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Rehabilitation of the Overhead Throwing Athlete: There Is More to It Than Just External Rotation/Internal Rotation Strengthening

Kevin E. Wilk, PT, DPT, FAPTA, Christopher A. Arrigo, MS, PT, ATC, Todd R. Hooks, PT, ATC, OCS, SCS, NREMT-1, CSCS, CMTPT, FAAOMPT, James R. Andrews, MD

Abstract

The repetitive nature of throwing manifests characteristic adaptive changes to the shoulder, scapulothoracic, and hip/pelvis complexes that result in a set of unique physical traits in the overhead throwing athlete. An effective rehabilitation program is dependent upon an accurate evaluation and differential diagnosis to determine the causative factors for the athlete's pathologic features. The treatment program should be individualized with specific strengthening and flexibility exercises to achieve the dynamic stability that is required for overhead function. In this article we describe the characteristics of the throwing shoulder, along with a multiphased rehabilitation program that allows for the restoration of strength, mobility, endurance, and power and is aimed toward a return to unrestricted sporting activity. We also describe exercises that link the upper and lower extremities because of the importance of core control and leg strength in the development of power during the act of throwing. Additionally, proper throwing mechanics, utilization of pitch counts, appropriate rest, and proper off-season conditioning will help decrease overall injury risk in the overhead throwing athlete.

Introduction

The repetitive nature of overhead throwing causes the shoulder complex to be a common site of disfunction in overhead throwing athletes. Conte et al [1] reported that shoulder injuries represented 27.8% of all disabled days among professional baseball players. Major League Baseball pitchers have been shown to have a 34% greater upper extremity injury rate compared with position players, and when pitchers were placed on the disabled list, they remained on the list for an average of 20.10 more days (74.25 days for pitchers compared with 54.15 days for position players) [2]. According to the National Collegiate Athletic Association Injury Surveillance System, shoulder strains/tendinitis injuries equated to 8.2% of all injuries occurring during games and 16.7% of injuries during practice [3]. The shoulder has also been reported to be the most commonly injured region in high school baseball players, representing 34.2% of all injuries in pitchers and 24.9% in catchers, with an overall prevalence of 17.6% for all positions [4].

The throwing motion places tremendous forces across the glenohumeral joint, with angular velocities reaching 7250°/s and anterior shear forces approaching 50% of body weight [5-7]. Throwing also generates high levels of muscular activity, with forces reaching 120% of maximal volitional isometric contractions [8]. Although an inherent degree of mobility is needed during the throwing motion, the athlete is dependent upon dynamic stability while throwing to minimize the potential for injury. The "thrower's paradox," as described by Wilk et al [9], illustrates the essential rehabilitation challenge in the overhead throwing athlete—that the shoulder must be loose enough to throw yet stable enough to prevent injury. The inability to successfully balance this paradox is the primary reason overhead throwing athletes are commonly injured and that their successful return to athletic participation can be difficult to manage.

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Musculoskeletal adaptations occur within the shoulder joint complex as a result of throwing at a young age, throwing frequently, and high-volume throwing. Adaptations can occur to osseous structures (eg, the humeral head and glenoid fossa) or soft tissue structures (eg, the rotator cuff and glenohumeral joint capsule). In addition, postural adaptations to the scapular position are also apparent. Furthermore, specific adaptations occur at the hip joint complex as a result of throwing [10].

The focus of this article is a discussion of a thorough rehabilitation process for the overhead thrower and the concept that rehabilitation must entail more than just rotator cuff exercises when an athlete experiences shoulder pain; rather, the entire body needs to be comprehensively examined and systematically treated to ensure an uncomplicated return to overhead throwing.

Key Rehabilitation Principles

The keys to the successful rehabilitation of the overhead throwing athlete are tied to the ability to adequately ascertain and appropriately address the unique characteristics and underlying pathologic processes inherent to the thrower's shoulder. These characteristics and processes include the intrinsic soft tissue and osseous adaptations evident during physical examination, as well as extrinsic factors that include variables such as frequency, intensity, and duration of throwing. The keys to successful rehabilitation of the overhead throwing athlete include the importance of proper shoulder mobility, the need for a functional scapular base of support, the critical role of dynamic stability and neuromuscular control, and the importance of core, hip, and leg strength.

Normalizing Shoulder Mobility

Normalizing shoulder motion is essential for successful rehabilitation of the throwing athlete. Particular attention should be directed to restoring shoulder internal rotation (IR), total rotational motion (TRM), and horizontal adduction. It is common for the overhead thrower to exhibit a significant loss of IR. This loss of IR is often referred to as GIRD (glenohumeral internal rotation deficit) and is defined as a loss of IR in the throwing shoulder of 17° or more when compared with the nonthrowing arm [11,12]. The loss of IR seen in throwers is most often due to osseous adaptations of the humerus and posterior muscular tightness, which have been suggested to cause specific shoulder injuries, including internal impingement and superior labral lesions [12,13]. TRM is the value derived by adding the IR and external rotation (ER) measurements in 90° of shoulder abduction [9]. This total arc of rotation has been shown to be within 5° bilaterally in asymptomatic professional pitchers [14]. A TRM arc greater than 5° has also been shown to be a contributing factor in the development of throwing shoulder injuries [9,14,15].

