[Sports Physical Therapy]

Rehabilitation of the Overhead Athlete's Elbow

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The activities required during overhead sports, particularly during baseball pitching, produce large forces at the elbow joint. Injuries to the elbow joint frequently occur in the overhead athlete because of the large amount of forces observed during the act of throwing, playing tennis, or playing golf. Injuries may result because of repetitive overuse, leading to tissue failure. Rehabilitation following injury or surgery to the throwing elbow is vital to fully restore normal function and return the athlete to competition as quickly and safely as possible. Rehabilitation of the elbow, whether following injury or postsurgical, must follow a progressive and sequential order, building on the previous phase, to ensure that healing tissues are not compromised. Emphasis is placed on restoring full motion, muscular strength, and neuromuscular control while gradually applying loads to healing tissue. In addition, when one is creating a rehabilitation plan for athletes, it is imperative to treat the entire upper extremity, core, and legs to create and dissipate the forces generated at each joint.

Keywords: ulnar collateral ligament; valgus extension overload; baseball pitcher

Injuries to the elbow are common in the overhead athlete. Approximately 22% to 26% of all injuries to major league baseball pitchers involve the elbow joint.[18,69] The repetitive overhead motion required of these athletes, in particular with throwing, is responsible for unique and sport-specific patterns of injuries to the elbow. Chronic stress overload or repetitive microtraumatic stress is observed during the overhead pitching motion as the elbow extends at over 2300 degrees per second, producing a medial shear force of 300 N and compressive force of 900 N.[35,94] In addition, the valgus stress applied to the elbow during the acceleration phase of throwing is 64 Nm,[35,94] exceeding the ultimate tensile strength of the ulnar collateral ligament (UCL).[25] Thus, the medial aspect of the elbow undergoes tremendous tension (distraction) forces, while the lateral aspect is forcefully compressed during the throw. These forces may cause a variety of specific elbow injuries in this athletic population

A number of forces act on the elbow during the act of throwing.[35,94] These forces are maximal during the acceleration phase of throwing.[35] Valgus stress in particular creates tensile forces across the medial aspect of the elbow, which may eventually cause tissue breakdown and the inability to throw. Compression forces are also applied to the lateral aspect of the elbow during the throwing motion. The posterior compartment is subject to tensile, compressive, and torsional forces during both the acceleration and deceleration phases, which may result in valgus extension overload within the posterior compartment, potentially leading to osteophyte formation, stress fractures of the olecranon, or physeal injury.[5,101]

GENERAL REHABILITATION GUIDELINES

Rehabilitation following elbow injury (Table 1) or elbow surgery (Table 2) follows a sequential and progressive multiphased approach. The phases of the rehabilitation program should overlap to ensure proper progression. The ultimate goal of elbow rehabilitation is to return the athlete to his or her previous functional level as quickly and safely as possible.

Phase 1: Immediate Motion

The first phase of elbow rehabilitation is the immediate motion phase. The goals of this phase are to minimize the effects of immobilization, reestablish nonpainful range of motion (ROM), decrease pain and inflammation, and retard muscular atrophy.

Early ROM activities are performed to nourish the articular cartilage and assist in the synthesis, alignment, and organization of collagen tissue.[19,24,40,66,68,78,79,96] ROM activities are performed for all planes of elbow and wrist motions to prevent the formation of scar tissue and adhesions. Active-assisted and passive ROM exercises are performed at the humeroulnar joint to restore flexion/extension, as well as at both the

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humeroradial and radial-ulnar joints for supination/pronation. Reestablishing full elbow extension, typically defined as preinjury motion, is the primary goal of early ROM activities to minimize the occurrence of elbow flexion contractures.[1,37,64] The preoperative elbow motion must be carefully assessed and recorded. Postoperatively, if the patient was not seen prior to injury or surgery, the athlete should be asked how much elbow extension had been present in the past 2 to 3 years. Attempting to compare elbow ROM to the contralateral side may not be adequate when restoring back to baseline. The professional baseball pitcher often lacks approximately 3° to 5° of extension when tested in spring training physicals. The elbow is predisposed to flexion contractures due to the intimate congruency of the joint articulations, the tightness of the joint capsule, and the tendency of the anterior capsule to develop adhesions following injury.[96] The brachialis muscle also attaches to the capsule and crosses the elbow joint before becoming a tendinous structure. Injury to the elbow may cause excessive scar tissue formation of the brachialis muscle as well as functional splinting of the elbow.[96] Wright et al[103] reported on 33 professional baseball players prior to the competitive season. The average loss of elbow extension was 7°, and the average loss of flexion was 5.5° compared to the opposite elbow joint. It is critical that postoperative ROM match preoperative motion, especially in the case of UCL reconstruction. This loss of extension can be a deleterious side effect for the overhead athlete.

