Rehabilitation of the Shoulder and Elbow in the Throwing Athlete

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KEYWORDS

• Overhead throwing athlete • Rehabilitation • Shoulder • Elbow

KEY POINTS

- The overhead thrower displays unique range of motion (ROM), postural, strength, and joint mobility characteristics that occur as a result of physical adaptation to the imposed stresses and demands of repetitive throwing.
- The success of the rehabilitation program is dependent upon an accurate recognition of the underlying cause of the pathology. The program is individualized based on the athlete's diagnosis, evaluation, and goals.
- An effective rehabilitation program will focus on re-establishing full full throwing ROM, dynamic rotator cuff stability, scapulothoracic control, and muscular endurance, while implementing a progressive resistance exercise program that progressively challenges the athlete preparing them to return to throwing.

The shoulder and elbow joints are common sites of pathology in the baseball player. The frequency of repetitive stress injuries in the overhead athlete, particularly baseball pitchers, continues to increase.[1–4] Major League Baseball (MLB) pitchers are the most injured players. Conte and colleagues[5] reported that shoulder injuries represented 27.8% of all disabled list (DL) days in professional baseball players while elbow injuries account for 22% to 26% of all pitchers' injuries.[5–7] Based upon DL days, Posner and colleagues[7] noted that pitchers in MLB experienced a 34% higher injury rate compared to fielders, and when a pitcher was placed upon the DL for injuries to the upper extremity, their absence lasted for a longer duration (74.25 days vs 54.15 days). Recently, Conte (presentation at 2024 Injuries in Baseball Course) reported that in 2023 MLB spent US$1.1 billion on players on the injured list (IL).

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According to the National Collegiate Athletics Association (NCAA) Injury Surveillance System from 1998 to 2004, for all injuries that lasted 10 or more days, shoulder strains/tendinitis equated to 8.2% of all injuries occurring during games and 16.7% of injuries during practice.[8] The shoulder has also been reported to be the most 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.[9]

Shoulder and elbow injuries are common due to the repetitive nature of overhead throwing. Tremendous forces are placed across the shoulder and elbow joints as angular velocities reach 7250°/s during throwing.[10] Anterior shear forces at the shoulder approach 50% body weight during the throwing motion.[10–12] Elbow extension occurs at more than 2300°/s, producing a medial sheer force of 300 N and a compressive force of 900 N creating a valgus elbow stress 64 N m^2 during the acceleration phase of throwing, which exceeds the ultimate tensile strength of the ulnar collateral ligament (UCL), potentially causing osteophytes posteriorly, olecranon stress fractures, and physeal injuries.[2,13,14]

High levels of muscular activity are also generated during the throwing motion with forces reaching 120% maximal volitional isometric contraction.[15] Although an inherent degree of mobility is needed to achieve the extreme arc of motion necessary to throw, the thrower depends on dynamic stability to minimize the potential for injury. Therefore, an essential balance between mobility and stability is needed to maintain joint integrity during high levels of extreme torque.

The rehabilitation program for the throwing athlete described in this article follows a multiphased, systematic approach focused on a return to prior level of function. This program is divided into 4 phases designed to allow a gradual progression of exercises and imparted stresses that methodically build on the previous exercises designed to restore strength, increase dynamic stability, and develop neuromuscular control. Critical to the successful restoration of function in the thrower is the identification of the causative pathologic factors unique to each player and implementing an individualized treatment program designed to address them.

This article will describe a rehabilitation program for the throwing athlete that can be applied to both conservative and operative conditions of the shoulder or elbow. Additionally, we will outline the postoperative rehabilitation milestones for common shoulder and elbow procedures in the throwing athlete.

REHABILITATION PROGRAM FRAMEWORK

This framework aims to provide a structure to address the causative factors common in the overhead thrower. Its success relies on a thorough clinical examination and appropriate sequencing through all phases of the rehabilitation process.

Phase 1: Acute Phase

The goals in this initial phase of the rehabilitation program are to diminish pain and inflammation, normalize range of motion (ROM), correct postural adaptations, normalize muscle balance, and re-establish baseline dynamic joint stability. During the acute phase of treatment, the athlete may be prescribed nonsteroidal anti-inflammatory drugs (NSAIDs) and/or undergo a local injection. Additionally, therapeutic modalities such as ice, iontophoresis, laser therapy, piezo wave therapy, and/or electrical stimulation may be used clinically to assist in the alleviation of pain and inflammation. The athlete is educated on activity modification/avoidance (including throwing, strenuous activities, and exercise performance) as well as sitting and

standing postural education to increase subacromial space, appropriately activate postural musculature, and optimally position the athlete at rest.[16]

Following the abating of acute inflammation, the rehabilitation specialist may implement the use of moist heat, ROM, and joint mobilization techniques aimed to increase local circulation of the joint capsule and surrounding soft tissues. Decreased electromyography (EMG) activity of 23% with a corresponding reduction of 32% external rotation (ER) force production has been documented in a painful shoulder.[17] This lends credence to the importance of pain reduction to allow for the restoration of normal rotator cuff and upper quarter muscular recruitment.

