 38:1456-1461, 2010
53. Sarkar S, Seeley S, Beranek K, et al: Rotator cuff proximity to potential impinging structures during clinical impingement tests. In: Paper presented at: IXth Conference of the International Shoulder Group, Wales, UK, 2012; Wales, UK.
54. Ellenbecker TS, Cools A: Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: An evidence-based review. Br J Sports Med 44:319-327, 2010
55. Mihata T, McGarry MH, Kinoshita M, et al: Excessive glenohumeral horizontal abduction as occurs during the late cocking phase of the throwing motion can be critical for internal impingement. Am J Sports Med 38:369-382, 2010
56. Kuhn JE: Exercise in the treatment of rotator cuff impingement: A systematic review and a synthesized evidence-based rehabilitation protocol. J Shoulder Elbow Surg 18:138-160, 2009
57. Wilk KE, Macrina LC, Fleisig GS, et al: Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers: A prospective study. Am J Sports Med 43:2379-2385, 2015
58. Tripp B, Uhl TL, Mattacola CG, et al: Functional multijoint position reproduction acuity in overhead athletes. J Ath Train 41:146-153, 2006
59. Ludewig PM, Kamonseki DH, Staker JL, et al: Changing our diagnostic paradigm: Movement system diagnostic classification. Int J Sports Phys Ther 12:884-893, 2017
60. Sciascia AD, Kibler WB: Principles of physical examination eds. In: Kibler WB, Sciascia AD (eds): Mechanics, Pathomechanics and Injury in the Overhead Athlete: A Case-Based Approach to Evaluation, Diagnosis, and Management, Switzerland: Springer, 63-74, 2019
61. Garcia GH, Gowd AK, Cabarcas BC, et al: Magnetic resonance imaging findings of the asymptomatic elbow predict injuries and surgery in major league baseball pitchers. Orthop J Sports Med 7:2325967118818413, 2019
62. Lesniak BP, Baraga MG, Jose J, et al: Glenohumeral findings on magnetic resonance imaging correlate with innings pitched in asymptomatic pitchers. Am J Sports Med 41:2022-2027, 2013
63. Sciascia A, Cromwell R: Kinetic chain rehabilitation: A theoretical framework. Rehabil Res Pract 2012:1-9, 2012
64. McMullen J, Uhl TL: A kinetic chain approach for shoulder rehabilitation. J Ath Train 35:329-337, 2000
65. Oliver GD, Washington JK, Barfield JW, et al: Quantitative analysis of proximal and distal kinetic chain musculature during dynamic exercises. J Strength Cond Res 32:1545-1553, 2018
66. Yamauchi T, Hasegawa S, Matsumura A, et al: The effect of trunk rotation during shoulder exercises on the activity of the scapular muscle and scapular kinematics. J Shoulder Elbow Surg 24:955-964, 2015
67. Suprak DN, Sahlberg JD, Chalmers GR, et al: Shoulder elevation affects joint position sense and muscle activation differently in upright and supine body orientations. Hum Move Sci 46:148-158, 2016
68. Bouisset S, Zattara M: A sequence of postural movements precedes voluntary movement. Neurosci Let 22:263-270, 1981
69. Agresta CE, Krieg K, Freehill MT: Risk factors for baseball-related arm injuries: A systematic review. Orthop J Sports Med 7:2325967119825557, 2019
70. Manske R, Wilk KE, Davies G, et al: Glenohumeral motion deficits: Friend or foe? Int J Sports Phys Ther 8:537-553, 2013
71. Wilk KE, Macrina LC, Fleisig GS, et al: Loss of internal rotation and the correlation to shoulder injuries in professional baseball pitchers. Am J Sports Med 39:329-335, 2011