Chapter 9

Epicondylitis

INTRODUCTION

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Epidemiology

Age/Sex

- Age: Those 35 to 50 years of age are at the highest risk
- Females and males

Sport

- Tennis
- Golf
- Occupations or hobbies with repetitive activities
- 1% to 3% of the general population affected
  - Adult players: 35% to 50%
  - Elite players: 11% to 12%

Pathophysiology

Intrinsic Factors

- Proximal strength deficits at the scapula and glenohumeral joint
- Glenohumeral flexibility deficits such as loss of posterior shoulder flexibility
- Poor weightshifting during backhand, late backswing, and hitting with the front shoulder up
- Increased wrist extension at ball impact
- Poor general condition
- Poor upper-limb posture
- Inadequate rest and recovery
- Inadequate warmup

Extrinsic Factors

- Improper racquet grip size
- Racquet string tension too high
- Strings not resilient or soft enough
- Improper handle size of racquet or other sporting equipment that requires grip

Traumatic Factors

- Gradual increased load-related pain with increased activity
- Repetitive microtrauma
- Vascular compromise
- High eccentric and concentric stresses on the common extensor tendon (especially during the tennis backhand)

Classic Pathological Findings

- Angiofibroblastic hyperplasia, tendinosis
- Excessive vascular granulation
- Disorganized or degenerative collagen
- Degeneration, tendonopathy, tendinosis, and microtears of the extensor carpi radialis brevis (ECRB) and EDU tendon

Clinical Presentation

History

- Gradual onset of pain at the origin of the common extensor tendon (Figure 9-1)

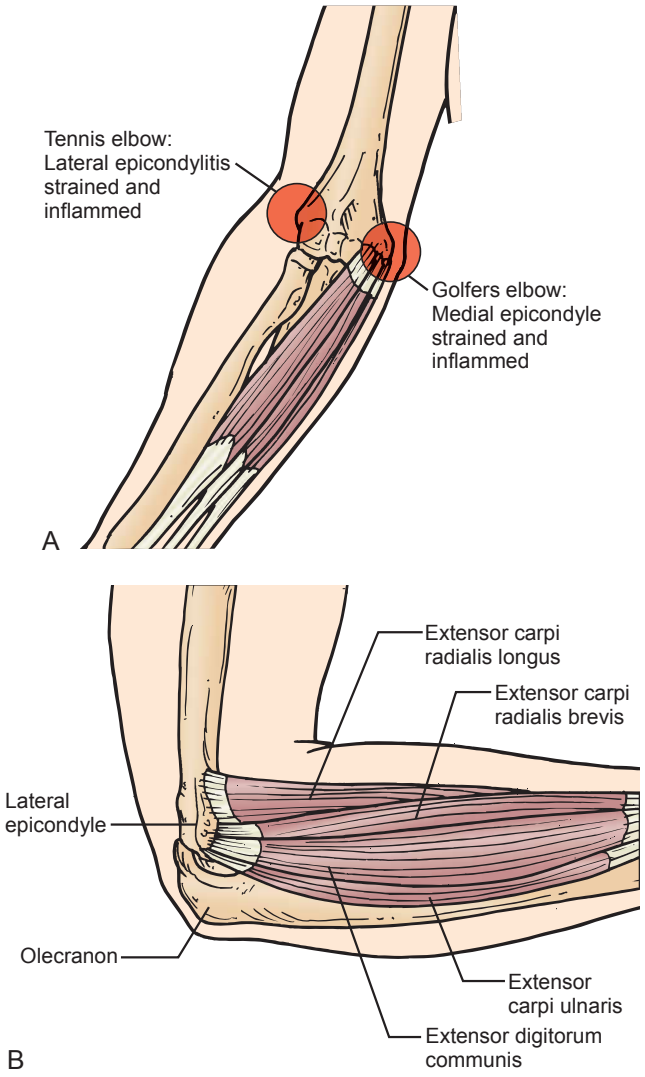

FIGURE 9-1. Lateral and medial epicondylitis. **A**, In lateral epicondylitis, or "tennis elbow," inflammation and pain occur in the outer side of the elbow, where muscles and tendons attach to the bone. The structures involved are the muscles or tendons of the forearm that bring the wrist back or extend the wrist, which is why this condition occurs not only in tennis players but also in anyone who performs repeated resisted motions of the wrist. In medial epicondylitis, or "golfer's elbow," inflammation and pain occur in the inner side of the elbow, where muscles and tendons attach to the bone. The structures involved are the muscles and tendons of the forearm that bring the wrist down and flex the wrist. This occurs not only in golfers but in anyone who performs repeated resisted motions of the wrist. **B,** Origin of the common extensor tendon.

- Often related to the backhand, especially in the novice and the recreational tennis player
- Other complaints may be related to repetitive labor activities, excessive computer work, or carrying bags with the elbow in extension.
- Symptoms often progress from pain after athletic or work-related activities to simple activities of daily living, such as shaking hands or holding an object with the elbow in extension.
- The elbow becomes painful at rest and disturbs sleep.

Physical Examination

Abnormal Findings

- Loss of wrist flexion range of motion
- Tenderness to palpation of the extensor origin at the lateral epicondyle (see Figure 9-1*B*)
- Localized edema, erythema
- Grip weakness
- Pain with passive wrist flexion
- Pain with resistive wrist and third-finger extension

Imaging

- Radiographs: tendinous calcific changes
- Magnetic resonance imaging (MRI): tears of the extensor tendon, abnormal tendinous tissue

Differential Diagnosis

- C6 to C7 nerve root compression: symptoms more radicular in nature
- Posterior interosseous nerve syndrome: may be differentiated by pain with wrist extension and radial deviation, weakness of finger extensors, and pain with thumb extension at the lateral epicondyle
- Lateral antebrachial cutaneous nerve irritation (the terminal sensory branch of the musculocutaneous nerve)

Treatment

Nonoperative Management

- Activity modification to avoid the aggravating behaviors
- Corticosteroid injections
- Nonsteroidal antiinflammatory drugs
- Counterforce bracing, wrist cockup splint
- Shock-wave therapy
- Physical therapy: strength, flexibility, conditioning, manipulation, and mobilization
  - Physical therapy modalities: cryotherapy, transcutaneous electrical nerve stimulation, iontophoresis, ultrasound, and low-level laser
- Improvement of sport mechanics
- Plasma-rich platelet injections

Guidelines for Choosing Nonoperative Treatments

- Diagnosis of tendinitis versus tendonopathy
- Severity and history of symptoms
- Clinical findings, such as strength, flexibility, postural, and conditioning deficits

Surgical Indications

- Failure of injections
- Associated intraarticular pathology
- Failure of conservative treatment for a minimum of 6 months

Aspects of History, Demographics, or Examination Findings that Affect Choice of Treatment

- Persistent pain that interferes with activities of daily living and disturbs sleep
- Pain that prevents return to sport such as tennis
- Persistent pain localized to the origins of the ECRB and extensor digitorum communis (EDC)
- Tear of the extensor demonstrated on MRI evaluation

Aspects of Clinical Decision-Making When Surgery Is Indicated

- Surgeon's experience and the efficiency of the procedure
- Other intraarticular pathology may dictate an arthroscopic procedure.
- Lateral epicondyle drilling can increase pain and potentially damage the EDC.
- Release techniques have potential for complications, such as damage to the lateral ligament complex, instability, and loss of grip strength.

Evidence

Barr S, Cerisola FL, Blanchard V: Effectiveness of corticosteroid injections compared with physiotherapeutic interventions for lateral epicondylitis: a systematic review. *Physiotherapy* 95:251–265, 2009.

This systematic review of randomized control trials compares corticosteroid injections with physiotherapeutic interventions. The authors indicate that injections are effective at short-term follow-up examinations and physiotherapeutic interventions are effective at intermediate and long-term follow-up examinations. (Level IIIA evidence).

Garg R, Adamson GJ, Dawson PA, et al: A prospective randomized study comparing a forearm strap brace versus a wrist splint for the treatment of lateral epicondylitis. *J Shoulder Elbow Surg* 19:508–512, 2010.

In this prospective, randomized study, 42 patients with lateral epicondylitis were given either a counterforce forearm strap or a wrist extension splint. Utilizing the Mayo Elbow Performance and ASES Assessment form, the researchers found that the wrist extension splint led to a greater degree of pain relief. (Level II evidence).

Nirschl RP, Rodin DM, Ochiai DH, et al: Iontophoretic administration of dexamethasone sodium phosphate for acute epicondylitis. *Am J Sports Med* 31:189–195, 2003.