Eccentric muscle contractions have been correlated with a rise in passive muscular tension and a loss of joint range of motion (ROM) [16]. It is our experience that baseball players often describe generalized tightness in the musculature of the posterior shoulder after pitching. The muscles responsible for ER of the shoulder exhibit high eccentric muscle activity during the acceleration portion of the throwing motion as the shoulder internally rotates between 6000° and 7000° per second [5-7]. It appears that the muscle activity involved in baseball pitching may be responsible for an acute loss in IR immediately after pitching. Previous studies examining the effect of repetitive eccentric contractions have shown a loss of joint ROM in the upper and lower extremities during testing [17].

We do not believe that the loss of IR is routinely due to posterior capsular tightness. Most throwers exhibit significant posterior laxity when evaluated [13]. Borsa et al [13] studied glenohumeral translation in 43 healthy baseball pitchers and reported an increased posterior translation compared with anterior translation in the throwing arm and no difference in translation between dominant and nondominant shoulders [8].

Functional Scapular Base

Scapular stability is crucial for normal asymptomatic arm function, especially in an overhead throwing athlete. Several authors have emphasized the importance of scapular muscle strength and neuromuscular control in contributing to normal shoulder function [16,18-20]. The force couples of the upper trapezius, serratus anterior, and lower trapezius play an integral role in the throwing motion by posteriorly tilting, elevating, and upwardly rotating the scapula, thereby placing it in a functionally appropriate position for successful throwing.

Throwers frequently exhibit rounded shoulders and forward head posture. This postural positioning is associated with muscle weakness of the scapular retractors due to prolonged elongation and altered length tension relationships between synergistic muscle groups that elevate, posteriorly tip, abduct, and protract the scapula during active arm elevation. In addition, the scapula on the throwing side may often appear protracted, depressed, and anteriorly tilted in relationship to the contralateral scapula. An anteriorly tilted scapula has been shown to contribute to a loss of glenohumeral joint IR [21,22]. In overhead throwers, it is our experience that this abnormal scapular positioning is associated with pectoralis minor muscle tightness, coracoid pain, lower trapezius muscle weakness, and a forward head posture. In some instances, tightness of the pectoralis minor muscle can lead to axillary artery occlusion and neurovascular symptoms such as arm fatigue, pain, tenderness, and cyanosis [23-26]. Tightness of the pectoralis minor most frequently results in an anteriorly tilted scapula and may contribute to shoulder pain during throwing or exercising. The lower trapezius muscle is an important muscle in arm deceleration because of its controlling effect on scapular elevation and protraction [8]. Weakness of the lower trapezius muscle may result in improper throwing mechanics or a greater propensity toward developing shoulder symptoms while throwing. Careful assessment of scapular position, mobility, and strength in the thrower is essential to ensure symptom-free overhead athletic function.

Neuromuscular Control and Dynamic Stability

Neuromuscular control plays a critical role in the generation of dynamic shoulder stability [27,28]. In the shoulder, neuromuscular control refers to the constant interplay of afferent input and efferent output required to produce stable and effective volitional movement.

The primary stabilizers of the glenohumeral complex produce a co-contraction that enhances humeral head stability during active arm movements. The combined effect of the rotator cuff musculature is a synergistic action that creates humeral head compression within the glenoid and counterbalances the shearing forces generated by the deltoid [29,30].

Additionally, active glenohumeral joint stability is provided through blending of the rotator cuff tendons in the shoulder capsule, which produces tension with the capsular ligaments. As the rotator cuff contracts, fibers of the muscle tighten the capsule, thus enhancing the static stabilizers of the glenohumeral joint, which accentuates the centering of the humeral head within the glenoid fossa.

Core and Leg Strength and Proper Functioning

The importance of a strong and properly functioning core, hips, and legs cannot be overemphasized in the rehabilitation of the overhead throwing athlete. Many of the exercises we perform today focus on linking the shoulder and the lower extremity to facilitate the transfer of power from the lower extremity to the arm during throwing. These exercises are frequently performed on a stability ball to challenge the core and hips in the process. We frequently see poor core, hips, and leg strength in adolescent and preadolescent athletes. Their posterior chain musculature (gluteals, hamstrings, and erector spinae) is frequently underdeveloped and lacks adequate control and sequential activation during basic athletic movements. Beckett et al [31] reported a high prevalence of poor single-legged squat test results in these athletes. We will discuss numerous exercises and drills for this age group that are designed to emphasize core, hip, and leg strength in the rehabilitation process.