Another goal of this phase is to decrease the patient's pain and inflammation. Cryotherapy, laser, and high-voltage stimulation may be needed to reduce pain and inflammation. Once the acute inflammatory response has subsided, moist heat, warm whirlpool, and ultrasound may be used at the onset of treatment to prepare the tissue for stretching and improve the extensibility of the capsule and musculotendinous structures. Grade I and II mobilization techniques may also be utilized in the early phases to neuromodulate pain by stimulating type I and type II articular receptors.[53,104]

In addition to ROM exercises, joint mobilizations may be performed as tolerated to minimize the occurrence of joint contractures. Grade I and II mobilizations are initially used to help decrease pain and inflammation and later progressed to more aggressive grade III and IV mobilization techniques at end ROM, with the intended goal of improving ROM during later stages of rehabilitation when symptoms have subsided. Joint mobilization must include the radiocapitellar and radioulnar joints as well as maintain supination and pronation ROM. Posterior glides of the humeroulnar joint with oscillations are performed at end ROM to assist in regaining full elbow extension.

If the patient continues to have difficulty achieving full extension using ROM and mobilization techniques, a low-load, long-duration (LLLD) stretch may be performed to produce a deformation (creep) of the collagen tissue, resulting in tissue elongation.[47,82,92,93] This technique appears to be extremely beneficial for regaining full elbow extension. The patient lies supine with a towel roll or a foam pad placed under the distal brachium to act as a cushion and fulcrum. Light-resistance exercise tubing is applied to the wrist of the patient and secured to the table or a dumbbell on the ground (Figure 1). The patient is instructed to relax as much as possible for 10 to 15 minutes per treatment. The resistance applied should enable the patient to stretch for the entire duration without pain or muscle spasm. This technique is intended to impart a low load during a long-duration stretch. Patients are instructed to perform the LLLD stretches several times per day, totaling at least 60 minutes of total end range time. We typically recommend a 15-minute stretch, 4 times per day. This program has been referred to as a TERT program (total end range time)[54] and has been extremely beneficial for patients with a stiff elbow. However, in some patients who are not responding, splinting and bracing may be needed to create this LLLD stretch. This would require the patient to wear the brace at night for several hours while sleeping (Figure 2).

Figure 1. A low-load, long-duration stretch into elbow extension is performed using light resistance. The shoulder is internally rotated while the forearm is pronated to best isolate and maximize the stretch on the elbow joint.

The aggressiveness of stretching and mobilization techniques is dictated by the healing constraints of involved tissues, as well as specific pathology/surgery and the amount of motion and end feel. For example, if the patient presents with a decrease in motion and hard end feel without pain, more aggressive stretching and mobilization technique may be used. Conversely, a patient exhibiting pain before resistance or an empty end feel will be progressed slowly with gentle stretching. In addition, it is beneficial to incorporate interventions to maintain proper glenohumeral joint ROM as indicated with each patient, including stretching and glenohumeral joint mobilizations.

The early phases of rehabilitation also focus on voluntary activation of muscle and retarding muscular atrophy. Subpainful and submaximal isometrics are performed initially