In this randomized, double-blind, placebo-controlled trial, 199 patients with epicondylitis either were treated with iontophoresis with dexamethasone or received placebo treatment. More patients treated with dexamethasone scored moderate or better on the investigators' global improvement scale at 2 days, but the difference was not significant at 1 month. (Level IV evidence).

Oken O, Kahraman Y, Ayhan F, et al: The short-term efficacy of laser, brace and ultrasound treatment in lateral epicondylitis: a prospective, randomized, controlled trial. *J Hand Surg* 21:63–68, 2008.

In this prospective, randomized, controlled trial, three groups of patients with lateral epicondylitis were treated with braces and exercise, ultrasound and exercise, or low-level laser and exercise. Laser therapy was more effective than ultrasound or bracing in restoring grip strength. (Level IIIb evidence).

Peerbooms JC, Sluimer J, Bruijn DJ, et al: Positive effect of an autologous platelet concentrate in lateral epicondylitis in a double-blind randomized controlled trial: platelet-rich plasma versus corticosteroid injection with a 1-year follow-up. *Am J Sports Med* 38:255–262, 2010.

In this double-blind, randomized control trial, the researchers compared treatment of 100 patients with lateral epicondylitis, 51 treated with platelet-rich plasma (PRP), and 49 with corticosteroid injection. The results, based on the score on the visual analogue scale Disabilities of the Arm, Shoulder, and Hand Module, demonstrated that PRP reduces pain and increases function, exceeding the results of corticosteroid injection. (Level I evidence).

Multiple-Choice Questions

QUESTION 1. Which of the following is not an intrinsic factor that may predispose the patient to lateral epicondylitis while playing tennis?

A. Proximal strength or flexibility deficits
B. Increased wrist extension at ball impact
C. Increased wrist flexion at ball impact
D. Inadequate rest and recovery

QUESTION 2. Which of the following is not an extrinsic factor that contributes to lateral epicondylitis?

A. Improper racquet grip size
B. Racquet string tension that is too high
C. Improper footwear
D. Racquet string that is not resilient or soft enough

QUESTION 3. Which of the following conditions can easily be confused with, and needs to be differentiated from, lateral epicondylitis?

A. Posterolateral instability
B. Posterior interosseous nerve syndrome
C. Ulnar collateral ligament tear
D. C4 to C5 radiculopathy

QUESTION 4. Which of the following would not be a finding in a clinical examination for lateral epicondylitis?

A. Decreased grip strength
B. Loss of passive wrist extension
C. Pain with passive wrist and third-finger extension
D. Tenderness to palpation at the lateral epicondyle

QUESTION 5. Which of the following activities of daily living can exacerbate symptoms of lateral epicondylitis?

A. Handshaking
B. Excessive computer use
C. Carrying bags with the elbow in extension
D. All of the above

Answer Key

QUESTION 1. Correct answer: **C** (see Pathophysiology)

QUESTION 2. Correct answer: **C** (see Extrinsic Factors)

QUESTION 3. Correct answer: **B** (see Differential Diagnosis)

QUESTION 4. Correct answer: **D** (see Clinical Examination)

QUESTION 5. Correct answer: **D** (see Clinical Presentation)

NONOPERATIVE REHABILITATION OF LATERAL EPICONDYLITIS (TENNIS ELBOW)

Michael Levinson, PT, CSCS, and David Altchek, MD

GUIDING PRINCIPLES OF NONOPERATIVE REHABILITATION

- Understand the pathology: tendinitis versus tendonopathy
- Reduction of pain and inflammation and promotion of healing are the primary goals
- Control excessive loads to the injured area
- Pathologic tissue needs to be repaired and revitalized
- Reproduce the functional demands throughout the entire kinetic chain
- The patient's general fitness is critical to recovery and avoiding reinjury

Phase I (Guidelines are evaluation-based)

Protection

- Counterforce bracing or a wrist-cockup splint may be used for activities of daily living (Figure 9-2).
- Wrist splints should not be used during sleep, as they may cause shortening of the extensor tendons.
- Activity modification should be a significant factor in the treatment plan. The amount of incidental activities performed at home or at work (e.g., computer work, hand-shaking, carrying bags) should be taken into account.

Management of Pain and Swelling

- Modalities include cryotherapy, iontophoresis, ultrasound, TENS, and low-level laser.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization may be used for pain control or if any capsular restrictions are present. Manipulations (Mill's manipulation) may also be utilized. Mill's manipulation is a small-amplitude, high-velocity thrust performed at the end of elbow extension while the wrist and hand are held flexed.

Soft-Tissue Techniques

- It is the authors' opinion that deep-tissue massage often exacerbates symptoms and has little therapeutic value.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Stretching of the wrist and finger extensors should be initiated in a pain-free range of motion (ROM) (Figure 9-3).

Other Therapeutic Exercises

- Multijoint, upper-extremity exercises should be initiated to restore total arm strength (TAS) and proximal stability. These should include scapula, deltoid, and rotator cuff strengthening.
- Often, the tennis player has a proximal muscle deficit.
- Biceps and triceps strengthening should be initiated in a pain-free ROM, avoiding full elbow extension.

FIGURE 9-2. Counterforce brace.

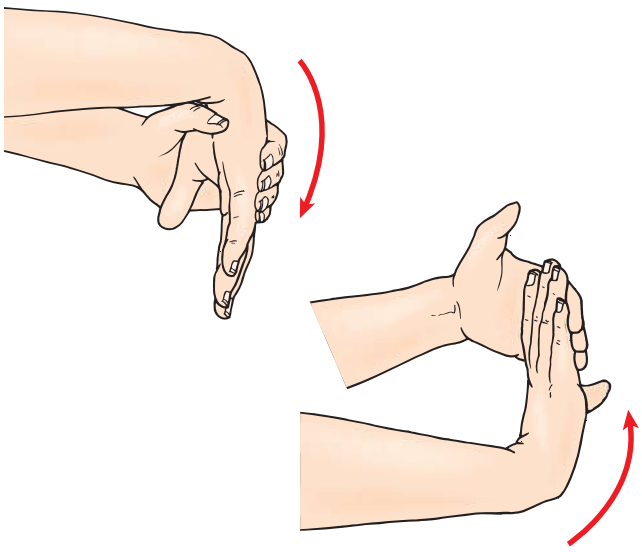

FIGURE 9-3. Stretching of the wrist and finger extensors.

- For the tennis player, core and lower-extremity strengthening may be initiated without holding weights in the hands.
- Upper-extremity posture should be addressed.

Open and Closed Kinetic Chain Exercises

- Closed kinetic chain exercises generally are performed with the wrist in extension and the elbow moving into full extension. This is contraindicated in Phase I.

Milestones for Progression to the Next Phase

- Reduction of symptoms (pain, edema, inflammation)
- Restoration of proximal stability (scapula function, rotator cuff strength)
- Normal wrist flexion ROM

Phase II (Guidelines are evaluation-based)

Protection

- Counterforce bracing or wrist-cockup splint as needed.

Management of Pain and Swelling

- Cryotherapy, iontophoresis, ultrasound, TENS, low-level laser as needed

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- Joint mobilization and manipulation if any capsular restrictions are needed

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue pain-free stretching of the wrist and finger extensors. Begin to address any shoulder flexibility deficits. For example, many tennis players have a loss of posterior shoulder flexibility.

Other Therapeutic Exercises

- Continue to progress general upper-extremity, multijoint exercises to normalize shoulder and scapula strength. For the tennis player, emphasize the scapula and posterior rotator cuff.
- Continue biceps- and triceps-strengthening to include concentric and eccentric activity.
- Initiate forearm-strengthening to include wrist flexion.
- Core and lower-extremity strengthening may be progressed, but the patient should still avoid holding heavy weights in the hands.

Activation of Primary Muscles Involved

- Initiate wrist extension and forearm pronation and supination. Exercises should be initiated with the elbow supported and in flexion to reduce the amount of bone-to-tendon contact at the origin of the common extensor tendon (Figure 9-4).

Techniques to Increase Muscle Strength, Power, and Endurance

- If proximal strength is adequate, the upper-body ergometer can be used to begin to restore power and endurance.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization should be initiated proximal to the elbow.

Functional Exercises

- Proprioceptive neuromuscular facilitation (PNF) patterns should be initiated.

Milestones for Progression to the Next Phase

- Normal upper-extremity flexibility
- Normal proximal upper-extremity strength
- Minimal pain with wrist extension exercises

Phase III (Guidelines are evaluation-based)

Management of Pain and Swelling

- Continue with prior modalities as needed as forearm-strengthening is progressed, symptoms may increase.

FIGURE 9-4. Forearm pronation (**A**) and supination (**B**) with the elbow in flexion.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- A full upper-extremity flexibility program should be continued. Overstretching of the wrist and finger extensors should be avoided.