The clinician may utilize soft tissue mobilization techniques with the goal of improving tissue extensibility, reducing pain and guarding, and preparing the athlete for physical activities. Active-assisted range of motion (AAROM), light manual stretches, and grade 1 and 2 joint mobilizations are performed to diminish pain and muscle guarding via stimulation of the type 1 and 2 mechanoreceptors.[18–20]

During the acute phase of rehabilitation, the clinician should ensure the normalization of motion by incorporating AAROM, passive ROM, manual stretches, and joint mobilization techniques of both the shoulder and the elbow. Although all aspects of mobility should be assessed, it is common for the overhead throwing athlete to display a loss of internal rotation (IR) and horizontal adduction. The loss of IR is commonly described as glenohumeral internal rotation deficit (GIRD). The loss of IR of greater than 20° on the throwing shoulder compared to the nonthrowing shoulder has been implicated in shoulder and elbow injuries.[21–24] Glenohumeral IR loss has been attributed to osseous adaptations, posterior rotator cuff tightness, posterior capsule tightness, and an anteriorly tilted scapula.[5,25–30] Additionally, a loss of full shoulder elevation has been linked to increased elbow stress. A proper clinical assessment to differentiate among these factors is essential for the clinician to implement the appropriate treatment interventions.

It is common for throwing athletes in, particular, to exhibit a loss of elbow extension after injury or surgery.[31,32] The elbow is predisposed to flexion contractures because of the intimate congruency of the joint articulations, the tightness of the joint capsule, and the tendency of the anterior capsule and brachialis to develop adhesions and scar following injury.[31] ROM activities should be performed for all planes of elbow and wrist motions to prevent the formation of scar tissue and adhesions by providing nourishment to the articular cartilage and assisting in the synthesis, alignment, and organization of collagen tissue.[31,33,34] Restoring full elbow extension is the primary goal of early ROM activities.[35] At times, it can be difficult to regain full elbow extension and low-load, long duration (LLLD) stretch is needed to produce deformation or creep of the collagen tissue. This stretch can be performed by having the athlete lie supine with a towel roll placed under the distal humerus to act as a cushion and fulcrum. Light resistance exercise tubing is applied to the athlete's wrist and secured to the table or to a dumbbell on the ground (**Fig. 1**) as the athlete is instructed to relax for the duration of 10 to 15 minutes of LLLD treatment. The amount of resistance applied should be of low magnitude to enable the athlete to perform the stretch for the entire duration of the treatment without pain or muscle spasm. Athletes are instructed to perform the LLLD stretches several times per day, equaling at least 60 minutes of total end range time to improve extension and reduce joint stiffness.[36]

A postural assessment should be performed and scapular mobility assessed, as an anteriorly tilted scapula is frequently seen in overhead throwers. Postural assessment of the scapula often reveals a protracted, depressed, and anteriorly tilted position compared to the contralateral side. This positioning can create muscle weakness and/or inhibition of the scapular retractors resulting in an altered length tension

Fig. 1. LLLD stretch to increase elbow extension. The stretch is performed using light resistance while the shoulder is placed in IR, with the forearm pronated to minimize compensation and best isolate the stretch on the elbow joint.

relationship. In addition, pectoralis minor tightness, coracoid pain, and lower trapezius muscle weakness are often noted. The decreased flexibility of the pectoralis minor can cause symptoms including arm fatigue, pain, tenderness, and cyanosis due to neurovascular occlusion as these structures pass underneath this muscle.[37,38] 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. An asymmetry greater than 3 cm is considered abnormal.[39] We commonly perform pectoralis minor muscle stretches with the scapula placed in a retracted and posteriorly tilted position with 30° of shoulder flexion as the humerus is placed in an abducted and ER position.[40,41]

The posterior shoulder is subject to repetitive eccentric forces during throwing, which can result in increased internal stiffness and decreased ROM.[42] The modified sleeper stretch (**Fig. 2**), modified cross-body horizontal adduction stretch (**Fig. 3**), and horizontal adduction stretch with concomitant IR are performed to improve flexibility of the posterior shoulder.[43] The posterior capsule has been shown to exhibit

Fig. 2. Modified sleeper stretch. The athlete is rotated slightly posterior to position the shoulder in the scapular plane as IR is passively performed.

Fig. 3. Modified cross body stretch. The athlete passively horizontally adducts the shoulder as the scapula is stabilized against the table while ER is restricted with counter-pressure of the opposite forearm.

significant laxity in throwers that exhibit GIRD; therefore, a proper evaluation should be performed to assess between capsular and soft tissue mobility.[44] Mobilizations for the posterior capsule are performed parallel to the glenoid fossa in a posterior-lateral direction to increase pliability of the posterior capsule (**Fig. 4**).

During this early phase of rehabilitation, strengthening exercises are initiated with the intention of restoring muscle balance/ratios and impeding muscle atrophy.[45,46]

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

The aim of this phase is to re-establish dynamic stability; therefore, initial focus is on the innately weak rotator cuff and scapulothoracic musculature.[45,46] Eccentric control of the lower trapezius is essential in controlling scapular elevation and protraction as the arm decelerates, and weakness can result in improper mechanics leading to potential shoulder symptoms.[12] The clinician may opt to initiate submaximal, pain-free isometrics during the acute phase in the presence of excessive pain and/or soreness, progressing to isotonics as tolerated. Rhythmic stabilization (RS) exercises are initially performed for the internal and external rotators with the arm in the neutral rotation and the shoulder in 30° of abduction. Manual cueing is used to facilitate cocontraction of the internal and external rotators to provide isometric stabilization of the glenohumeral joint during these exercises. These drills can also be progressed as the shoulder is placed in a "balanced position," approximately 100° of elevation and 10° of horizontal abduction, which is beneficial because the rotator cuff and deltoid musculature resultant force vectors provide a centralized compression of the humeral head.[47,48] The athlete's arm can be placed at various angles of both ER and elevation while applying manual cueing in various planes to facilitate recruitment of the surrounding musculature using this manual RS technique.