Multi-Phased Rehabilitation Program

The optimal rehabilitation program for the throwing athlete involves a progressive, sequential, multi-phased approach that is based on the findings identified during the physical examination with regard to pathologic findings, specific structures involved, and the root cause of the condition. The 4 rehabilitative phases for the overhead throwing athlete are presented in Table 1. This approach should be paired with the therapist's knowledge of the sequential and progressive implementation of principles related to the restoration of strength, dynamic stability, and neuromuscular control in the overhead throwing athlete. Each phase represents a progression in which exercises become more aggressive and demanding and the stresses applied to the shoulder joint gradually intensify.

Phase 1: Acute Phase

The goals in the initial phase of the rehabilitation program are to diminish pain and inflammation, normalize motion, correct postural adaptations, normalize muscle balance, restore proper muscle activation, and re-establish baseline dynamic joint stability. During the acute phase of treatment the athlete may be prescribed nonsteroidal anti-inflammatory drugs and/or a local injection; however, clinically, local therapeutic modalities such as ice, laser treatments, iontophoresis, and/or electrical stimulation are also used to diminish pain and inflammation. The athlete is educated regarding activity modification/avoidance (such as throwing, strenuous activities, and exercises), as well as posture while sitting and standing to increase subacromial space [32].

After the resolution of acute inflammation, the rehabilitation specialist may implement the use of moist heat to increase local circulation and improve soft tissue extensibility, including the joint capsule and musculotendinous tissues. This type of passive warm-up is combined with ROM and joint mobilization techniques to improve joint mobility and reduce symptoms. During this initial phase, it is essential to normalize the patient's shoulder joint passive ROM (PROM).

The clinician may utilize soft tissue mobilization techniques with the goal of improving tissue extensibility, reducing pain and guarding, and preparing the athlete for activities. Decreased electromyography (EMG) activity of 23% with a corresponding reduction of 32% ER force production has been documented in a painful shoulder, lending credence to the importance of pain reduction to permit restoration of normal rotator cuff recruitment [33]. Additionally, to diminish pain and muscle guarding via stimulation of the type 1 and 2

Table 1
Rehabilitation of the overhead throwing athlete: phases and goals

Phase 1: Acute Phase
Goals
Diminish pain and inflammation
Normalize motion
Delay muscular atrophy
Re-establish dynamic stability (muscular balance)
Control functional stress/strain
Exercises and modalities
Cryotherapy, iontophoresis, ultrasound, electrical stimulation
Flexibility and stretching for posterior shoulder muscles to improve shoulder internal rotation and horizontal adduction
Rotator cuff strengthening (especially external rotator muscles)
Scapular muscles strengthening (especially retractor and depressor muscles)
Dynamic stabilization exercises (rhythmic stabilization)
Weight-bearing exercises
Proprioception training
Abstain from throwing
Phase 2: Intermediate Phase
Goals
Progress strengthening exercises
Restore muscular balance
Enhance dynamic stability
Control flexibility and stretches
Exercises and modalities
Continue stretching and flexibility (especially shoulder internal rotation and horizontal adduction)
Progress isotonic strengthening
Complete shoulder program
Thrower's Ten program
Rhythmic stabilization drills
Initiate core lumbopelvic region strengthening program
Initiate leg lower extremity program
Phase 3: Advanced Strengthening Phase
Goals
Aggressive strengthening
Progress neuromuscular control
Improve strength, power, and endurance
Exercises and modalities
Flexibility and stretching
Rhythmic stabilization drills
Advanced Thrower's Ten program
Initiate plyometric program
Initiate endurance drills
Initiate short-distance throwing program
Phase 4: Return to Activity Phase
Goals
Progress to throwing program
Return to competitive throwing
Continue strengthening and flexibility drills
Exercises
Stretching and flexibility drills
Thrower's Ten program
Plyometric program
Progress interval throwing program to competitive throwing

mechanoreceptors, active-assisted ROM (AAROM), light manual stretches, and grade 1 and 2 joint mobilizations are also performed [34-36].