Other Therapeutic Exercises

- Continue to progress a full upper-extremity strengthening program, including overhead activities.
- Progress core and lower-extremity strengthening and flexibility program.
- Sport-specific general conditioning exercises

Activation of Primary Muscles Involved

- Eccentric wrist extension should be emphasized if tolerated. This should be initiated with the elbow in flexion and progressed to extension (Figure 9-5). All muscle groups of the forearm should be addressed to restore normal functional movement patterns.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization may be progressed to a longer-lever arm (distal to the elbow).

FIGURE 9-5. Resistive eccentric wrist extension.

- Exercises may be progressed to more challenging positions for the shoulder and elbow (Figure 9-6).
- The patient may then progress to the Bodyblade from a neutral position to positions throughout the tennis stroke.

Plyometrics

- A plyometric program should be initiated if the patient is asymptomatic and has a normal strength base and normal upper-extremity flexibility.

TIMELINE 9-1: Nonoperative Rehabilitation of Lateral Epicondylitis (Tennis Elbow)

PHASE I	PHASE II
• Physical therapy (PT) modalities • Pain-free wrist extensor stretching • Counterforce bracing/wrist-cockup splint • TBS/TAS/TLS activities as recommended and tolerated • Multijoint shoulder, scapula, and elbow strengthening • Mobilization and manipulation as needed	• PT modalities • Shoulder flexibility exercises • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises, shoulder exercises, and elbow exercises (including eccentrics) • Wrist flexion–extension, forearm pronation–supination (elbow in flexion) • Core and lower-extremity exercises • Rhythmic stabilization with proximal resistance • PNF patterns • Upper-body ergometer

FIGURE 9-6. Rhythmic stabilization in the overhead position with distal resistance.

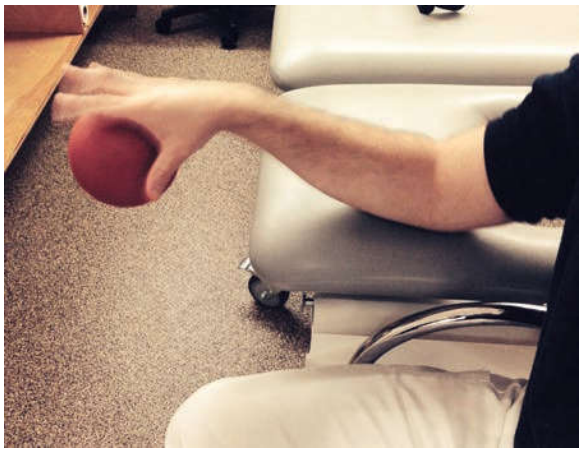

FIGURE 9-7. Wrist flips and snaps.

- A functional progression for a tennis player would follow: two-handed chest pass, side-to-side wood chops, overhead soccer pass, one-handed external rotation, one-handed backhand, one-handed 90° internal and 90° external position.
- Deceleration exercises by catching the plyo ball and slowing it down should be included.
- Wrist flexion flips and wrist flexion snaps may be incorporated (Figure 9-7).

Sport-Specific Exercises

- Resistive forehand and backhand exercises using elastic resistance or a cable system should be initiated.

Milestones for Progression to Advanced Sport-Specific Training and Conditioning

- Completion of a plyometric program without symptoms
- Full forearm strengthening without residual symptoms
- Upper-extremity strength and endurance that is equal or greater than the contralateral side

Phase IV (Guidelines are evaluation-based)

Management of Pain and Swelling

- Cryotherapy should be utilized throughout the return.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue full upper-extremity flexibility program.
- Avoid overstretching the extensor tendons.
- Stretching should always be pain-free.

Other Therapeutic Exercises

- Continue a full upper-extremity strengthening program to include the scapula, shoulder, elbow, forearm, and wrist.

TIMELINE 9-1: **Nonoperative Rehabilitation of Lateral Epicondylitis (Tennis Elbow)** (Continued)

PHASE III	PHASE IV
• PT modalities as needed • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: Biceps/triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises, including 90° internal and 90° external position PREs • Full forearm PREs • Eccentric wrist extension: PREs • PNF exercises • Rhythmic stabilization exercises with long lever arm; progress to Bodyblade • Core and lower-extremity exercises • Sport-specific plyometrics • Sport-specific PREs (forehand and backhand)	• PT modalities as needed • Full upper-extremity flexibility program • Wrist flexion–extension isokinetics • TBS/TAS/TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps/triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Forearm exercises • Core and lower extremity: PREs • PNF exercises • Open kinetic chain rhythmic stabilization exercises • Core and lower-extremity flexibility exercises • Interval tennis program

- Continue core stability with emphasis on trunk rotation and posture.
- Continue full lower-extremity strengthening program with emphasis on closed-chain activities, hip rotation, and unilateral activities. These may include leg press, squats, forward stepups, lunges, side lunges, back lunges, split squats, and lunges with trunk rotation.

Techniques to Increase Muscle Strength, Power, and Endurance

- Isokinetics for wrist flexion–extension and pronation–supination once a strength base has been established. This can be used to reproduce sport-specific speeds and train for endurance.

Plyometrics

- As an interval tennis program is initiated, plyometrics should be phased out.

Sport-Specific Exercises

- An interval tennis program should be initiated if criteria are met.
- The program should entail a progression of volume and intensity. The program should be progressed individually.
- Each phase should be completed without significant symptoms or fatigue prior to advancing to the next phase.

Criteria for Abandoning Nonoperative Treatment and Proceeding to Surgery or More Intensive Intervention

- Unable to perform sport-specific activities or return to preinjury activity level
- Continued pain with activities of daily living
- Failure to restore normal grip strength

Milestones for Progression to Sport-Specific Training and Conditioning

- Able to complete interval tennis program without symptoms
- Maintain normal upper-extremity strength and flexibility

Tips and Guidelines for Transitioning to Performance Enhancement

- When resuming tennis activities, the patient should not try to work through pain or fatigue.
- Use of low-compression tennis balls has been advocated when initiating an interval tennis program. These decrease the amount of stress on the elbow at ball impact.
- The patient's racquet should be evaluated for string tension and grip size. These can also be valuable in avoiding reinjury.
- Adequate rest and recovery are important to avoiding and minimizing fatigue and reducing the chances of reinjury.

Performance Enhancement and Beyond Rehabilitation: Training/Trainer and Optimization of Athletic Performance

- When returning to tennis activities, supervision by a professional to improve mechanics can enhance performance and prevent reinjury.
- Learning to weight-shift properly, use the core and lower extremities, and avoid hitting too late with the leading elbow posture can be very valuable.
- Upon returning to tennis, a program for full-body strength, flexibility, and endurance should be maintained. This will also reduce the risk of reinjury.

Specific Criteria for Return to Sports Participation: Tests and Measurements

- Normal grip strength on dynamometer
- Shoulder strength greater than contralateral side
- Normal upper-extremity flexibility
- Completion of full-interval tennis program

Evidence

Struijs PAA, Damen PJ, Bakker EWP, et al: Manipulation of the wrist for management of lateral epicondylitis: a randomized pilot study. *Phys Ther* 83:608–616, 2003.

In this randomized pilot study, two protocols were compared for patients with lateral epicondylitis. One was wrist manipulation, and the other consisted of ultrasound, friction massage, stretching, and strengthening. Follow-up was at 3 and 6 weeks. Manipulation of the wrist appeared to be more effective for the short-term.

Tanaka Y, Aoki M, Izumi T, et al: Effect of elbow and forearm position on contact pressure between the extensor origin and the lateral side of the capitellum. *J Hand Surg [Am]* 36:81–88, 2011.

In this cadaveric study, contact pressure between the origin of the common extensor tendons and the lateral side of capitellum was measured with a pressure sensor. Bone-to-tendon contacts is considered to be a cause of lateral epicondylitis with elbow extension, forearm pronation, and varus stress to the elbow.

Tyler TF, Thomas GC, Nicholas SJ, et al: Addition of isolated wrist extensor eccentric exercise to standard treatment for chronic lateral epicondylosis: A prospective randomized trial. *J Surg Shoulder Elbow* 19:917–922, 2010.

In this prospective randomized study, 21 patients with lateral epicondylosis were treated with eccentric strengthening for the wrist extensors using an inexpensive rubber bar. All outcome measures were found to have markedly improved with eccentric training on the basis of the Disabilities of the Arm, Shoulder, and Hand questionnaire; visual analogue scale measurement; and strength testing.

Vincenzino B, Smith D, Cleland J, et al: Development of a clinical prediction rule to identify initial responders to mobilisation with movement and exercise for lateral epicondylalgia. *Man Ther* 14:550–554, 2009.