Proprioceptive sense can be diminished due to microtrauma or macrotrauma, thus the rehabilitation specialist should initiate techniques to heighten the sensory awareness of the afferent mechanoreceptors during this phase of rehabilitation.[49,50] Studies have demonstrated improvements in proprioception and enhanced functional throwing performance test scores following a 5 week program emphasizing neuromuscular and proprioceptive neuromuscular facilitation (PNF) training drills that challenge the glenohumeral musculature.[51,52] PNF movement patterns are performed while incorporating RS to the internal and external rotators to augment proprioception and dynamic stability.[45,46,49,50,53,54] Joint congruency is enhanced by facilitation of agonist and antagonist muscles, which assists in restoring a balance in the force couples of the shoulder joint complex.[55] Joint repositioning 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 stages of treatment.[46,56,57]

Effective transfer of kinetic energy from the lower to the upper extremity is vital during throwing requiring adequate mobility, stability, and strength. Core and hip complex exercises are employed in this phase for postural re-education, stability, and mobility.

Phase 2: Intermediate Phase

The goals of phase 2 are to progress the strengthening program, while increasing the flexibility, mobility, and ROM of the entire upper quarter, while enhancing the athlete's neuromuscular control. During this stage, the implementation of the Thrower's Ten Program designed by Wilk and colleagues based-on EMG data[56] facilitates the progression to more aggressive isotonic strengthening activities aimed at restoring muscle balance.[58–66] Because the external rotators are commonly weak, side-lying shoulder ER and prone rowing into shoulder ER are prescribed due to the high EMG activity of the posterior cuff elicited during these movements.[58]

Neuromuscular control drills are progressed as the clinician incorporates RS drills at the end ROM during the prior phase 1 movement drills. PNF exercises that are performed in a full arc of the patient's available ROM serve to promote endurance training and dynamic stabilization of the rotator cuff. Manual resistance training can also be incorporated during this stage, allowing the clinician the ability to apply variable resistance throughout the movement, incorporate concentric and eccentric contractions, add RS during the exercise, and perform manual cueing for the scapular musculature.

The strength of the periscapular musculature is vital for optimal upper extremity function, as it provides proximal stability to allow for efficient distal arm mobility and has been described by several authors to contribute to normal overhead function.[67–70]

Wilk and colleagues[46] formulated specific exercises designed to normalize force couples of the scapular musculature and stimulate the proprioceptive and kinesthetic awareness to facilitate neuromuscular control of the scapulothoracic joint. The scapular retractors, protractors, and depressors are frequently emphasized due to commonly observed weakness of these muscle groups in the throwing athlete.

Closed kinetic chain exercises are advanced to include proprioceptive drills. This includes table push-ups on a ball or tilt board (**Fig. 5**) as this has been shown to generate more upper and middle trapezius, and serratus anterior activity compared to performing a standard push-up exercise.[71] Stabilization drills can also be performed with perturbations to the athlete's arm while the hand is on a small ball (**Fig. 6**).

Flexibility and ROM exercises for the shoulder and elbow joints are continued throughout this phase of treatment. The athlete will also integrate mobility, stabilization, and strengthening exercises for the trunk and lower back into the treatment program. In addition, athletes are encouraged to perform lower extremity strengthening and sport-specific conditioning activities beginning in this phase of the program.

Phase 3: Advanced Strengthening Phase

Phase 3 is designed to initiate aggressive strengthening exercises, augment power and endurance, progress functional drills, and gradually initiate throwing activities. Full shoulder and elbow ROM and flexibility should be maintained throughout this phase. Muscle fatigue has been shown to decrease neuromuscular control and diminish proprioceptive sense[72]; therefore, the athlete is challenged with strengthening activities used in the Advanced Throwers 10 program.[73] This program incorporates challenging, alternating movement patterns focused on endurance to further challenge shoulder girdle neuromuscular control and facilitate activation of the rotator cuff musculature via alternating dynamic movements with sustained holds. The incorporation of sustained holds challenges the athlete to maintain a static position while the opposite extremity performs isotonic exercises. Three sets are incorporated into each exercise, each following a sequential progression integrating bilateral isotonic movement, unilateral isotonic movement with contralateral sustained hold, and alternating isotonic/sustained hold sequencing. The athlete can be instructed to perform

Fig. 5. Push-ups on an unstable surface with manual RSs to facilitate dynamic stability for the shoulder and core musculature.

Fig. 6. Stabilization exercises as the athlete performs ball dribbles with the shoulder maintained at 90° abduction as manual stabilizations are performed.

these exercises on a stability ball to further challenge the core and postural control (Fig. 7), as well as with manual resistance drills to increase muscle excitation and promote endurance of the upper quarter and core musculature.