During the acute phase of rehabilitation, the clinician should ensure the normalization of motion by incorporating AAROM, PROM, manual stretches, and mobilization techniques. Although all aspects of shoulder mobility should be assessed, it is common for the overhead throwing athlete to display a loss of IR and horizontal adduction. The loss of IR is commonly described as GIRD. As previously described, a loss in IR of 17° or more in the throwing shoulder has been found in persons with shoulder and elbow injuries [37-40]. Glenohumeral IR loss has been largely attributed to osseous adaptations, but other structures can contribute to the loss of IR, such as posterior rotator cuff tightness, posterior capsule tightness, and an anteriorly tilted scapula [9,41-46]. A proper clinical assessment to differentiate between altered scapula positioning, posterior glenohumeral joint capsule tightness, and/or posterior shoulder muscle tightness as the causative factor(s) of the diminished ROM is essential for the clinician to guide the appropriate treatment selection to restore IR. Mobility of the glenohumeral joint capsule can be assessed by centering the humeral head within the glenoid fossa and assessing the amount of translation available, comparing dominant with nondominant shoulders. In addition, the clinician can perform diagnostic ultrasound imaging of the humeral head, in particular the bicipital groove, and determine the amount of humeral head retroversion. Several investigators have documented the use of ultrasound as a reliable and valid method of determining humeral retroversion [47-51].

A complete assessment of posture and scapular mobility should be conducted, because an anteriorly tilted, protracted, and depressed scapular position is often seen when compared with the nonthrowing side. This positioning can create muscle weakness and/or inhibition of the scapular retractors as a result of an altered length tension relationship of the scapular force couples. Lower trapezius weakness and/or poor muscle activation with delayed muscle firing can result in improper scapular mechanics and potential shoulder symptoms, which must be addressed with focused strengthening activity [7]. In addition, pectoralis minor tightness and coracoid pain are often noted. The decreased flexibility of the pectoralis minor can cause neurovascular symptoms including arm fatigue, pain, tenderness, and cyanosis due to occlusion as they pass underneath this muscle [25,26]. The pectoralis minor muscle can be assessed for tightness by having the patient stand against a wall and measuring the distance from the wall to the anterior acromial tip; a side to side asymmetry greater than 3 cm is considered abnormal [52]. We commonly perform pectoralis minor muscle stretches with the scapula placed in a retracted and posteriorly tilted position in 90° of shoulder flexion as the humerus is placed in an abducted and ER position [53,54].

The posterior shoulder is subjected to repetitive eccentric loads during throwing, which can result in increased internal stiffness and decreased shoulder ROM [55]. The modified sleeper stretch (Figure 1), modified cross-body horizontal adduction stretch (Figure 2), and

Figure 1. Modified sleeper stretch. The athlete is rotated slightly posterior to position the shoulder in the scapular plane as internal rotation is passively performed.

Figure 3. Horizontal adduction with concomitant internal rotation. The clinician performs passive horizontal adduction while stabilizing the scapula as the athlete applies an internal rotation stretch.

horizontal adduction stretch with concomitant IR (Figure 3) are performed to improve flexibility of the posterior shoulder [56]. The posterior capsule has been shown to exhibit significant laxity in throwers who exhibit GIRD, and therefore a proper evaluation should be performed to determine capsular mobility prior to initiating any posterior mobilization efforts [13]. Mobilizations for the posterior capsule are performed parallel to the glenoid fossa in a posterior-lateral direction to increase pliability of the posterior capsule only when true posterior capsular tightness is present (Figure 4).

In addition, Kibler [19] and Beckett et al [31] have reported an association between scapular dyskinesis and hip abduction weakness. Recently, Beckett et al [31] assessed scapular position and hip strength in preadolescent and adolescent baseball players. The investigators reported a higher rate of scapular dyskinesis in the adolescent group compared with the preadolescent group and poor outcomes of single-leg squat tests. During the physical examination, we recommend that the patient perform a single-leg squat test and that the movement be compared bilaterally (Figure 5). The clinician should assess for any excessive lateral trunk displacement, valgus knee collapse, excessive hip flexion, lateral dropping of the pelvis, and lower extremity pain or dysfunction during the movement. Hip girdle weakness can be treated with lower extremity exercises discussed in this article and neuromuscular control activities to improve scapular kinesis and proprioception. We believe that hips, core, and scapular exercises are critical to the successful treatment of the throwing athlete (especially young baseball players).

During this early phase of rehabilitation, strengthening exercises are initiated with the intention of restoring muscle balance and impeding any further muscle atrophy [27,28]. The clinician may opt to initiate isometrics during this acute phase in the presence of excessive pain and/or soreness and progress to isotonics as tolerated. The aim of exercises in this phase is to reestablish dynamic stability; therefore, the initial focus is on the innately weak posterior rotator cuff and supraspinatus musculature [27,28]. Rhythmic stabilization (RS) exercises are also performed, beginning with

Figure 2. Modified cross-body stretch. The athlete passively horizontally adducts the shoulder as the scapula is stabilized against the table while external rotation is restricted with counter-pressure of the opposite forearm.

Figure 4. Mobilizations are performed for the posterior capsule in a posterior-lateral direction.