In this post hoc analysis, 64 patients with lateral epicondylalgia were treated with standardized physical therapy. After

3 weeks, patients were categorized as improving or not improving. Factors with relationships to improvement were entered into a logistic regression model. Probability of improvement rose from 79% to 100% if all three factors were positive (Identify what the three factors were).

Wen DY, Schultz BJ, Schaal B, et al: Eccentric strengthening for chronic lateral epicondylosis: a prospective randomized study. *Sports Health* 3:500–503, 2011.

In this prospective randomized study, 28 patients with lateral epicondylosis were treated with eccentric strengthening or stretching. Pain scores rated with a visual analogue scale were used. Both groups had improved at 4 weeks, but there was no significant difference between groups at any follow-up time point.

Multiple-Choice Questions

QUESTION 1. Which cannot be utilized for protection and symptom reduction during the initial phase of nonoperative treatment?

A. Sling
B. Elbow counterforce brace
C. Activity modification
D. Wrist cockup splint

QUESTION 2. Which would not be considered a criterion for return to sport?

A. Normal shoulder forearm and shoulder flexibility
B. Completion of a sport-specific plyometric program
C. Interval tennis program with only minimal to moderate symptoms
D. Shoulder strength greater than contralateral side

QUESTION 3. Which position allows the most bone-to-tendon contact for the extensor tendons?

A. Elbow flexion and forearm supination
B. Elbow extension and forearm pronation
C. Elbow extension and forearm supination
D. Elbow flexion and forearm pronation

QUESTION 4. Which of the following should one do when returning to tennis activities?

A. Use tennis balls with high compression
B. Hit unsupervised
C. Play through fatigue to build endurance
D. Learn to weight-shift properly and avoid hitting too late with leading elbow

QUESTION 5. When should isolated strengthening of the wrist and finger extensors be initiated?

A. When a proximal strength base has been established
B. When forearm flexibility is restored
C. When the patient is asymptomatic
D. All of the above

Answer Key

QUESTION 1. Correct answer: **D** (see Phase I: Protection)

QUESTION 2. Correct answer: **C** (see Specific Criteria for Return to Sports Participation)

QUESTION 3. Correct answer: **B** (see Evidence)

QUESTION 4. Correct answer: **D** (see Performance Enhancement and Beyond)

QUESTION 5. Correct answer: **D** (see Phase II)

POSTOPERATIVE REHABILITATION AFTER OPEN OR ARTHROSCOPIC SURGERY FOR LATERAL EPICONDYLITIS

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Indications for Surgical Treatment

- Failure of conservative treatment, which may include nonsteroidal antiinflammatory drugs, cortisone injections, splinting, and physical therapy and activity modification for a minimum of 6 months
- Persistent pain that interferes with activities of daily living
- Pain that prevents an athlete from returning to sport
- Clear localization of pain at the anatomic areas of the extensor carpi radialis brevis (ECRB) and extensor digitorum communis
- Tear of the extensor tendon diagnosed

Brief Summary of Surgical Treatment

Major Surgical Steps

- Supine position on the operating table
- Extensor carpi radialis longus (ECRL) is split longitudinally and retracted medially and laterally.
- The ECRB is exposed.
- Fibrinous material is debrided.
- Mini-Mitek suture anchor (De Puy Synthes, West Chester, Pennsylvania) is inserted into the lateral epicondyle.
- Two limbs of suture are passed through the ECRL and ECRB and reattached to the lateral epicondyle.
- Placed in posterior splint

Other Surgical Techniques and Options

- Major differences in other surgical techniques (if not covered in other sections)
- The ECRB can be debrided and released arthroscopically.
- The arthroscope is used to identify the location of the ECRB tendon and identify any other elbow joint pathologies, such as loose bodies.
- Any variance from rehabilitation guidelines would result from any postoperative joint effusion that might interfere with restoring range of motion (ROM) and strength.
- The clinician should be cognizant of any posterolateral instability that may result from this procedure.

Before Surgery: Overview of Goals, Milestones, and Guidelines[1]

GUIDING PRINCIPLES OF POSTOPERATIVE REHABILITATION

- Understand the surgical procedure performed and healing rates of the tissues involved
- Understand the positions and activities that stress the wrist and finger extensors and their attachment at the lateral epicondyle
- Minimize active wrist and finger extension during the early phases of rehabilitation
- Avoid painful ROM and strengthening
- Understand the criteria for returning to functional and athletic activities

Phase I: Immediate Postoperative Period (days 0 to 14)

Clinical Pearls

- Early range of motion is important. It should be performed actively or actively with assistance.
- Aggressive passive range motion should be avoided to allow optimal soft-tissue healing.
- A brace is generally not required. However, it may be indicated if patient activity modification is a concern.

Goals

- Patient education
- Activity modification to avoid stressing the repair
- Protect the surgical repair
- Minimize swelling, pain, and inflammation
- Avoid contracture

[1]*Prehabilitation, if appropriate, is described in the Nonoperative Rehabilitation section of this chapter.*

Protection

- A posterior splint is used for 1 week. As mentioned above, a brace is generally not indicated.

Management of Pain and Swelling

- Oral pain medications are prescribed.
- Cryotherapy is used for pain and inflammation.
- Activity modification to avoid pain is also critical. Minimizing activities that stress the wrist and finger extensors will help to reduce postoperative pain.
- For swelling, cryotherapy and activity modification

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Codman exercises are used to increase blood flow into the entire upper extremity and maintain flexibility of the glenohumeral joint.
- Scapular retraction exercises are used to maintain posture and begin to restore proximal strength.
- Elbow active range of motion (AROM) and active assisted range of motion (AAROM) exercises are initiated. The therapist should not engage the patient with passive range of motion (PROM).

Other Therapeutic Exercises

- Once the sutures are removed, the patient may begin to use a stationary bicycle, but should avoid gripping the handle with the surgically treated hand.

Milestones for Progression to the Next Phase

- Minimal pain and swelling

Phase II (weeks 2 to 6)

Clinical Pearls

- The therapist should continue to avoid engaging the patient with aggressive PROM to allow optimal soft-tissue healing.
- Elbow extension should be restored by a low-intensity/long-duration stretch in supine.
- Patients should be advised to perform activities with their surgically treated arm with the elbow in flexion to reduce stress to the repair.

Goals

- Protect surgical repair
- Minimize pain, swelling, and inflammation
- Continue to modify activities of daily living (computer use, handshaking, carrying, and lifting)
- Avoid painful exercises.

Protection

- No protection is needed if the patient is compliant.

Management of Pain and Swelling

- Continue cryotherapy and oral pain medications as indicated.
- Continue cryotherapy and activity modification to control swelling.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Continue AROM and AAROM of the elbow.
- Low-intensity/long-duration stretch for elbow extension if needed; performed while supine with a towel roll under the humerus
- Gentle wrist ROM is initiated to avoid forearm stiffness and promote healing. This should be performed with the elbow in flexion.
- AROM of the shoulder is performed to maintain glenohumeral ROM and flexibility.

Other Therapeutic Exercises

- Continue stationary bicycle while avoiding gripping with the surgically treated hand.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Begin manual sidelying scapular stabilization exercise with resistance proximal to the elbow to continue to establish proximal strength (Figure 9-8).

Milestones for Progression to the Next Phase

- Minimal pain or swelling

FIGURE 9-8. Manual sidelying scapular stabilization exercises with proximal resistance.

Phase III (weeks 6 to 10)

Clinical Pearls

- When initiating isotonic exercises for the shoulder, scapula, and elbow, the patient should avoid end ranges of elbow extension. This will avoid excessive stress to the surgically repaired extensor tendon.
- Strengthening of the wrist and finger extensors should begin with the elbow supported and flexed. This will decrease bone-to-tendon contact pressure at the origin of the common extensor tendon at the lateral epicondyle.

Goals

- Continue to avoid excessive stress to the surgical repair.
- No pain with exercise or activities of daily living
- Full elbow ROM
- Begin to restore shoulder and scapular strength/flexibility.
- Begin to restore elbow and forearm strength.

Management of Pain and Swelling

- Cryotherapy is continued, and oral pain medication should be discontinued.

Techniques for Progressive Increase in Range of Motion

Manual Therapy Techniques

- In cases where extension is not full by 6 to 10 weeks, joint mobilization, such as joint distraction and posterior gliding of the ulna on the humerus, should be utilized.

Stretching and Flexibility Techniques for the Musculotendinous Unit

- If full extension has not been restored, a low-intensity/long-duration stretch should continue to be used. A weight or elastic resistance may be added.