Dynamic stabilization drills, such as RS performed in a functional throwing position, and ball throws are performed to improve proprioception and neuromuscular control of the throwing arm. Perturbations and end-range stability exercises such as RS while throwing a ball against a wall (Fig. 8), push-ups onto an unstable surface with

Fig. 7. Advanced Throwers 10 exercise performed on a stability ball to facilitate stabilization of the core musculature as rotator cuff and scapular musculature endurance exercises are performed. This exercise is referred to as "prone on stability ball T's."

perturbations, and ER tubing with concomitant manual resistance are all utilized in advancing challenges to the athlete. In addition, these exercises can be performed on a physio ball to improve dynamic stabilization of the scapular, shoulder, arm, and trunk musculature. Advanced Throwers 10 exercises including prone horizontal abduction and row into ER with sustained holds and alternating arm/sustained hold sequencing are initiated to challenge the endurance of the posterior rotator cuff, scapular musculature, lumbar extensors, and gluteals (Fig. 9). Side-lying ER, prone row, and prone horizontal abduction with 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 throwers.

Muscle fatigue has been shown to diminish proprioceptive sense, alter biomechanics, contribute to superior humeral head migration upon initiation of arm

Fig. 8. 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 RSs.

elevation, and increase valgus elbow stress.[2,74,75] Kinematic and kinetic motion analysis performed by Murray and colleagues[101] reported a decrease in shoulder ER ROM and ball velocity, along with lead knee flexion and shoulder adduction torque once a thrower became fatigued. Lyman and colleagues[76] noted the greatest predisposing factor to shoulder and elbow injury in Little League pitchers was muscle fatigue. Based on these findings, muscle endurance training must be included in the rehabilitation program for overhead throwers. Endurance training includes wall dribbles with a Plyo ball (Functional Integrated Technologies, Watsonville, CA, USA), wall arm circles, upper body cycle, and Advanced Throwers 10 exercises.

Plyometrics are initiated to further enhance dynamic stability and proprioception while gradually increasing functional stresses on the upper extremity. The athlete is instructed to coordinate the trunk and lower extremity to efficiently allow the transfer of energy into the upper extremity during plyometric drills. Wilk and colleagues[77,78] 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, the athlete can progress to one-handed drills such as standing one-handed throws, wall dribbles, and plyometric step and throws (**Figs. 10–12**).

An interval throwing program (ITP) can be introduced during the second portion of this third phase. The ITP was developed to gradually introduce volume, distance, intensity, and types of throws needed to facilitate the restoration of normal throwing motions. The ITP is divided into 2 phases. Phase I is a long-toss program and phase II is a mound-throwing program used for pitchers. Phase I begins at 45 feet (15 m) and is

Fig. 9. Advanced Throwers 10: Prone on stability during horizontal abduction at 105° with shoulder ER (Prone Y's) with sustained holds.

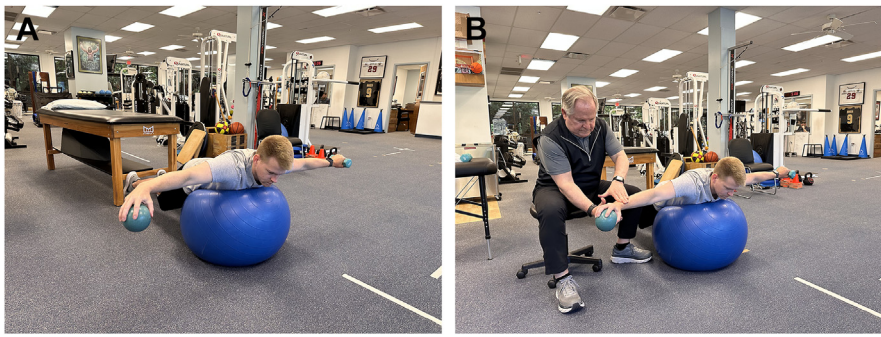

Fig. 10. (*A*) Prone ball drops with a 1 kg (2 lbs) Plyo ball. (*B*) Prone plyo ball drops with random stabilizations.

Fig. 11. Plyometric medicine ball (2 lbs) throws into the wall with dynamic stabilization at end range.

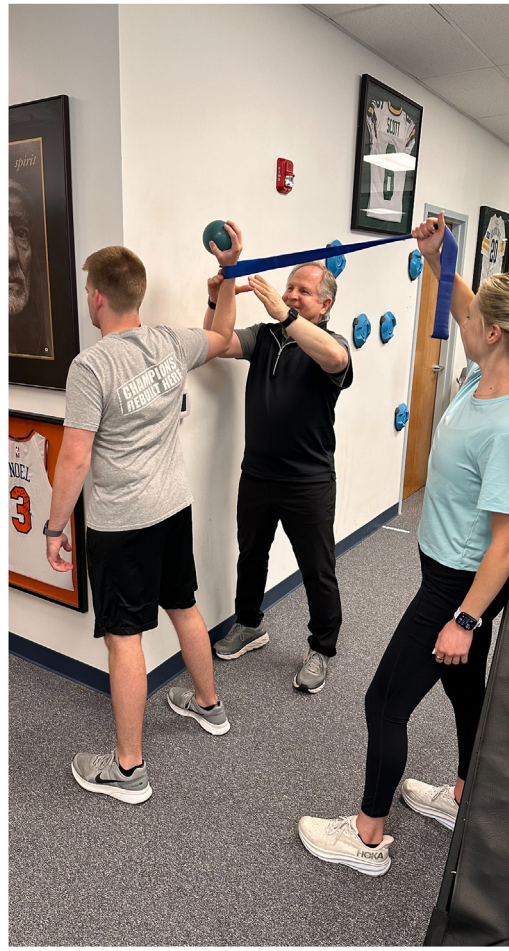

Fig. 12. Plyometric medicine ball throws (2 lbs) with resistance band applied to resist IR with dynamic stabilization applied at end range.