Figure 5. Single leg squat assessment. Bilateral comparison of position and movement of the trunk, pelvis, knee, and ankle.

holds for the internal and external rotators with the arm in neutral rotation and the shoulder in 30° of abduction. Manual cueing is used to facilitate a co-contraction of the internal and external rotators to provide isometric stabilization of the glenohumeral joint. These drills also can be performed with the shoulder in approximately 100° of elevation and 10° of horizontal abduction. This "balanced position" is beneficial because the resultant force vectors of the rotator cuff and deltoid musculature provide a centralized compression of the humeral head in this position [57,58]. The athlete's arm can be placed at various angles of both external rotation and elevation while applying manual cueing in various planes to facilitate recruitment of the surrounding musculature and promote dynamic stability. The goal is to train the patient to stabilize and control humeral head translation during applied movements.

Proprioceptive sense can be diminished as a result of hypermobility from joint laxity and micro- or macrotrauma of the glenohumeral joint, and thus the rehabilitation specialist should initiate techniques to heighten the sensory awareness of the afferent mechanoreceptors during this phase of rehabilitation [59,60]. Proprioception and enhanced functional throwing performance test scores have been shown to improve after a 5-week neuromuscular and proprioceptive neuromuscular facilitation (PNF) training program that challenges the glenohumeral musculature [61,62]. RS drills discussed previously and D2 flexion/extension PNF movement patterns are performed to augment proprioception and dynamic stability of the shoulder [20,27,28,59,60,63]. Joint congruency is enhanced by facilitation of agonist and antagonist muscles in restoring a balance in the force couples of the shoulder joint complex [64]. Joint position reproduction drills and upper extremity axial loading exercises such as weight shifts, weight shifts on a ball, wall push-ups, and quadruped drills are performed to stimulate the articular mechanoreceptors and aid in training proprioception during the early stage of treatment [27,65,66].

Effective transfer of kinetic energy from the lower body to the upper extremity, which is vital during throwing, requires adequate mobility, stability, and strength of the legs, hips, and trunk. Core and hip complex exercises are used in this phase for postural reeducation, stability, and mobility of the trunk.

Phase 2: Intermediate Phase

Along with progression of the strengthening program, the goals of the second phase are to increase the flexibility, mobility, and ROM of the shoulder joint complex and enhance the athlete's overall neuromuscular control. An EMG data—driven exercise program designed by Wilk et al [65], the Thrower's Ten, is implemented during this stage to permit a progression to more aggressive isotonic strengthening activities that emphasize the restoration of muscle balance [18,67-74] (Table 2). Because the external rotators are often weak, side-lying shoulder ER and prone rowing into shoulder ER are prescribed as a result of the high EMG activity of the posterior rotator cuff during these movements [67].

The Thrower's Ten program is most commonly initiated in the standing position for the glenohumeral joint exercises and in the prone position for scapular exercises. Once proper muscle activation has been established, we recommend performing the Throwers Ten exercises on a stability ball to maximally challenge the upper extremity and core musculature together.

Neuromuscular control and stabilization drills from phase 1 progress toward the end ROM, including PNF exercises in a full arc of the patient's available painfree ROM. These drills promote endurance training and dynamic stabilization of the rotator cuff. Manual resistance training also can be performed during this stage,

Table 2
Thrower's Ten program

Diagonal pattern D2 extension
Diagonal pattern D2 flexion
External rotation at 0° abduction
Internal rotation at 0° abduction
Shoulder abduction to 90°
Scaption, external rotation ("full cans")
Side-lying external rotation
Prone horizontal abduction
Prone horizontal abduction (full external rotation, 100° abduction)
Prone rowing
Prone rowing into external rotation
Press-ups
Push-ups
Elbow flexion
Elbow extension
Wrist extension
Wrist flexion
Wrist supination
Wrist pronation

which provides the clinician with the ability to vary resistance throughout the movement, incorporate concentric and eccentric contractions, add RS during the exercise, and perform manual cueing for the scapular musculature at the same time.

The scapula is vital for optimal arm function because it provides proximal stability to allow for efficient distal mobility. The significance of its musculature in permitting normal shoulder function has been well described by various authors [19,75-77]. Wilk and Arrigo [27] formulated specific neuromuscular exercises designed to normalize the force couples of the scapular musculature and stimulate proprioceptive and kinesthetic awareness to improve the neuromuscular control of the scapulothoracic joint. The scapular retractors, protractors, and depressors are typically emphasized because they are commonly weak in the overhead throwing athlete (Figure 5).

Closed kinetic chain exercises are advanced to include proprioceptive drills, such as planks and table push-ups on a ball or tilt board (Figure 6) because these exercises have been shown to generate more upper and middle trapezius activity, as well as serratus anterior activity, compared with performing a standard push-up exercise [78]. Stabilization drills also can be performed with the athlete's hand on a small ball against the wall as the clinician performs perturbation drills against the athlete's arm (Figure 7).