Other Therapeutic Exercises

- Sport-specific core and lower-extremity strengthening may be introduced. However, holding heavy weights in the hands while performing these exercises should be avoided.
- Proximal strengthening should be introduced for the shoulder and scapula, including the rhomboids; serratus; upper, middle, and lower trapezius; and latissimus dorsi and rotator cuffs.
- All exercises should be performed while avoiding the end range of elbow extension (Figures 9-9 to 9-11).
- Begin biceps and triceps strengthening while avoiding the end stage of elbow extension.

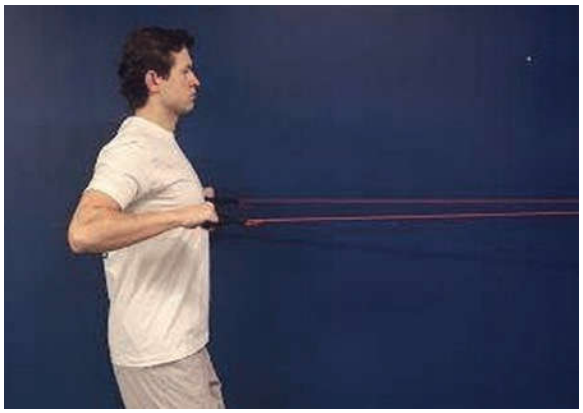

FIGURE 9-9. Scapula retraction with elastic resistance.

FIGURE 9-10. Serratus punch.

FIGURE 9-11. Latissimus dorsi pull-down.

Activation of Primary Muscles Involved in Injury Area or Surgical Structure

- Isotonic exercises for the wrist and finger extensors are initiated with the elbow supported and in flexion.

Open and Closed Kinetic Chain Exercises

- Most closed kinetic chain exercises put significant stress on the lateral epicondyle and common extensor tendon.

TIMELINE 9-2: Postoperative Rehabilitation after Open or Arthroscopic Surgery for Lateral Epicondylitis

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 6 to 10)
• Posterior splint for 1 week • Physical therapy (PT) modalities • Elbow AROM and AAROM • Codman's exercises	• PT modalities • Elbow AROM and AAROM • Low-intensity/long-duration stretch for extension (LILD) • Wrist AROM with elbow in flexion • Full elbow ROM • Manual sidelying scapular stabilization	• PT modalities as needed • Full AROM • Mobilization as needed • LILD as needed • Scapular exercises: progressive resistive exercises (PREs) • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Wrist flexor exercises • Wrist and finger extensor exercises with elbow in flexion • Rhythmic stabilization exercises proximal to the elbow • Closed kinetic chain exercises

FIGURE 9-12. Rhythmic stabilization with proximal resistance.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercises for the shoulder can be initiated with resistance proximal to the elbow (Figure 9-12).

Milestones for Progression to the Next Phase

- Full elbow ROM. Using standard goniometry, average elbow ROM is 0° internal and 140° external. However, it should be compared with the nonoperative side.
- Pain free with exercises and activities of daily living
- Good proximal strength base. All shoulder strength should be 5/5 using standard manual muscle testing. Scapulothoracic function should be within normal limits based on observation and comparison to the nonoperative side.
- Good shoulder flexibility determined using standard goniometry and compared with the nonoperative side. For shoulder internal rotation, vertebral level may be used.

Phase IV (weeks 10 to 14)

Clinical Pearls

- Elbow pathology in the athletic population is often associated with a selective loss of shoulder flexibility.
- In preparing for athletic activities, begin to restore proximal flexibility, especially in the posterior structures of the shoulder.
- The common extensor tendon often undergoes significant eccentric stresses. Eccentric training should begin to be incorporated into the program.

Goals

- Restore normal shoulder and scapular strength
- Restore normal shoulder flexibility
- Begin to restore forearm flexibility
- Progress to overhead activities

Management of Pain and Swelling

- Cryotherapy is continued to prevent any muscle soreness.
- Any significant pain in this phase indicates that the patient's activity level should be reduced.
- The surgeon should address any significant swelling in this phase.

TIMELINE 9-2: Postoperative Rehabilitation after Open or Arthroscopic Surgery for Lateral Epicondylitis (Continued)

PHASE IV (weeks 10 to 14)	PHASE V (weeks 14 to 24)	PHASE VI (weeks 24 to 52)
• PT modalities as needed • Full AROM • Mobilization as needed • Forearm stretching • Posterior shoulder stretching • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PRE progression to 90° internal and 90° external position • Eccentric wrist and finger extensor exercises • Proprioceptive neuromuscular facilitation (PNF) exercises • Rhythmic stabilization exercises distal to elbow and overhead position • Upper-body ergometry	• AROM: Maintain full motion • Mobilization as needed • Full upper-extremity flexibility exercises • Total body strengthening (TBS), total arm strengthening (TAS), and total leg strengthening (TLS) activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Forearm exercises with elbow extension: PREs • Isokinetics if available • PNF exercises • Rhythmic stabilization exercises • Bodyblade when available • Deceleration exercises • Plyometrics: Two-arm progressing to one arm • Interval tennis or sport-specific program begins • Full lower-extremity and core strength and flexibility	• AROM: maintain full motion • Maintain full-body flexibility • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS: biceps and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Internal rotation/external rotation exercises at 90° • Core and lower-extremity PREs • PNF exercises • Forearm exercises: PREs • Progress sport-specific program • Return to play

FIGURE 9-13. Posterior shoulder stretch.

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Forearm stretching for both the lateral and medial side should be performed. Posterior shoulder flexibility exercises should be initiated (Figure 9-13).

Other Therapeutic Exercises

- Scapula, shoulder, and elbow strengthening should be progressed as tolerated.
- Rotator cuff strengthening should be progressed to the 90° internal and 90° external position (Figure 9-14).

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Wrist and finger extension strengthening should begin to emphasize the eccentric activity of muscle contraction.

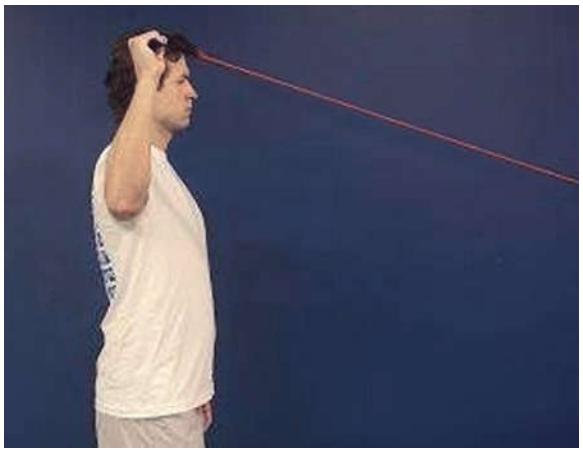

FIGURE 9-14. Rotator cuff strengthening in the 90° internal and 90° external position.

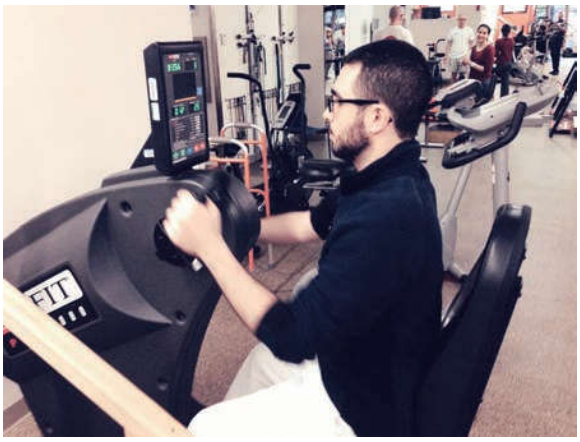

FIGURE 9-15. Upper-body ergometry

Sensorimotor Exercises

- Proprioceptive neuromuscular facilitation patterns are initiated.

Techniques to Increase Muscle Strength, Power, and Endurance

- Upper-body ergometry may be initiated to improve general upper-extremity endurance (Figure 9-15).

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization exercise should be progressed to resistance distal to the elbow and to the overhead position.

Phase V (weeks 14 to 24)

Clinical Pearls

- Sport- or work-specific programs should be initiated only after the patient has demonstrated normal strength, flexibility, and endurance.
- The patient should have tolerated all neuromuscular drills, including plyometrics, prior to beginning a sport- or work-specific program.
- For the tennis player, problems are often initiated by strength and flexibility deficits at more proximal points in the chain, such as the trunk and hips.

Goals

- Restore normal neuromuscular function
- Begin sport- or work-specific activities without pain
- Restore full-body strength, ROM, flexibility, and endurance

Management of Pain and Swelling

- Cryotherapy

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- A full upper-extremity flexibility program should be continued for the shoulder, elbow, wrist, and forearm.