progressed with increased distances and progressive 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 and colleagues[79] reported that when pitchers were asked to throw at 50% effort, radar analysis showed it was approximately 83% of their maximum speed, and at 75% effort, the pitchers threw at 90% of their maximum speed. This study demonstrates the inherent difficulty in self-imposing velocity limitations; therefore, we implement a slight arc (vs 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 is needed for each distance. The long-toss program is designed to gradually introduce loads and strains and should be successfully completed prior to allowing throwing from the mound. In addition, position players can begin a progressive hitting program that begins with swinging a light bat, progressing to hitting off a tee, soft-toss hitting, and ultimately returning batting practice.

Phase 4: Return to Throwing Phase

Phase 4 of the rehabilitation program is designed to systemically progress the athlete through the ITP with throwing activities. It is important for the clinician to continuously monitor and assess the athlete's mechanics and intensity throughout this throwing program. Position players progress throughout the program to 180 feet (60 m). Pitchers are progressed to 120 feet (40 m) and can progress to throwing from a wind-up on level ground at 60 feet (20 m) before beginning phase II of the program and starting to throw from the mound.[80] Position players during this phase will be progressed with position-specific fielding and functional drills.

The athlete is instructed to continue with all previously described exercises and drills aimed at improving upper extremity, core, and lower extremity strength, power, and endurance during this phase of treatment.[81–83] Moreover, it is essential to educate the athlete on a year-round conditioning program, which includes periodization of throwing and strength training activities. This regimen serves to prevent overtraining, initiating throwing when poorly conditioned, and adequately prepare for the upcoming season.[84] Wooden and colleagues[85] showed that a dynamic variable resistance exercise program significantly increased throwing velocity. Likewise, throwing velocity in high school baseball players increased following a program that utilizes variable resistance during both plyometric and Thrower's Ten training.[86,87]

Rehabilitation Following Arthroscopic Glenoid Labrum Procedures

The specific rehabilitation program following surgical intervention of the glenoid labrum is dependent on the severity of the pathology and the specific surgical intervention. Following a type I slap lesion, or simple arthroscopic debridement of the frayed labrum, the rehabilitation program is rather aggressive in restoring motion and function. Full ROM is expected by no more than 14 days postoperatively. Gradual isotonic strengthening occurs between weeks 2 and 8, with initiation of tubing internal and ER exercises by postop day 10. The athlete gradually progresses toward beginning an ITP 8 to 12 weeks following surgery.

The rehabilitation following a type II SLAP lesion is approached with greater caution. The athlete is advised to wear an immobilizer during the day and night for the first 4 weeks. In addition, no isolated biceps strengthening is permitted for 6 to 8 weeks to allow for adequate healing. ROM activity is restricted for the first 4 weeks to below 90° of elevation. During the first 2 weeks, IR and ER are performed passively in the scapular plane to approximately 10° to 15° of ER and 45° of IR and is progressed to perform at 90° of abduction at week 5 to 6. Excessive ER, extension, or abduction is prohibited until week 5 to 6, when a light isotonic strengthening program is initiated. Motion is gradually increased to restore full range by 10 weeks at the latest and progressed to thrower's motion by week 10 to 12. Two-handed plyometric exercises are initiated at week 12 and the ITP at week 16. Return to play following surgical repair of a type II SLAP lesion occurs between 9 and 11 months for pitchers, and 7 months for position players.

Rehabilitation Following Arthroscopic Capsular Plication

Due to the inherent congenital laxity, a conservative approach in restoring glenohumeral ROM is taken during the initial stages of rehabilitation following capsular plication. Therefore, limited ROM exercises are delayed until 2 weeks after surgery. The athlete is instructed to sleep in an immobilizer and limit overhead activities for 12 weeks after surgery. ROM is limited to 90° of flexion and ER performed in the scapular plane to 0° at 2 weeks, with a gradual progression to allow 145° of flexion and 45° of ER at

4 weeks. At 6 weeks, ER ROM is progressed to 70° at 90° of abduction and flexion is permitted to 160°. The overhead thrower will continue a gradual progression of motion allowing for thrower's motion at 10 to 12 weeks after plication.

Isometric rotator cuff and scapular exercises are integrated into the early stages of rehabilitation and progressed to light isotonics and closed-chain RS exercises to emphasize cocontraction at 4 weeks following surgery. The athlete can continue to progress the strengthening program to include the Thrower's Ten program at week 7 to 8 that is progressed to overhead dynamic strengthening at week 12. Interval sporting activities are initiated at week 16 to allow the athlete to return to participation 7 to 9 months following surgery.