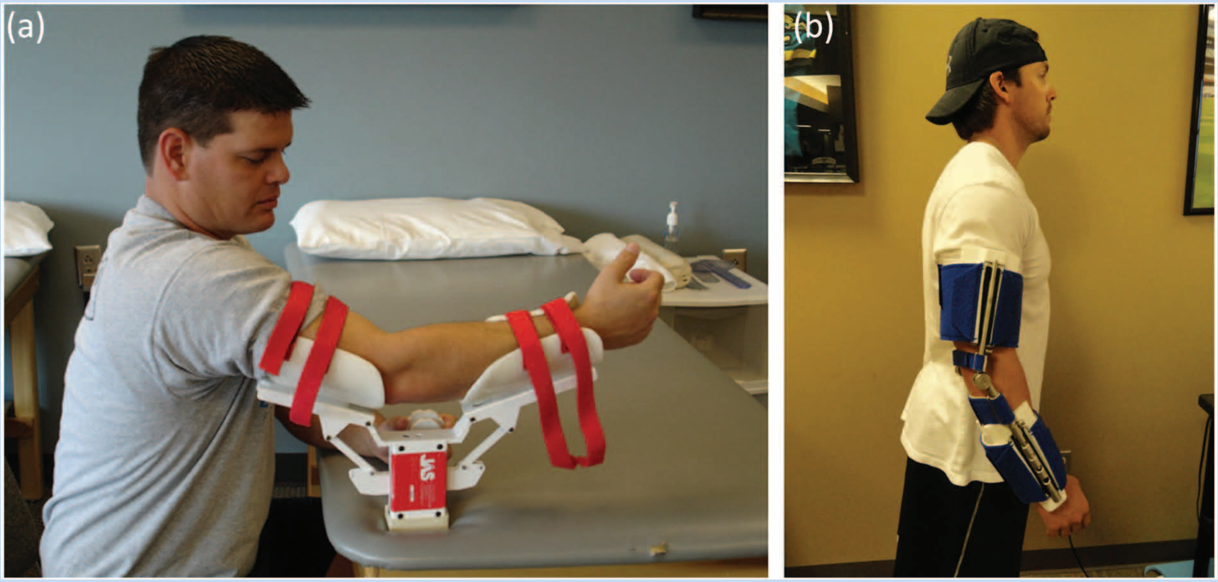

Figure 2. (a) Joint Active System (JAS, Effingham, Illinois) and (b) Dynasplint (Severna Park, Maryland) are 2 commercial devices commonly used by patients at home to work on elbow extension range of motion.

for the elbow flexor and extensor, as well as the wrist flexor, extensor, pronator, and supinator muscle groups. Shoulder isometrics may also be performed during this phase with caution against internal and external rotation exercises, if painful, as the elbow joint becomes a fulcrum for shoulder isometrics. Scapular muscle strengthening is initiated immediately following the injury. Alternating rhythmic stabilization drills for shoulder flexion/extension/horizontal abduction/adduction, shoulder internal/external rotation, and elbow flexion/extension/supination/pronation are performed to reestablish proprioception and neuromuscular control.

Phase 2: Intermediate

Phase 2, the intermediate phase, is initiated when the following are achieved: full throwing ROM (as it was prior to the injury), minimal pain and tenderness, and a good (≥ 4/5) manual muscle test of the elbow flexor and extensor musculature. The emphasis of this phase includes maintaining and enhancing elbow and upper extremity mobility, improving muscular strength and endurance, and reestablishing neuromuscular control of the elbow complex.

Stretching exercises are continued to maintain full elbow and wrist ROM. Mobilization techniques may be progressed to more aggressive grade III and IV techniques as needed to apply a stretch to the capsular tissue at end range. Flexibility is progressed during this phase to focus on wrist flexion, extension, pronation, and supination. Elbow extension and forearm pronation flexibility are of particular emphasis in throwing athletes to perform efficiently. Shoulder flexibility is also maintained with emphasis on external and internal rotation at 90° of abduction, flexion, and horizontal adduction. In particular, shoulder external rotation at 90° abduction is emphasized; loss of external rotation may result in increased strain on the medial elbow structures during the overhead throwing motion.[32] Additionally, internal rotation motion is also diligently performed, as internal rotation range of motion of the shoulder may create a protective varus force at the elbow. The rehabilitation program for shoulder joint ROM should consider the total ROM, and appropriate treatments should be employed to restore equal motion bilaterally.[97]

Strengthening exercises are progressed during this phase to include isotonic contractions, beginning with concentric and progressing to include eccentric. Emphasis is placed on elbow flexion and extension, wrist flexion and extension, and forearm pronation and supination. The glenohumeral and scapulothoracic muscles are also placed on a progressive resistance program if there is no elbow pain. Emphasis is placed on strengthening the shoulder external rotators and periscapular muscles. A complete upper extremity strengthening program, such as the Thrower's Ten program,[98] may be performed (Supplemental Appendix A; available at http://sph.sagepub.com/content/suppl). This program has been designed based on electromyographic studies to illicit activity of the muscles most needed to provide dynamic stability.[73,74] Strengthening exercises are advanced to include external and internal rotation with exercise tubing at 0° of abduction and active ROM exercises against gravity. These exercises initially include standing scaption in external rotation (full can),[72-74] standing abduction, side-lying external rotation, and prone

Figure 3. Manual concentric and eccentric resistance exercises for the elbow flexors and wrist flexor-pronators.

rowing. As strength returns, the program may be advanced to full upper extremity strengthening with emphasis on posterior rotator cuff muscles and scapular strengthening. Recently, a 6-week training program utilizing the Thrower's Ten program resulted in a 2-mph increase in throwing velocity in high school baseball pitchers.[31]

Neuromuscular control exercises are initiated in this phase to enhance the muscles' ability to control the elbow joint during athletic activities. A decrease in neuromuscular control has also been associated with muscular fatigue. Detection of both internal and external rotation decreases following isokinetic fatigue protocol.[16] A significant decrease in accuracy occurs following muscle fatigue during both active and passive joint reproduction.[88] Fatigue of the shoulder rotators results in decreased accuracy at mid- and end ROM.[59,60] These exercises include proprioceptive neuromuscular facilitation with rhythmic stabilizations and manual resistance elbow/wrist flexion drills (Figure 3).