Other Therapeutic Exercises

- For the athlete, a full core and lower-extremity strengthening and flexibility program should be incorporated.
- For the tennis player, emphasis on hip and trunk flexibility and strength is critical.

Activation of Primary Muscles Involved in Injury Area or Surgical Structures

- Wrist and finger extensor strengthening should be performed with the elbow in extension if tolerated.
- Forearm pronation and supination exercises should be incorporated to improve total forearm function. Heavy resistance is not required and, in most cases, is contraindicated.

Techniques to Increase Muscle Strength, Power, and Endurance

- When available, isokinetics can be utilized to build endurance and simulate the speeds and loading rates of functional activities, such as tennis.

Neuromuscular Dynamic Stability Exercises

- Rhythmic stabilization may be progressed to all functional positions.
- The patient may be progressed to the Bodyblade if one is available.
- A functional progression should be followed from the patient's side to external rotation, then to the 90° internal and 90° external position, and then to follow-through (Figure 9-16).

FIGURE 9-16. Bodyblade.

FIGURE 9-17. Deceleration exercises using a Plyoball.

Plyometrics

- When the patient is asymptomatic and with a normal strength base and upper-extremity flexibility within normal limits, a plyometric program should be initiated.
- Progression: Chest pass, side-to-side wood chops, overhead soccer pass, one-handed external rotation with arm at side, one-arm external rotation in 90° internal and 90° external position.

Functional Exercises

- Deceleration exercises are performed first in a kneeling position. Tossing a Plyoball over the shoulder and catching it and decelerating the arm.
- This should be progressed to a standing position where the patient trains the larger body parts to absorb stress from the upper extremity during a serve (Figure 9-17).

Sport-Specific Exercises

- For the tennis player, an interval tennis program should be initiated after completing several weeks of plyometrics without symptoms.
- Any sport-specific interval program should progress the intensity and volume of work.

Milestones for Progression to the Next Phase

- Normal grip strength
- Normal upper-extremity flexibility
- Normal upper-extremity strength, power, and endurance
- Completion of a sport-specific interval program.

Phase VI (weeks 24 to 52)

Goals

- Return to play
- Avoid reinjury
- Maintain strength and flexibility
- Maintain general fitness and improved posture

Management of Pain and Swelling

- Cryotherapy after activity or exercise

Techniques for Progressive Increase in Range of Motion

Stretching and Flexibility Techniques for the Musculotendinous Unit

- Maintain full upper-body, lower-body, and core flexibility program during play.

Other Therapeutic Exercises

- Continue full upper-body, lower-body, and core strengthening as they play.

Plyometrics

- Plyometrics should be phased out as the volume of play increases.

Sport-Specific Exercises

- Return to play.

Criteria for Return to Sport

General

- Pain free
- Normal grip strength with handheld dynamometer. Comparison with nonoperated side. There are also normative values for dominant and nondominant hands for various age groups.
- Normal rotator cuff ratio. Isokinetic dynamometer. External rotation/internal rotation is 66% in the normal population.
- Scapular symmetry. Observational comparison to the nonoperative side.
- Normal shoulder flexibility comparable to the contralateral side. Standard goniometry or vertebral level for shoulder internal rotation.

Sport-Specific

- See above.

After Return to Sport

Continuing Fitness or Rehabilitation Exercises

- Lower-extremity and core strengthening and flexibility training
- Full upper-extremity strengthening and flexibility training
- General conditioning

Exercises and Other Techniques for Prevention of Recurrent Injury

- Improve mechanics (emphasis on the backhand) to use the larger body parts more and improve weight shifting (for example, the trunk and lower extremities)
- Adjust racquet grip size
- Adjust racquet tension

Evidence

Baker CL, Jr, Baker CL, 3rd: Long-term follow-up of arthroscopic treatment of lateral epicondylitis. *Am J Sports Med* 36:254–260, 2008.

In this case series, 30 patients were located for follow-up after being treated for lateral epicondylitis with arthroscopic resection of pathologic tissue. A numeric pain scale and the Mayo Clinic Elbow Performance Index were used. The rate of success was maintained after a mean follow-up of 130 months. (Level IV evidence).

Dunn JH, Kim JJ, Davis L, et al: Ten- to 14-year follow up of the Nirschl surgical technique for lateral epicondylitis. *Am J Sports Med* 36:261–266, 2008.

Eighty-three patients with a mean follow-up of 12.6 years underwent the mini-open surgical technique for resection of tendinosis tissue. On the basis of the Numeric Pain Intensity Scale, the Nirschl and Verhaar tennis elbow scoring systems, and the American Shoulder and Elbow Surgeons elbow form, the surgery was successful. (Level IV evidence).

Rosenberg N, Henderson I: Surgical treatment of resistant lateral epicondylitis: follow-up study of 19 patients after excision, release and repair of proximal common extensor tendon origin. *Arch Orthop Trauma Surg* 122:514–517, 2002.

In this study, the researchers reported on 19 patients treated by excision, release, and repair of the common extensor tendon. Eighteen patients reported recovery from pain and a satisfactory regaining of forearm strength 3 to 4 months after surgery. (Level IIc evidence).

Szabo SJ, Savoie FH, Field LD, et al: Tendinosis of the extensor carpi radialis brevis: an evaluation of three methods of operative treatment. *J Shoulder Elbow Surg* 15:721–727, 2006.

In this retrospective review, outcomes were evaluated for 109 patients with lateral epicondylitis who had undergone open, arthroscopic, or percutaneous surgery. Outcomes were evaluated with the visual analogue scale and the Andrews-Carson score. At a mean follow-up of 47.8 months, there was no significant difference between the three procedures. All were considered effective. (Level IIb evidence).

Zingg PO, Schneeberger AJ: Debridement of extensors and drilling of the lateral epicondyle for tennis elbow: a retrospective follow-up study. *J Shoulder Elbow Surg* 15:347–350, 2006.

In this retrospective follow-up study, 21 patients treated for tennis elbow with extensor debridement without repair and with decortication drilling were reviewed after a mean follow-up of 15 months. Ninety-five felt they had improved; however, they reported that recovery was slow and painful. (Level IIb evidence).

Multiple-Choice Questions

QUESTION 1. When is AROM of wrist extension safe with the elbow in flexion?

A. 0 to 2 weeks
B. 3 weeks
C. 6 weeks
D. 8 weeks

QUESTION 2. In the initial postoperative phase, which of the following should be excluded?

A. Scapula retraction
B. Elbow AROM
C. Codman exercises
D. Elbow PROM

QUESTION 3. If there is difficulty in restoring elbow extension ROM, which of the following therapeutic techniques should be employed?

A. Aggressive PROM by the clinician
B. Manipulation
C. Low-intensity long-duration stretch and joint mobilization
D. Deep-tissue massage

QUESTION 4. When is it safe to initiate eccentric strengthening of the extensors?

A. 3 to 6 weeks
B. 6 to 10 weeks
C. 10 to 14 weeks
D. 14 to 24 weeks

QUESTION 5. Which of the following would not be an indication for surgical intervention for lateral epicondylitis?

A. Failure of at least 3 months of conservative treatment
B. Tear of the extensor tendon
C. Pain with activities of daily living
D. Unable to return to sport

Answer Key

QUESTION 1. Correct answer: **B** (see Phase II, 3 to 6 weeks)

QUESTION 2. Correct answer: **D** (see Phase I, 0 to 2 weeks)

QUESTION 3. Correct answer: **C** (see Phases II and III, 3 to 10 weeks)

QUESTION 4. Correct answer: **C** (see Phase IV, 10 to 14 weeks)

QUESTION 5. Correct answer: **A** (see Indications for Surgical Treatment)

BEYOND BASIC REHABILITATION: RETURN TO TENNIS AFTER TREATMENT FOR LATERAL EPICONDYLITIS

Jamie Osmark, CSCS, Michael Levinson, PT, CSCS, and David Altchek, MD

Introduction

- This injury is more common in the novice tennis player. It is not often seen in competitive tennis players.
- It is often related to poor mechanics in the tennis backhand, but it also can be related to trying to create topspin on a serve or forehand.
- Returning to tennis can be challenging. However, success can be correlated with becoming asymptomatic, restoring strength and flexibility and improving mechanics.