Rehabilitation Following Ulnar Collateral Ligament Injury

Nonsurgical treatment is generally attempted for partial UCL tears. A brace can be used to restrict motion and minimize valgus stress in a nonpainful arc of motion generally from 10° to 100°, progressing gradually by 5° to 10° per week expecting full ROM in 3 to 4 weeks. Because the flexor carpi ulnaris and flexor digitorum superficialis overlay the UCL, isotonic and stabilization activities for these muscles can assist the UCL in resisting valgus stresses at the elbow.[88] In addition, posterior rotator cuff and scapular strengthening exercises are performed to restore proximal stabilization. The advanced strengthening phase usually is initiated at 6 to 7 weeks after injury, with valgus loading monitored throughout the rehabilitation program. An interval return-to-throwing program is initiated after the athlete regains full motion, adequate strength, and dynamic stability of the elbow. The athlete can return to competition following the asymptomatic completion of the interval sport program. If symptoms recur during the ITP, they typically present when throwing at longer distances, with greater intensity, or during throwing from the mound. If symptoms persist, the athlete is reassessed, and surgical intervention is considered.

Rehabilitation Following Ulnar Collateral Ligament Reconstruction Surgery

Rehabilitation following UCL reconstruction begins with the athlete's arm placed in a posterior splint with the elbow immobilized at 90° of flexion for the first 7 days postoperatively if an ulnar nerve transposition is concomitantly performed, allowing for early healing of the fascial slings involved in the nerve transposition. The athlete is progressed to a hinged elbow ROM brace to protect the healing tissues from valgus stresses until the beginning of postoperative week 5.

Passive ROM activities are initiated immediately after the first week to reduce pain and slowly stress the healing tissues. Initially, the focus of the rehabilitation is on obtaining full elbow extension while gradually progressing flexion. Elbow extension is encouraged early, to at least 15°, but full extension is allowed if the patient can comfortably achieve it and there is no discomfort. Bernas and colleagues[89] demonstrated that passive ROM of the elbow produced 3% or less strain in both bands of the reconstructed ligament and approximately 1% strain for the anterior band of the UCL. Therefore, it has been determined that in the immediate postoperative period, full elbow extension is safe and does not place excessive stress on the healing graft. Conversely, elbow flexion to 100° is allowed and should be progressed at about 10° per week until full ROM is achieved by 4 to 6 weeks postoperatively.

Isometric exercises are progressed to include light resistance isotonic exercises at week 4 and the full Thrower's Ten Program by week 6. Progressive resistance exercises are incorporated at week 8 to 9.

Aggressive exercises involving eccentric and plyometric contractions are included in the advanced phase, usually weeks 12 through 16. The Advanced Throwers 10

Exercise Program is initiated at week 12 after surgery. Two-hand plyometric drills are performed at week 12, and 1 hand drills are executed at week 14. An ITP is allowed at postoperative week 16. Progression to throwing from a mound may occur within 4 to 6 weeks following the initiation of an ITP, and a return to competitive throwing may commence at approximately 9 months following surgery. Position players could possibly return to play at 7 to 8 months if they are ready.

Rehabilitation Following Ulnar Collateral Ligament Internal Brace Repair Surgery

Rehabilitation after UCL repair with internal brace surgery is accomplished via a sequential and progressive 5 phased approach, designed to return the athlete to their previous level or higher as quickly and safely as possible.[90] Initially interventions are designed to minimize the effects of immobilization, facilitate early healing of the UCL repair, re-establishing pain-free ROM, reduce pain and inflammation, and retard muscular atrophy. Early limited passive elbow/forearm ROM exercises and grade I/II joint mobilizations are incorporated in conjunction to neuromodulate pain, promote articular cartilage nutrition and aide in the synthesis, alignment, and organization of collagen tissue. Local modalities, including cryotherapy, electrical stimulation, and class IV deep tissue laser are used to control pain, inflammation, speed healing of the incision, and increase nitrous oxide in the healing tissue. Pain-free, submaximal isometrics are used to initiate muscle activation and retard atrophy for all planes of elbow, forearm, wrist, and shoulder movements. Shoulder ER and IR isometrics are performed with caution and must be completely pain free. RS and neuromuscular control drills for shoulder, elbow, and wrist along with seated scapular and postural exercises are also introduced early in the rehabilitation process.

The controlled mobility phase runs for a total of 3 weeks starting at the second week after surgery and focuses on a stepped restoration in elbow ROM, improved muscular strength/endurance, and normalizing joint arthrokinematics. Active-assisted, active, and passive ROM exercises, as well as more aggressive joint mobilizations, are all incorporated for the elbow, forearm, and wrist with the primary goal to achieve full elbow extension and minimize the risk of developing an elbow flexion contracture. Strengthening exercises at this point are performed beginning with concentric and progressing to eccentric muscle contractions with the focus placed on a comprehensive strengthening program for the throwing athlete, such as the Thrower's Ten Program.[56] At 4 weeks, the athlete is progressed to the Advanced Throwers 10 Program to place greater demands on the posterior shoulder and scapular muscles.[73]

The intermediate phase is from postoperative week 6 to 8 and emphasizes the maintenance of joint mobility, improving muscular strength, endurance, neuromuscular control of the elbow complex, and continuing with a functional progression of activity. Stretching, flexibility, and mobilizations are used to maintain full motion with a particular focus on elbow extension and forearm pronation flexibility.

Neuromuscular control manual resistance exercises are incorporated for both the shoulder and elbow, PNF, RSs, and slow reversal hold techniques. Two-handed plyometrics are introduced 6 weeks following surgery progressing to 1 hand exercises 2 weeks later.