Phase 3: Advanced Strengthening

The third phase involves a progression of activities to prepare the athlete for sport participation. The goals of this phase are to gradually increase strength, power, endurance, and neuromuscular control to prepare for a gradual return to sport. Specific criteria that must be met before entering this phase include full nonpainful external and internal rotation total ROM, no pain or tenderness, and strength that is 70% of the contralateral extremity.

Advanced strengthening activities during this phase include a gradual progression to higher resistance, functional movements, eccentric contraction, and plyometric activities. Elbow flexion exercises are progressed to emphasize eccentric control. The biceps muscle is an important stabilizer during the follow-through phase of overhead throwing. Eccentric control decelerates the elbow, preventing pathological abutting of the olecranon within the fossa.[7,35] Elbow flexion can be performed with elastic tubing to emphasize slow- and fast-speed concentric and eccentric contractions. Furthermore, manual resistance may be applied for concentric and eccentric contractions of the elbow flexors. Aggressive strengthening exercises with weight machines are also incorporated during this phase when the athlete demonstrates the use of machines with an appropriate weight. These most commonly begin with bench press, seated rowing, and front latissimus dorsi pull-downs. The triceps are primarily exercised with a concentric contraction due to the muscle-shortening activity during the acceleration phase of throwing. During this phase, the overhead athlete may be placed on the Advanced Thrower's Ten program[100] (Supplemental Appendix B). This program incorporates exercises and movement patterns specific to the throwing motion, in a discrete series, utilizing principles of coactivation, high-level neuromuscular control, dynamic stabilization, muscular facilitation, endurance, and coordination that restore muscle balance and symmetry in the throwing athlete.[100] Examples include the full can raise with sustained holds while seated on a stability ball (Figure 4) or prone horizontal abduction on a stability ball while performing sustained holds (Figure 5).

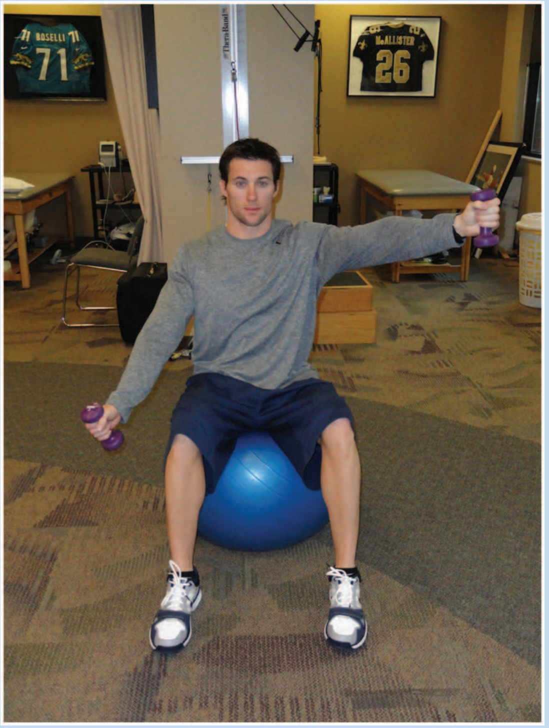

Figure 4. Advanced Thrower's Ten: Full can raises with sustained holds while seated on a stability ball.

Neuromuscular control exercises are progressed to side-lying external rotation with manual resistance. Concentric and eccentric external rotation is performed against the clinician's

Figure 5. Advanced Thrower's Ten: Prone horizontal abduction on a stability ball while performing sustained holds.

Figure 6. External rotation at 0° abduction with exercise tubing, manual resistance, and rhythmic stabilizations while the athlete is seated on a stability ball.

Figure 7. Plyometric wall throws with a 2-lb (0.91 kg) ball while the rehabilitation specialist performs a rhythmic stabilization at end range.

Figure 8. Plyometric wrist flips using a 2-lb (0.91 kg) medicine ball to strengthen the wrist flexors.

resistance with the addition of rhythmic stabilizations at end range. This manual resistance exercise may be progressed to external rotation with exercise tubing at 0° (Figure 6) while seated on a physioball and finally at 90°of abduction.