Aspects of Tennis that Require Special Attention in Rehabilitation

- Repetitive activities
- Rapid development of muscular activity, short bursts, and high intensity

- Strength, speed, power, flexibility, muscular endurance, and muscular balance
- Velocity, spin, and placement
- Number of strokes
- Anaerobic and aerobic activity

Phase I: Advanced Strength and Conditioning Programs

Periodization

- Linear
- Macrocycles
- Mesocycles
- Microcycles

Program Design/Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility and joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for speed, agility, and quickness (SAQ)
- Functional training

Olympic Lifts Used in the Training Program

- Clean and jerk
- Power clean

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: Specific adaptation to imposed demands (SAID)

Application of Acute Training Variables

- When returning to tennis, a linear periodized program consisting of endurance, hypertrophy, strength, and power phases should be implemented for a safe, strong return.
- Repetitions
  - Endurance phase: 12 to 20 repetitions
  - Hypertrophy phase: 7 to 12 repetitions
  - Strength phase: Four to six repetitions
  - Power phase: Two to five repetitions
- Sets
  - Endurance phase: Two or three sets
  - Hypertrophy phase: Three to six sets
  - Strength phase: Three to five sets
  - Power phase: Three five sets
- Rest interval
  - Endurance phase: 30 to 45 seconds
  - Hypertrophy phase: 45 to 60 seconds
  - Strength phase: 120 seconds
  - Power phase: 120+ seconds

TIMELINE 9-3: **Postoperative Rehabilitation After Open or Arthroscopic Posterior Shoulder Stabilization**

PHASE I (weeks 1 to 2)	PHASE II (weeks 3 to 6)	PHASE III (weeks 7 to 10)
• Sling • PT modalities • ROM: Scapular plane elevation to 90° • Active assisted Codman's exercises • TBS, TAS, and TLS activities as recommended and tolerated	• Sling • PT modalities • ROM during Wk 4: Scapular plane elevation to 120° • ROM during Wk 6: Scapular plane elevation to 160° • ROM during Wk 4: Start flexion to 90° • ROM during Wk 6: ER to 30° • ROM during Wk 6: Internal rotation (IR) to 0° • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises • Wk 4: Active assisted range of motion exercises • Wk 4: Submaximal isometrics for glenohumeral joint muscles • Wk 4: Submaximal isometrics for external rotation (ER)	• DC sling • PT modalities as needed • PROM: Full • Mobilization as needed • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: Progressive resistive exercises (PREs) • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Limit IR exercises to minimize strain to posterior capule • Proprioceptive neuromuscular facilitation (PNF) exercises • OKC rhythmic stabilization exercises • CKC exercises • Wk 10: Seated press-ups and increased weight-bearing through joint • CKC manual perturbation exercises

- Intensity
  - Endurance phase: <67% of 1RM
  - Hypertrophy phase: 67% to 85% of 1RM
  - Strength phase: >85% of 1RM
  - Power phase: 75% to 85% of 1 RM
- Repetition tempo
  - Endurance: 2/1/2
  - Hypertrophy: 2/0/2
  - Strength: 2/0/1
  - Power: 1/0/X
- Training frequency
  - 3 or 4 days
- Training duration
  - 60 minutes per session
  - 3 to 5 weeks per mesocycle
- Training volume
  - Endurance: 12 to 60 repetitions per exercise
  - Hypertrophy: 18 to 72 repetitions per exercise
  - Strength: 12 to 30 repetitions per exercise
  - Power: 6 to 25 repetitions per exercise
- Specific exercises used in the training
  - Clean and jerk
  - Clean
  - Squat
  - Dumbbell overhead press
  - Dead lift
  - Push press
  - Row
  - Lat pull-down
  - Pushup
  - Serratus punch
  - Chest fly
  - Prone Y's and T's
  - Plank
  - Side plank
  - Palloff press (Figure 9-18)
  - Stability chop and lift
  - Bridge
  - Dead bug (Figure 9-19)
  - Russian twist
  - Wrist extension and flexion
  - Wrist pronation and supination
  - Shoulder external rotation
  - Shoulder internal rotation
  - Quadruped thoracic rotation (Figure 9-20)
  - Hip airplane
  - Wall slide stretch
  - Sleeper stretch

FIGURE 9-18. Palloff press.

TIMELINE 9-3: Postoperative Rehabilitation After Open or Arthroscopic Posterior Shoulder Stabilization (Continued)

PHASE IV (weeks 11 to 14)	PHASE V (weeks 15 to 24)	PHASE VI (weeks 25 to 52)
• Physical therapy (PT) modalities as needed • PROM: Full • Mobilization as needed TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Thrower's Ten • Limit IR exercises to minimize strain to posterior capsule • PNF exercises • Open kinetic chain (OKC) rhythmic stabilization exercises • Closed kinetic chain (CKC) exercises • CKE manual perturbation exercises	• Passive range of motion (PROM): Maintain full motion • Mobilization as needed • TBS, TAS, and TLS activities as recommended and tolerated • Scapular exercises: PREs • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: Two- arm progressing to one-arm • Overhead strengthening exercises • Sport-specific exercises begin • Overhead throwing athletes can begin an easy interval throwing program • 20 wks: Begin full-windup throwing	• PROM: Maintain full motion • Mobilization as needed • Total body strengthening (TBS), total arm strengthening (TAS), and total leg strengthening (TLS) activities as recommended and tolerated • Scapular exercises: PREs • TAS, biceps, and triceps PREs • Glenohumeral exercises: PREs • Rotator cuff exercises: PREs • IR/ER exercises at 90° • Thrower's Ten progress intensity • PNF exercises • OKC rhythmic stabilization exercises • CKC exercises • CKC manual perturbation exercises • Plyometrics: Two-arm chest passes progressing to 90° internal and 90° external one-arm plyometrics • Overhead strengthening exercises • Sport-specific exercises progressed • Overhead throwing athletes progress through an interval throwing program

FIGURE 9-19. Dead bug.

Application of Chronic Training Variables

- The first phase, endurance, helps acclimate the player back to strength training by preparing the muscles, tendons, and overall joint stability for more volume and intensity. This phase also helps reestablish the neuromuscular connection to maximize muscular recruitment.
- The second phase, hypertrophy, is aimed to build muscular size.
- The third phase, strength, focuses on gaining maximal functional strength.
- The final phase, power, ties the prior phases together. Its focus is on the transfer and development of power through the legs, torso, and upper body.

Phase II: Performance Enhancement Training Techniques

Periodization

- Linear
- Macrocycles
- Mesocycles
- Microcycles

Program Design and Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility and joint mobility for joint stability

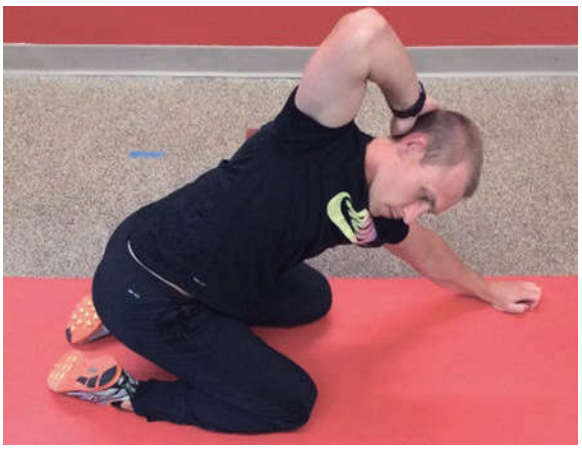

FIGURE 9-20. Quadruped thoracic rotation.

- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Plyometric training
- Functional training
- Sport-specific training
- Power training
- Speed agility training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: SAID

Application of Acute Training Variables

- Repetitions
  - Plyometrics: 8 to 12 repetitions
  - Rotational power: 3 to 12 repetitions
  - Core strength: 1 to 12 repetitions
- Sets
  - Plyometrics: Two or three sets
  - Power: Three to five sets
  - Strength: One or two sets
- Rest interval
  - Plyometrics: 1 to 3 minutes
  - Rotational power: 3 to 5 minutes
  - Core strength: 1 to 2 minutes
- Intensity
  - Plyometrics: Body weight, medicine ball, dead ball, near-maximal effort (>90% of maximal effort)
  - Rotational power: 67% to 85% of 1RM
  - Strength: Body weight and weighted vest
- Repetition tempo
  - Plyometrics: Maximal effort
  - Rotational Power: Maximal effort
  - Strength: Controlled 3/1/2
- Training frequency
  - Two or three times per week
- Training duration
  - 60 minutes
  - 3 to 4 weeks
- Training volume
  - Plyometrics: 16 to 36 repetitions per exercise
  - Rotational power: 9 to 60 repetitions per exercise
  - Strength: 1 to 24 repetitions per exercise
- Specific exercises used in the training
  - Plyometrics
    - Bounding
    - 90°, 180° jumping exercise
    - Lateral bounding with resistance

FIGURE 9-21. Medicine ball rotational throw.