In this phase, specific exercises may be incorporated to link the shoulder joint complex and core/lower extremity. An effective exercise for this purpose is the side plank with external rotation (Figure 8). This exercise specifically engages the hip abductors and shoulder muscles. Additionally, prone full planks (with 1- to 2-minute holds), upper extremity wall slides for the serratus anterior, and wall circles for lower trapezius activation and anterior shoulder stretching are effective

Figure 6. Push-ups on an unstable surface with manual rhythmic stabilizations to facilitate dynamic stability for the shoulder and core musculature.

[79]. During this phase, specific exercises for lower trapezius activation and strengthening are incorporated, such as the modified robbery (Figure 9), table press-downs, and prone scapular lift-offs.

Flexibility and ROM exercises for the shoulder joint complex are continued throughout this phase of treatment, along with appropriate stretching for the trunk and lower quarter. Stabilization and strengthening

Figure 7. Stabilization exercises as the athlete performs ball dribbles with the shoulder maintained at 90° abduction as manual stabilizations are performed.

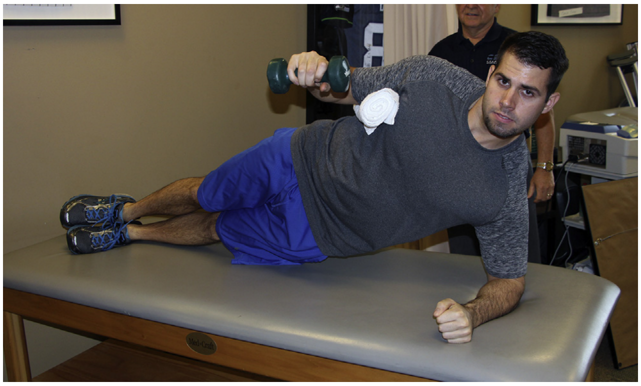

Figure 8. Side plank with external rotation.

exercises for the abdomen and lower back also should be incorporated into the treatment program. In addition, athletes are encouraged to perform lower extremity strengthening exercises and sport-specific conditioning activities beginning in this phase.

Phase 3: Advanced Strengthening Phase

The advanced strengthening phase is designed to initiate aggressive strengthening exercises, augment power and endurance, advance functional drills, and gradually initiate throwing activities. Full shoulder ROM and flexibility should be maintained throughout this phase; failure to maintain motion and flexibility at this point is a potential pitfall that can result in recurrent symptoms. Muscle fatigue has been shown to decrease neuromuscular control and diminish proprioceptive sense [80]. In this phase, strengthening activities are advanced using the Advanced Thrower's Ten program, which incorporates high-level endurance, alternating movement patterns to further challenge shoulder girdle neuromuscular control and facilitate the rotator cuff musculature via alternating dynamic movements with sustained hold drills [81] (Table 3). The incorporation of sustained holds challenges the athlete to maintain a set position while superimposed isotonic movements are performed with the opposite extremity. Two sets are incorporated into each exercise, each following a sequential progression integrating bilateral isotonic movement and unilateral isotonic movement with contralateral sustained holds. The athlete can be instructed to perform these exercises on a stability ball to further challenge the core (Figure 10), as well as manual resistance drills to increase muscle excitation and promote endurance. Manual resistance provided by the clinician is used during seated stability ball exercises to augment muscle excitation and improve endurance of the shoulder and core musculature.

Table 3
Advanced Thrower's Ten program

External rotation at 0° abduction while seated on a stability ball
Internal rotation at 0° abduction while seated on a stability ball
External rotation at 0° abduction with sustained hold while seated on a stability ball
Internal rotation at 0° abduction with sustained hold while seated on a stability ball
Shoulder abduction to 90° with sustained hold while seated on a stability ball
Scaption, external rotation ("full can") with sustained hold while seated on a stability ball
Side-lying external rotation
Prone horizontal abduction with sustained hold on stability ball
Prone horizontal abduction (full external rotation, 100° abduction) with sustained hold on a stability ball
Prone row on a stability ball
Prone row into external rotation with sustained hold on a stability ball
Seated scapular retraction into external rotation on a stability ball
Seated low trap on a stability ball
Seated neuromuscular control on a stability ball
Tilt-board push-ups
Elbow flexion on a stability ball
Elbow extension on a stability ball
Wrist extension
Wrist flexion
Wrist supination
Wrist pronation