Plyometric drills can be an extremely beneficial functional exercise for training the elbow in overhead athletes.[83,99] Plyometric exercises are performed using a weighted medicine ball during the later stages of this phase to train the shoulder and elbow to withstand high levels of stress. Plyometric exercises are initially performed with 2 hands (chest pass, side-to-side throw, and overhead soccer throw). These may be progressed to one-handed activities such as 90/90 throws with rhythmic stabilization at end range (Figure 7), external and internal rotation throws at 0° of abduction into a trampoline, and wall dribbles to improve shoulder endurance. Specific plyometric drills for the forearm musculature include wrist flexion flips (Figure 8) and extension grips. The latter 2 plyometric drills are an important component of an elbow rehabilitation program, emphasizing the forearm and hand musculature. Plyometric training increases throwing velocity in high school baseball players.[31]

Phase 4: Return to Activity

The final phase of elbow rehabilitation, return to activity, allows the athlete to progressively return to full competition using an interval throwing program. Interval programs are used for the tennis player and golfer.[75]

Before an athlete is allowed to begin the return-to-activity phase, he or she must exhibit full pain-free throwing ROM, no pain or tenderness, a satisfactory isokinetic test, and medical clearance through MD clinical examination. Isokinetic testing is commonly utilized to determine the readiness of the athlete to begin an interval sport program.[75] Athletes are routinely tested at 180 and 300 degrees per second. Data indicate the bilateral comparison at 180 degrees per second for the throwing arm's elbow flexion 10% to 20% stronger and the dominant extensors, typically 5% to 15% stronger.[14,38,95] Also, the athlete's ability to perform sport-specific drills with a Plyoball is evaluated. These drills include one-hand Plyoball wall throws stabilization and throwing into rebounder (1-lb [0.45 kg] Plyoball) from 20 ft (6.10 m). Each one of these drills is evaluated for pain, technique, and quality of movement.

Upon the achievement of the previous goals, a formal interval sport program can begin.[75] For sports that involve the upper extremity, such as golf, tennis, baseball, and softball, an interval sport program is used. For the overhead thrower, we initiate a long-toss interval throwing program beginning at 45 ft (13.72 m) and gradually progressing to 120 or 180 feet (36.58 or 54.86 m; player and position dependent) (Supplemental Tables 3 and 4a). Throwing should be performed without pain or significant increase in symptoms. During the long-toss program, as intensity and distance increase, the stresses increase on the patient's medial elbow and anterior shoulder joint. The longer throwing distances significantly increased these forces.[34] It is important for the overhead athlete to perform stretching and an abbreviated strengthening program prior to and after performing the interval sport program. Typically, overhead throwers warm up, stretch, and perform 1 set of their exercise program before throwing, followed by 2 additional sets of exercises proceeding throwing. This provides an adequate warm-up but also ensures maintenance of necessary ROM and flexibility of the shoulder joint. The following day, the thrower will exercise his or her scapular muscles, external rotators, and perform a core stabilization program.[75]

Following the completion of a long-toss program, pitchers will progress to phase II, throwing off a mound (Supplemental Table 4b).[75] In phase II, the number of throws, intensity, and type of pitch are progressed to gradually increase stress on the elbow and shoulder joints. Generally, the pitcher begins at 50% intensity and gradually progresses to 75%, 90%, and 100% over a 4- to 6-week period. Breaking balls are initiated once the pitcher can throw 40 to 50 pitches at a minimum of 80% intensity without symptoms.

SPECIFIC NONOPERATIVE REHABILITATION GUIDELINES

UCL Injury

Injuries to the UCL are becoming increasingly more common in overhead throwing athletes, although the higher incidence of injury may be due to the ability to detect these injuries. The elbow experiences a tremendous valgus stress during overhead throwing.[33,94] The repetitive nature of overhead throwing activities further increases the susceptibility of UCL injury by exposing the ligament to repetitive microtraumatic forces.

Conservative treatment is attempted with partial tears and sprains of the UCL, although surgical reconstruction may be warranted for complete tears or if nonoperative treatment is unsuccessful. In the nonoperative rehabilitation program (Supplemental Table 5), ROM is initially permitted in a nonpainful arc of motion, usually from 10° to 100°, to decrease inflammation and align collagen tissue. A brace may be used to restrict motion and prevent valgus loading. Furthermore, it may be beneficial to rest the UCL immediately following the initial painful episode to prevent additional deleterious stress on the ligament. Isometric exercises are performed for the shoulder, elbow, and wrist to prevent muscular atrophy. Ice and anti-inflammatory medications are prescribed to control pain and inflammation.

ROM of flexion and extension is gradually increased by 5° to 10° per week during the second phase of treatment or as tolerated. Full pain-free ROM should be achieved by 3 to 4 weeks. Elbow flexion/extension motion is encouraged to promote collagen formation and alignment. Valgus loading of the elbow joint is controlled to minimize stress on the UCL. Rhythmic stabilization exercises are initiated to develop dynamic stabilization and neuromuscular control of the upper extremity. As dynamic stability is advanced, isotonic exercises are incorporated for the entire upper extremity.