The fourth phase of UCL repair rehabilitation is the advanced phase, which runs from weeks 9 to 14 and is specifically designed to increase strength, power, endurance, and neuromuscular control to prepare for a return to sports using strengthening activities that emphasize high speed, eccentric contractions, and plyometrics. Elbow flexion exercises in this phase emphasize high-speed eccentric control training elbow deceleration. Weight machine exercises are initiated 10 weeks after surgery and include seated chest press, seated rowing, and front latissimus dorsi pull-downs. A

hitting program is permitted at week 10 and an ITP 11 weeks after surgery if the athlete meets the objective criteria for throwing. Pitchers are generally able to advance to throwing off of a mound 8 weeks after they begin the first phase of a throwing program.

The return to activity phase is the last part of the process and emphasizes a proper dynamic warm-up, continued exercise loads and managing the progression back to unrestricted activity and competitive throwing. The general time frame to return to play following a UCL repair with internal brace is approximately 5 months. Functional testing can aide the return-to-play decision process. We use the prone ball drop test, developed by the senior author (KEW), which utilizes a 1 kg (2 pound) plyo ball with the patient prone, shoulder abducted to 90°, and elbow extended. The patient is instructed to perform as many ball drops and catches as possible in a 30 second time-frame, comparing successful catches bilaterally seeking a goal of 110% for the throwing side (see **Fig. 10**).

Rehabilitation of Medial Epicondylitis and Flexor-pronator Tendinitis

Medial epicondylitis occurs because of changes within the musculotendinous flexor-pronator unit, characterized by microscopic or macroscopic tearing within the flexor carpi radialis or pronator teres near the origin on the medial epicondyle. Overhead throwers who exhibit flexor-pronator tendinitis also may have UCL pathology that creates this secondary pathology due to the underlying increased laxity. Furthermore, it may be beneficial to determine the number of episodes and the chronicity of medial epicondylar symptoms.

Patients with long histories of medial epicondylitis may exhibit a chronic degeneration known as tendinosis or tendinopathy, not true tendinitis. The treatment of tendinopathy is based on a careful examination to determine the exact pathology present. Often, patients in whom tendinitis have been diagnosed only later discover that the tendon had undergone a degenerative process referred to as tendinosis.[91,92] The differential diagnosis of tendinosis may be made using MRI, ultrasonography, or tissue biopsy.

The treatment of tendinitis typically focuses on reducing inflammation and pain. This goal is accomplished through the reduction of activities, steroid injections, anti-inflammatory medications, cryotherapy, iontophoresis, light exercise, and stretching. Conversely, the treatment of tendinosis focuses on increasing the circulation to promote collagen synthesis and collagen organization. Such treatment would include heat, stretching, eccentric exercises, piezo wave shock wave therapy, laser therapy, transverse massage, and soft-tissue mobilization. These therapies are performed to increase the circulation and promote tissue healing. Dry needling has also been advocated for this pathology to promote tendon healing.[93] Piezo wave (shock wave) therapy is frequently utilized on the tendon if tendinosis is diagnosed.

The nonsurgical approach for the treatment of epicondylitis (tendinitis and/or paratendinitis) focuses on diminishing the pain and inflammation and then gradually improving muscular strength. The primary goals of rehabilitation are to control the applied loads and create an environment for healing. The initial treatment consists of stretching and light strengthening exercises to stimulate a repair response. Wrist flexion and extension activities should be performed, initially with the elbow flexed 30° to 45°. Therapeutic modalities often are used by rehabilitation specialists to reduce inflammation and promote healing. Very limited evidence supports using these modalities in isolation. Common modalities can include laser therapy, iontophoresis, nitric oxide, ice, and extracorporeal shock wave therapy. When used in combination with exercise or with other modalities, however, studies have shown improved tissue quality and outcomes.[94–96] Conversely, patients with tendinosis are treated with transverse friction massage, forceful stretching, a focus on eccentric

strengthening with gradually progressing loads, and warm modalities to promote tendon regeneration.

After the patient's symptoms have subsided, an aggressive stretching and strengthening program featuring high loads and low repetitions that emphasizes eccentric contractions is initiated. A gradual progression through plyometric and throwing activities precedes the initiation of the ITP.

Rehabilitation for Ulnar Neuropathy

The nonsurgical treatment of ulnar neuropathy focuses on reducing ulnar nerve irritation, enhancing dynamic medial joint stability, and returning the athlete to competition gradually. Using a night splint with the elbow flexed to 45° can help to restrict movement and prevent ulnar nerve irritation. NSAIDs can be prescribed as well as an iontophoresis disposable patch and cryotherapy. Throwing athletes are instructed to discontinue throwing activities for at least 4 weeks, depending on the severity and chronicity of symptoms. They will be progressed through the immediate motion and intermediate phases over 4 to 6 weeks, with emphasis on eccentric and dynamic stabilization drills. Plyometric exercises are used to facilitate further dynamic stabilization of the medial elbow. The athlete can begin an ITP when full pain-free ROM and muscle performance are achieved without neurologic symptoms.

Rehabilitation Following Ulnar Nerve Transposition

An ulnar nerve transposition can be performed in a subcutaneous manner using fascial slings. The clinician should use caution to avoid overstressing the soft-tissue structures involved in relocating the nerve while soft-tissue healing occurs.[97] A posterior splint at 90° of elbow flexion is used for the first postoperative week to prevent excessive extension ROM and tension on the nerve. The splint is discontinued at the beginning of week 2, and light ROM activities are initiated. Full ROM usually is restored by weeks 3 to 4. Gentle isotonic strengthening is begun during week 3 to 4 and progressed to the full Thrower's Ten Program by 4 to 6 weeks after surgery. Aggressive strengthening, including eccentric training, the Advanced Throwers 10 Exercise Program, and plyometric training, is incorporated at week 8, and an ITP is begun at week 8 to 9 if all previously outlined criteria are met. A return to competition usually occurs between weeks 12 and 16 postoperatively.