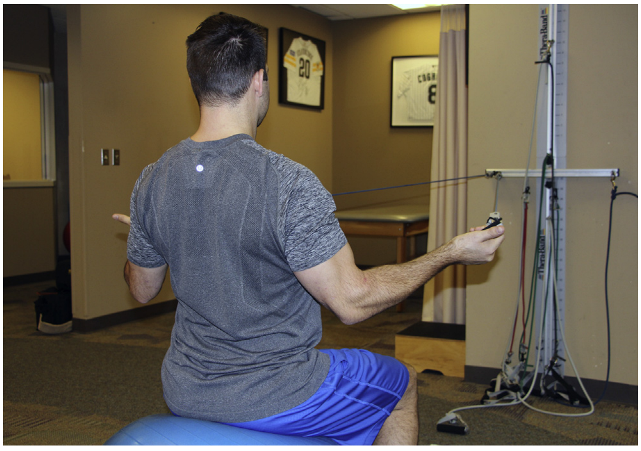

Figure 9. Modified robbery exercise for lower trapezius and posterior shoulder activation.

Figure 10. Advanced Throwers Ten exercise performed on a stability ball to facilitate stabilization of the core musculature as rotator cuff and scapular musculature endurance exercises are performed.

Dynamic stabilization drills such as RS are performed in a functional throwing position. Ball throws are performed to improve proprioception and neuromuscular control of the upper extremity. The athlete can perform stabilization techniques that include perturbations to enhance end-range stability through RS with performance of ball tosses into a wall (Figure 11), push-ups onto an unstable surface with perturbations, and external rotation tubing with concomitant manual resistance. In addition, these exercises can be performed on a physio ball to improve dynamic stabilization of the shoulder and trunk musculature. Advanced Thrower's Ten exercises, including prone horizontal abduction and row into external rotation with sustained holds and alternating arm/sustained hold sequencing, are initiated to challenge the endurance of the posterior rotator cuff, scapular musculature, lumbar extensors, gluteals, and hamstrings (Figure 12). These types of exercises engage the posterior lower extremity chain and again link the upper extremity with the lower extremity (Figure 13). Side-lying ER, prone row, and prone horizontal abduction manual resistance of the shoulder joint complex are utilized to promote increased muscular activity, neuromuscular control, and endurance, which are essential in the force production for overhead throwing athletes.

Plyometrics are initiated to further enhance dynamic stability and proprioception, as well as to introduce and gradually increase functional stresses to the shoulder joint. Wilk et al [82] have described numerous plyometric exercises for the overhead thrower. Enhanced joint position sense and kinesthesia, as well as decreased time for peak torque generation, have been demonstrated with plyometric strengthening [83]. Fortun et al [84] compared 8 weeks of plyometrics with conventional isotonic training and reported an increase of shoulder IR power and throwing distance using plyometrics. Plyometric exercises begin with a rapid eccentric prestretch that stimulates the muscle spindle, followed by the amortization phase, which is the time between the eccentric and concentric phase. To allow an effective transfer of energy and prevent the beneficial neurologic effects of the prestretch from being dissipated as heat, the amortization phase should be as short as possible. The athlete is instructed to coordinate

Figure 11. Dynamic stability training with the hand placed onto a ball with the arm in the scapular plane to provide compressive forces into the glenohumeral joint as the clinician provides rhythmic stabilizations.

Figure 12. Advanced Throwers Ten: Rowing into external rotation with sustained holds.

Figure 13. Linking the upper extremity and lower extremity: lateral lunges with shoulder abduction/external rotation movements with a resistance band.

the trunk and lower extremity to efficiently allow the transfer of energy into the upper extremity during the plyometric drills. Wilk et al [82,85] have described a plyometric program that systematically introduces stresses upon the healing tissues beginning with 2-handed drills such as chest pass, side-to-side throws, side throws, and overhead soccer throws. Upon successful completion of these 2-handed drills, the athlete can progress to one-handed drills such as standing one-handed throws, wall dribbles, and plyometric step and throws.

Muscle fatigue has been shown to diminish proprioceptive sense and alter biomechanics, increasing the risk of injury; therefore, muscle endurance training should be included in the rehabilitation program for every overhead throwing athlete [86]. Murray et al [87] performed kinematic and kinetic motion analysis and reported that shoulder external rotation and ball velocity decreased along with lead knee flexion and shoulder adduction torque once a thrower became fatigued. Muscle fatigue has been shown to contribute to superior humeral head migration upon the initiation of arm elevation [88]. Lyman et al [89] noted that the greatest predisposing factor to shoulder injury was muscle fatigue in Little League pitchers. Endurance training is performed by the athlete, including wall dribbles with a plyoball, wall arm circles, upper body cycle, and the Advanced Throwers Ten exercise program.