The advanced strengthening phase is usually initiated at 6 to 7 weeks postinjury. During this phase, the athlete is progressed to the Thrower's Ten (Appendix A) isotonic strengthening program, and plyometric exercises are slowly initiated. An interval return to throwing is initiated once the athlete regains full motion, adequate shoulder and elbow strength (5/5 manual muscle test), and dynamic stability of the elbow. The athlete is allowed to return to competition following the asymptomatic completion of the interval sport program. If symptoms reoccur during the interval throwing program, it is usually at longer distances, at greater intensities, or with off-the-mound throwing. If symptoms continue to persist, surgical intervention is considered.

Medial Epicondylitis and Flexor-Pronator Tendinitis

Medial epicondylitis pain occurs within the flexor-pronator musculotendinous unit. Nirschl et al[62] reported 4 stages of epicondylitis, beginning with an early inflammatory reaction, followed by angiofibroblastic degeneration, leading to structural failure, and ultimately, fibrosis or calcification. It is critical to identify the condition of the tendon because the stage of the injury will dictate treatment.

The treatment for tendonitis is typically targeted at reducing inflammation and pain through a reduction in activities, steroid injections, anti-inflammatory medications, cryotherapy, iontophoresis, light exercise, and stretching.

The nonoperative approach for treatment of epicondylitis (ie, tendinitis and/or paratendinitis) (Supplemental Table 6) focuses on pain and inflammation control and then gradual improvement in muscular strength. The initial treatment consists of modalities, stretching exercises, and light strengthening to stimulate a repair response. Common modalities include massage, cold laser therapy, iontophoresis (Hybresis DJO Global, Vista, California), ultrasound, nitric oxide, and extracorporeal shockwave therapy. When these are used in combination with exercise or with other modalities, improved tissue quality and outcomes may be realized.[§]

Once the patient's symptoms have subsided, an aggressive stretching and (high-load, low-repetitions) strengthening program with emphasis on eccentric contractions is initiated. Wrist flexion and extension activities should be performed initially with the elbow flexed 30° to 45° to decrease stress on the medial elbow structures. A gradual progression through plyometric and throwing activities precedes initiating the interval throwing program.

Conversely, the treatment for tendinosis focuses on increasing circulation to promote collagen synthesis and collagen organization.[48,61,63] Heat, stretching, eccentrics, laser therapy, transverse massage, and soft tissue mobilization are utilized to increase circulation and promote tissue healing. Dry needling may promote tendon healing.[43,86] Eccentric exercise and strength training can improve results by increasing collagen synthesis[50] and improving fiber orientation.[3,17,84] Laser therapy[13,28,49,85] and extracorporeal shockwave therapy[46,89,90] have also shown promising results.

The goal of these treatments is to stimulate a regenerative response that otherwise would not occur. Platelet-rich plasma (PRP) is promising by delivering humoral mediators and growth factors locally to induce a healing response.[||] Mishra et al[55] showed significant benefits to PRP in chronic lateral epicondylitis. Thanasas et al[87] showed improved visual analog scale scores in ultrasound-guided PRP injections. In a randomized controlled double-blind study, improved visual analog scale scores and DASH (Disabilities of the Arm, Shoulder and Hand) scores were seen in the PRP group compared with a corticosteroid group even at a 2-year follow-up in patients with chronic lateral epicondylitis.[36] Basic science and controlled studies have yet to truly surmise the efficacy of PRP.

Valgus Extension Overload

Valgus extension overload occurs during repetitive, forceful extension: during the acceleration or deceleration phase of throwing as the olecranon wedges up against the medial olecranon.[101] This may result in osteophyte formation and potentially loose bodies. Repetitive extension stress from the triceps may further contribute to this injury. There is often underlying valgus laxity of the elbow, further facilitating osteophyte formation through compression of the radiocapitellar joint and the posteromedial elbow.[4,10] Overhead athletes typically present with pain at the posteromedial elbow that is exacerbated with forced extension and valgus stress.

A conservative initial treatment involves relieving pain and inflammation with ice, laser, and iontophoresis. As symptoms subside and ROM normalizes, dynamic stabilization and strengthening exercises are initiated with emphasis on eccentric strength of the elbow flexors to control rapid extension at the elbow. Manual resistance exercises of concentric and eccentric elbow flexion are performed, as well as elbow flexion with exercise tubing. The athlete's throwing mechanics should be carefully assessed to determine if mechanical faults are causing the valgus extension overload symptoms or if a UCL injury is present.