Osteochondritis dissecans

Nonsurgical treatment includes 3 to 6 weeks of immobilization at 90° of elbow flexion. ROM activities for the shoulder, elbow, and wrist are performed 3 to 4 times a day. As symptoms resolve, a strengthening program is initiated with isometric exercises. Isotonic exercises are added after approximately 1 week of isometric exercise. Aggressive high-speed, eccentric, and plyometric exercises are included progressively to prepare the athlete for the start of an ITP.

If nonsurgical treatment fails or evidence of loose bodies exists, surgical intervention, including arthroscopic abrading and drilling of the lesion with fixation or removal of the loose bodies, is indicated.[98] Long-term follow-up studies regarding the outcome of patients undergoing surgery to drill or reattach the lesions have not reported favorable results, suggesting that prevention and early detection of symptoms may be the best form of treatment.[99]

Little Leaguer's Elbow Rehabilitation

During the arm-cocking and acceleration phases of throwing, the medial epicondyle physis is subject to repetitive tensile and valgus forces that can lead to a spectrum

of injuries to the medial epicondylar apophysis, ranging from microtrauma to the physis to fracture and displacement of the medial epicondyle through the apophysis. Pain in the medial elbow is common in adolescent throwers. These forces can result in microtraumatic injury to the physis, with potential fragmentation, hypertrophy, separation of the epiphysis, or avulsion of the medial epicondyle.

In the absence of an avulsion, a nonsurgical rehabilitation program like that used for the UCL is initiated. Initial emphasis is placed on the reduction of pain and inflammation and the restoration of motion and strength. Strengthening exercises are performed in a gradual manner. First, isometrics are performed, then, light isotonic strengthening exercises are initiated. Young throwing athletes often exhibit poor core and scapular control, along with weakness of the shoulder musculature; therefore, core, leg, and shoulder strengthening are emphasized. In addition, stretching exercises are performed to normalize shoulder ROM, especially into IR and horizontal adduction. No heavy lifting is permitted for 12 to 14 weeks. An ITP is initiated as tolerated when symptoms subside. It is always better to delay throwing and the return to play as long as possible to allow osseous healing. Additionally, a thorough analysis of the patient's throwing mechanics is critical to assess to ensure further injury or reoccurrence of symptoms are reduced.

In the presence of a nondisplaced or minimally displaced avulsion, a brief period of immobilization for approximately 7 days is encouraged, followed by a gradual progression of ROM, flexibility, and strength. An ITP usually is allowed at week 6 to 8. If the avulsion is displaced, open reduction and internal fixation may be required.

Rehabilitation Following Posterior Olecranon Osteophyte Excision

Surgical excision of posterior olecranon osteophytes is performed arthroscopically using an osteotome or motorized burr. Approximately 5 to 10 mm of the olecranon tip is removed, and a motorized burr is used to contour the coronoid, olecranon tip, and fossa to prevent further impingement during extreme flexion and extension.[100]

The rehabilitation program following arthroscopic posterior olecranon osteophyte excision is slightly more conservative in restoring full elbow extension secondary to postsurgical pain. ROM is progressed within the patient's tolerance, but by 10 days after surgery, the patient should exhibit at least 15 to 105-110 out of 110° of ROM, and 5-10 to 115 by day 14. Full ROM (0°–145°) typically is restored by day 20 to 25 after surgery. The rate of ROM progression most often is limited by osseous pain and synovial joint inflammation, usually located at the top of the olecranon.

The strengthening program is similar to the previously discussed progression. Isometric exercises are performed for the first 10 to 14 days, and isotonic strengthening is performed from weeks 2 to 6. During the first 2 weeks following surgery, forceful triceps contractions can produce posterior elbow pain; therefore, the clinician should avoid initiating or reducing the force produced by the triceps muscle. The full Thrower's Ten Program is initiated by week 6. An ITP is included by week 10 to week 12. Emphasis again is placed on eccentric control of the elbow flexors and dynamic stabilization of the medial elbow.

SUMMARY

The overhead thrower 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. As a result, there are distinct pathologies in this patient population that require specific approaches to effective rehabilitation. The success of the rehabilitation program is dependent upon an accurate recognition of the

underlying cause of the pathology. An effective rehabilitation program will focus on re-establishing full baseball-specific ROM, dynamic rotator cuff stability, scapulothoracic control, and total arm endurance, while implementing a progressive resistance exercise program that progressively challenges the athlete preparing them to return to throwing. This program will evolve to include sport-specific drills and functional activities to allow an optimal return to sport and activity as quickly and safely as possible.

CLINICS CARE POINTS

- Essential to restore proper shoulder motion (consider total ROM concept).
- Dynamic shoulder stabilization is imperative.
- Restore proper scapula posture & mobility/stability.
- Improve hips/core mobility/stability.
- Proper throwing mechanics is important.
- Plyometric throwing drills before initiating an interval throwing program.
- Utilize objective return to play testing before returning to competition.

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