An interval throwing program (ITP) can be introduced during this phase. The ITP was developed to gradually introduce quantity, distance, intensity, and types of throws needed to facilitate the restoration of normal throwing motions [90]. The ITP is divided into 2 phases: phase 1 is a long-toss program, and phase 2 is a mound-throwing program used for pitchers. Phase 1 is initiated at 45 feet (15 m) and progresses with increasing distance and volume of throws. The athlete is instructed to use a crow-hop method for throwing to incorporate the trunk and lower extremities while throwing with a slight arc for each prescribed distance. Fleisig et al [91] reported that when pitchers were asked to throw at 50% effort, radar analysis showed it was approximately 83% of their maximum speed, and at a requested effort of 75%, the pitchers threw at 90% of their maximum velocity. This study demonstrates the inherent difficulty in self-imposing velocity controls; therefore, we implement a slight arc (versus throwing on a line) in the long-toss program as a means to regulate the intensity of each throw and ensure the athlete is not throwing harder than the desired effort, allowing the program to be successfully advanced. The long-toss program is designed to gradually introduce loads, stress, and strains and should be successfully completed before throwing from the mound is permitted. Fleisig et al [91] reported increased forces on the medial elbow and anterior glenohumeral joint with increasing distance. Furthermore, the players' throwing biomechanics changed with increasing distance, including greater trunk extension, stride length, and shoulder ROM. Position players can in addition begin a progressive hitting program that begins with swinging a light bat and progresses to hitting off a tee, soft-toss hitting, and then batting practice.

Phase 4: Return to Throwing Phase

Phase 4 of the rehabilitation program encompasses the progression and continuation of the ITP and is designed to systemically allow the athlete to progress to unrestricted throwing activities. It is important for the clinician to continuously monitor and assess the athlete's mechanics and intensity of effort throughout the throwing program. Position players progress throughout the throwing program to 180 feet (60 m), whereas pitchers progress to 120 feet (40 m), and upon successful completion they can begin throwing from a windup on level ground at 60 feet (20 m). Pitchers can begin phase 2 of the ITP upon successful completion of phase 1 [90]. Position players during this phase will progress with use of position-specific fielding drills and throwing drills.

The athlete is instructed to continue with all previously described exercises and drills to maintain and improve upper extremity, core, and lower extremity strength, power, and endurance during this final phase of treatment [92-94]. Additionally, the athlete should be educated regarding a year-round conditioning program, including periodization of throwing and strength-training activities to help prevent overtraining and initiation of throwing when poorly conditioned and to properly prepare for the upcoming season [95]. Wooden et al [96] showed that a dynamic variable resistance exercise program significantly increased throwing velocity. Likewise, the throwing velocity in high school baseball players has been shown to increase when utilizing an exercise program that varies the type of resistance exercises and includes plyometric training and a Throwers Ten program [97,98].

Before the athlete is cleared to return to play or competition, a clinical examination is performed to establish whether specific criteria have been met. We have established specific criteria for the athlete to achieve prior to returning play (see Table 4). The criteria we use includes full nonpainful ROM, satisfactory results of a muscle strength test, a satisfactory shoulder examination, and successful completion of a throwing program without pain while exhibiting proper throwing mechanics. In addition, we ask each player/patient to complete the Kerlan-Jobe Subjective Form for Throwers. Because of the predictive association of this measure with shoulder injuries in baseball players, we look for a score of 95 or higher prior to returning to competition [99].

Table 4
Return to play criteria

Full nonpainful sports-specific range of motion
Strength that fulfills our specific criteria
Excellent stability with no painful tests
Demonstrates proper throwing mechanics
Has successfully completed the rehabilitation program
Satisfactory subjective shoulder score

Summary

The overhead throwing athlete displays unique ROM, postural, strength, and joint laxity characteristics that occur as a result of physical adaptation to the imposed stresses and demands of repetitive throwing over numerous years. The success of the rehabilitation program for the overhead throwing athlete is dependent upon an accurate recognition of the underlying cause of the condition and all associated pathologic features. An effective rehabilitation program should focus on correcting the cause of the dysfunction and/or pain with particular focus on re-establishing full ROM and dynamic shoulder stability and implementing a progressive resistance exercise program to fully restore strength and local muscle endurance of the shoulder and scapular musculature. In addition, the rehabilitation program should incorporate exercises that link the upper and lower extremity. This program will evolve to include sport-specific drills and functional activities to allow a return to sport and activity. Additionally, proper throwing mechanics, utilization of pitch counts, appropriate rest, and proper off-season conditioning will help decrease the overall injury risk in overhead throwing athletes.

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Disclosure

K.E.W. Champion Sports Medicine, 805 St Vincent's Dr, Suite G100, Birmingham, AL 35205; Tampa Bay Rays Baseball Team, Tampa Bay, FL; American Sports Medicine Institute, Birmingham, AL. Address correspondence to: K.E.W.; e-mail: kwilkpt@hotmail.com

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C.A.A. Advanced Rehabilitation, Tampa, FL

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T.R.H. Champion Sports Medicine, Birmingham, AL

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