Osteochondritis Dissecans

Osteochondritis dissecans of the elbow may develop because of the valgus strain on the elbow joint, which produces not only medial tension but also a lateral compressive force as the capitellum compresses the radial head.[9] Patients often complain of lateral elbow pain upon palpation and valgus stress. Morrey[57] described a 3-stage classification of pathological progression: stage 1, no evidence of subchondral displacement or fracture; stage 2, evidence of subchondral detachment or articular cartilage fracture; stage 3, detached osteochondral fragments, resulting intra-articular loose bodies. Nonsurgical treatment is attempted for stage 1 patients, only consisting of relative rest and immobilization until elbow symptoms.

Nonoperative 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 included after approximately 1 week of isometric exercise. Aggressive high-speed, eccentric, and plyometric exercises are progressively included to prepare the athlete for the start of an interval throwing program.

If nonoperative treatment fails or evidence of loose bodies exists, surgical intervention is indicated, including arthroscopic abrading and drilling of the lesion with fixation or removal of the loose body.[11,76,102] Long-term follow-up studies regarding the outcome of patients undergoing surgery to drill or reattach the lesions have not produced favorable results suggesting that prevention and early detection of symptoms may be the best form of treatment.[11]

Little League Elbow

Little League elbow is a spectrum of medial epicondylar apophyseal injury that ranges from microtrauma to the physis to fracture and displacement of the medial epicondyle through the apophysis. Pain of the medial elbow is common in adolescent throwers. The medial epicondyle physis is subject to repetitive tensile and valgus forces during the arm-cocking and acceleration phases of throwing. These forces

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§References 2, 13, 28-30, 39, 41, 42, 46, 49, 58, 65, 67, 70, 71, 85, 89-91.
||References 20, 22, 23, 45, 51, 52, 55, 56, 80, 81.

may result in microtraumatic injury to the physis with potential fragmentation, hypertrophy, separation of the epiphysis, or avulsion of the medial epicondyle. Treatment varies based on the extent of injury.

In the absence of an avulsion, a rehabilitation program similar to that of the nonoperative UCL program is initiated. Emphasis is placed on the reduction of pain and inflammation and the restoration of motion and strength. Strengthening exercises are performed in a gradual fashion; isometrics are prior to light isotonic exercises. In young throwing athletes, core, legs, and shoulder strengthening is encouraged. Often, these individuals exhibit poor core and scapula control along with weakness of the shoulder musculature. In addition, stretching exercises are performed to normalize shoulder ROM, especially into internal rotation and horizontal adduction. No heavy lifting is permitted for 12 to 14 weeks. An interval throwing program is initiated as tolerated when symptoms subside, typically after an 8- to 12-week rest period.

In the presence of a nondisplaced or minimally displaced avulsion, a brief period of immobilization for approximately 7 to 14 days is encouraged, followed by a gradual progression of ROM, flexibility, and strength. An interval throwing program is usually allowed at weeks 8 to 12. If the avulsion is displaced, an open-reduction, internal-fixation procedure may be required.

SPECIFIC POSTOPERATIVE REHABILITATION GUIDELINES

UCL Reconstruction

Surgical reconstruction of the UCL attempts to restore the stabilizing functions of the anterior bundle of the UCL.[6] Several surgical procedures exist, including the Jobe procedure,[44] the docking procedure,[27,77] and the DANE procedure.[8,10,26] The modified Jobe procedure uses the palmaris longus or gracilis graft in a figure-8 pattern through drill holes in the sublime tubercle of the ulna and the medial epicondyle.[38] A subcutaneous ulnar nerve transposition is performed at the time of reconstruction.

The rehabilitation program following UCL reconstruction is based on the surgical procedure (Supplemental Table 7). The athlete is in a posterior splint with the elbow immobilized at 90° of flexion for the first 7 days postoperatively. This allows early healing of the UCL graft and fascial slings involved in the nerve transposition. Wrist ROM gripping and submaximal isometrics for the wrist and elbow are allowed. The patient is progressed from the posterior splint to a hinged elbow ROM brace (Figure 9) to protect the healing tissues from valgus stresses after 4 weeks.

Passive ROM activities are initiated immediately to decrease pain and slowly stress the healing tissues. Initially, the focus of the rehabilitation is obtaining full elbow extension while gradually progressing flexion. Elbow extension is encouraged early on to at least 15°, but if the patient can comfortably obtain full extension, then it is allowed as long as there is no discomfort. Passive ROM of the elbow joint produces 3% strain or less in both bands of the reconstructed ligament and approximately 1% strain for the anterior band of the UCL.[12] 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 increased 10° per week until full ROM is achieved by 4 to 6 weeks postoperatively.

Figure 9. Hinged elbow brace utilized postoperatively to protect the graft from deleterious valgus stresses

Isometric exercises are progressed to include light resistance isotonic exercises at weeks 3 to 4, while the Thrower's Ten program is initiated by week 6. Progressive resistance exercises are incorporated at weeks 8 to 9. Focus is placed on developing dynamic stabilization of the medial elbow. Because of the anatomic orientation of the flexor carpi ulnaris and flexor digitorum superficialis overlaying the UCL, isotonic and stabilization activities may assist the UCL in stabilizing valgus stress at the medial elbow.[21]

Aggressive exercises involving eccentric and plyometric contractions are in the advanced phase (weeks 12-16), while the advanced Thrower's Ten program is initiated at week 12. Two-hand plyometric drills are performed at week 12, one-hand drills at week 14, and an interval throwing program at week 16 postoperatively. In most cases, throwing from a mound occurs 4 to 6 weeks following the initiation of interval throwing, and a return to competitive throwing, at approximately 9 months following surgery.

UCL reconstruction in 743 athletes during a 2-year minimum follow-up with subcutaneous ulnar nerve transposition was effective in correcting valgus elbow instability in the overhead athlete and allowed most athletes (83%) to return to previous or higher levels of competition in less than 1 year.[15] Major complications were noted in 4% of the athletes.

The rehabilitation program following UCL reconstruction utilizing the docking procedure is slightly different. An elbow brace with ROM from 30° to 60° is used for the first 3 weeks; 15° to 90° at week 4.[27] The athlete should obtain full ROM by 6 weeks. Isotonic strengthening exercises are initiated at week 6. Plyometric activities may be performed at approximately 10 weeks to further stress the healing tissues in preparation for the interval throwing program. The athlete may incorporate heavier strengthening exercises utilizing machine weights at this time. A positional player may begin a hitting program at 12 weeks: first hitting off of a tee, progressing to soft-toss throws and, finally, formal batting practice. The interval throwing program is permitted at 4 months postoperatively, and formal pitching is typically accomplished at 9 months.

Ulnar Nerve Transposition

Ulnar nerve transposition is often performed in a subcutaneous fashion using fascial slings. Caution is taken to avoid stressing the soft tissue surrounding the nerve while healing occurs (Supplemental Table 8).[96] A posterior splint at 90° of elbow flexion is used for the first week to prevent excessive flexion and tension on the nerve. The splint is discharged at week 2, and light ROM activities are initiated. Full ROM is usually restored by weeks 3 to 4. Gentle isotonic strengthening is begun during weeks 3 to 4 and progressed to the full Thrower's Ten program by 4 to 6 weeks. Aggressive strengthening, including eccentric, advanced Thrower's Ten, and plyometric training, is incorporated at week 8, and an interval throwing program, at weeks 10 to 12, if all criteria are met, similar to the advanced phase of the UCL protocol. A return to competition usually occurs at week 16 postoperatively.

Posterior Olecranon Osteophyte Excision

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; by 10 days postoperative, the patient should exhibit at least 15 to 105/110 degrees of ROM, and 5-10 to 115° by day 14. Full ROM (0°-145°) is typically restored by days 20 to 25. The rate of ROM progression is most often limited by osseous pain and synovial joint inflammation, usually located at the tip of the olecranon.

Isometrics are performed for the first 10 to 14 days, and isotonic strengthening, from weeks 2 to 6. Initially, especially during the first 2 weeks, forceful triceps contractions may produce posterior elbow pain. If present, the force produced by the triceps muscle should be avoided or reduced. The full Thrower's Ten program is initiated by week 6, with interval throwing program by weeks 10 to 12. The rehabilitation focus is similar to the nonoperative treatment of valgus extension overload with emphasis on eccentric control of the elbow flexors and dynamic stabilization of the medial elbow.

In 72 professional baseball players undergoing elbow surgery, 65% exhibited a posterior olecranon osteophyte. Twenty-five percent later required an UCL reconstruction, suggesting that subtle medial instability may accelerate osteophyte formation.[8]

CONCLUSION

The elbow joint is a common site of injury in the overhead athlete due to the repetitive microtraumatic injuries. In collision sports, elbow injury is often due to macrotraumatic forces resulting in fractures, dislocations, and ligamentous injuries. Rehabilitation of the elbow, whether postinjury or postsurgical, must be progressive and sequential to ensure that healing tissues are not overstressed but provide appropriate stress to promote proper collagen alignment. The rehabilitation program should limit immobilization and achieve full ROM early, especially elbow extension. The rehabilitation program must progressively restore strength and neuromuscular control while gradually incorporating sports-specific activities to successfully return the athlete to his or her previous level of function as quickly and safely as possible. The rehabilitation of the elbow must include the entire kinetic chain (scapula, shoulder, hand, core/hips, and legs) to ensure the athlete's return to high-level sports participation.

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