- Lateral bounding progression
- Box jumps
- Medicine ball squat thrust
- Medicine ball slam
- Medicine ball rotational throw (Figure 9-21)
- 90°/90° wall plyometrics
- Straight-arm ball dribbling on wall
- Medicine ball squat to rotational chest pass
- Medicine ball sit-up overhead throw
- Reaction/response training
- Rotational power
  - Squat to rotational press (Figure 9-22)
  - Rotational row (Figure 9-23)
  - Rotational push–pull
  - Rotational snatch
  - Explosive torso-and-hip rotation
  - Chop and lift
- Strength
  - Single-leg squat
  - Mini band lateral walk

FIGURE 9-22. Squat-to-rotational press.

FIGURE 9-23. Rotational throw.

- Single-leg Romanian dead lift
- Walking lunge with mini band rotation
- Triplanar lunge
- Pull-down
- Pushup
- Wrist extension and flexion
- Wrist pronation and supination
- Plank
- Side plank
- Quadruped thoracic rotation
- Hip airplane
- Wall slide stretch

Application of Chronic Training Variables

- During this phase of training, plyometrics are included in order to utilize the stretch-shortening cycle so that force production can be maximized. The typical focus in tennis is the development and transfer of lower-body power to upper-body rotational strength and stability. In this training phase, emphasis is placed on development of rotary power. The force delivered to the tennis ball from the tennis racket will be evenly distributed throughout the kinetic chain when rotational sequencing becomes more efficient. Additionally, stabilization exercises will complement the power movements and build the neuromuscular control required in tennis.

Phase III: Sport-Specific Training

Periodization

- Linear
- Macrocycles
- Mesocycles
- Microcycles

Program Design and Performance Training Program

Sport-Specific Concepts of Integrated Training

- Training continuum
- Flexibility and joint mobility for joint stability
- Training with optimum posture
- Sensorimotor and balance training
- Core training
- Cardiorespiratory training
- Multiplanar training activities
- Training for optimum muscle balance
- Training for optimum muscle functional strength
- Training for optimum muscle functional power
- Neuromuscular dynamic stability exercises
- Training for SAQ
- Plyometric training
- Functional training
- Sport-specific training

Training Principles Used in the Design of the Program

- Principle of progression
- Principle of overload
- Principle of variation
- Principle of individualization
- Principles of specificity: SAID

Application of Acute Training Variables

- Repetitions
  - Sport-specific agility: 8 to 20 repetitions
- Sets
  - Three or four sets
- Rest interval
  - 1:4 work-to-rest ratio
- Intensity
  - Maximal effort
- Training frequency
  - Two or three times per week
- Training duration
  - 60 to 90 minutes
  - 3 to 4 weeks
- Training volume
  - 24 to 80 repetitions per exercise
- Specific exercises used in the training
  - Medicine ball ground strokes
  - Lateral intervals
  - Linear intervals
  - Multidirectional intervals
  - Side shuffle
  - Crossover
  - Backpedal

Application of Chronic Training Variables

- In order to simulate the feeling of playing a match, sport-specific training will take place on the tennis court. Interval training should be implemented in order to exhaust the anaerobic system. As training progresses, rest time may be shortened to increase the conditioning

of the athlete. During this phase, the focus should be on improving response time, footwork, lateral speed, and overall conditioning.

Sports Performance Testing

General Information

- General history
- Subjective questionnaires
- Medical history
- Sports injury history
- Surgical history
- Chronic conditions and/or medications

Objective tests

- Physiological assessments
  - Lactate
    - Before, during, and after training
  - Heart rate
    - Throughout training
  - Rate of perceived exertion
    - Immediately after interval training
- Body composition tests: Body composition can be measured by using hydrostatic weighing, whole-body plethysmography (BOD POD), dual X-ray absorptiometry scan, or skin-fold measurements.
  - Preseason
  - End of preseason
  - Periodically through competition
- Static and dynamic postural assessments. Static posture can be assessed with the use of an AlignaBod (Dallas, TX) or a gridline, and dynamic posture can be observed on the tennis court by a coach.
  - Through preseason and competition
- Movement performance testing
  - Functional Movement Screen (FMS): The FMS is a great tool to use for looking at the athlete's overall movement strategy. It is a quick and easy way to screen the athlete for faulty movement patterns that potentially could lead to injury.
    - Periodically through preseason
  - Single-leg squat
    - Periodically through preseason
- Sport-specific testing: A tennis coach performs this type of testing by observing the overall form in real time or on two-dimensional videotape analysis.
  - Stroke analysis
    - Periodically through preseason and competition
  - Serve velocity
    - Periodically through preseason and competition
  - Ground stroke velocity
    - Periodically through preseason and competition

Specific Criteria for Progression to the Next Stage to Determine Readiness for Tennis

- The athlete is pain-free through all movements with symmetrical range of motion.
- Athlete has achieved increases in load, intensity, and volume and shows a strong adaptation to the current training phase.

Specific Criteria for Release to Unsupervised Complete Participation in Tennis

- There is no pain or tenderness in the affected area.
- The athlete presents symmetrical strength and range of motion through all strokes and can maintain adequate strength and symmetry as he or she fatigues.
- The athlete displays strong scapular and wrist stability and maintains proper form throughout a full match. Both can be observed and assessed by a skilled coach as the player transitions back to a full match.

Recommended Ongoing Exercises

- Wrist extension
- Wrist flexion
- Ball dribbling on wall
- Plank
- Side plank
- External rotation
- Internal rotation
- Prone T and Y
- Serratus punch

Evidence

Ellenbecker TS, Pluim B, Vivier SV, et al: Common injuries in tennis players: exercises to address muscular imbalances and reduce injury risk. *Strength Cond J.* 31:50–58, 2009.

This article explains common injuries presented in tennis and the muscle imbalances that may cause these injuries. Specific exercises are suggested to restore balance and improve performance and prevent injury.

Fernandez-Fernandez J, Sanz-Rivas D, Mendez-Villanueva A: A review of the activity profile and physiological demands of tennis match play. *Strength Cond J.* 31:15–26, 2009.

This review gives insight into the physical demands of a competitive tennis match. It also provides information that will help strength and conditioning coaches implement training protocols to improve performance.

Kovacs MS: Movement for tennis: the importance of lateral training. *Strength Cond J.* 31:77–85, 2009.

Tennis involves many different movement changes throughout a match with an emphasis on lateral movement. This article explains the importance of lateral movement training and offers exercises that train the lateral movements specific to tennis.

Kovacs MS: Tennis physiology: training the competitive athlete. *Sports Med* 37:189–198, 2007.

This article outlines the physiological changes that have occurred through the evolution of tennis. It illustrates how these physiological changes affect the way tennis performance and injury prevention programs are designed and implemented.

Lorenz DS, Reiman MP, Walker JC: Periodization: current review and suggested implementation for athletic rehabilitation. *Sports Health*. 2:509–518, 2010.

The authors review of 91 articles related to periodization, methods of periodization, and periodization program outcomes. They conclude that despite the evidence in the strength training literature supporting periodization programs, there is a considerable lack of data in the rehabilitation literature about program design and successful implementation of periodization in rehabilitation programs.

Roetart EP, Ellenbecker TS, Reid M: Biomechanics of the tennis serve: implications for strength training. *Strength Cond J*. 31: 35–40, 2009.

In this review, the authors discuss the biomechanics of the tennis serve and offer specific training exercises to optimize performance.

Roetart EP, Kovacs M, Knudson D, et al: Biomechanics of the tennis groundstrokes: implications for strength training. *Strength Cond J*. 31:41–49, 2009.

This article summarized recent research related to the biomechanics of tennis technique in groundstrokes and offers specific strength and conditioning exercises to improve performance and prevent injury.

Wakeham TR, Jacobs R: Preseason strength and conditioning for collegiate tennis players. *Strength Cond J*. 31:86–93, 2009.

In this article, the authors outline the requirements of tennis and how to achieve these outcomes by adhering to an annual plan consisting of different phases. The authors' objective is to review off-season strength and power training as well as preseason general and sport-specific conditioning.

Multiple-Choice Questions

QUESTION 1. Which of the following is the appropriate intensity for an athlete in the endurance phase of strength and conditioning program?

A. 60% to 67% of 1 RM
B. 85% to 95% of 1 RM
C. 75% to 85% of 1 RM
D. 10% of body weight

QUESTION 2. Which of the following is the result when rotational sequencing becomes more efficient?

A. Loss of energy transfer
B. Increase in upper-body dominance
C. Even force distribution through kinetic chain
D. Decrease in racket velocity

QUESTION 3. Which of the following is an example of a rotational power exercise?

A. Snatch
B. Chop and lift
C. Power clean
D. Side Plank

QUESTION 4. If an athlete continues to participate in tennis, which of the following exercises should he or she do indefinitely?

A. Pull-over
B. Ball-dribbling on wall
C. Snatch
D. Push press

QUESTION 5. In Phase I of strength and conditioning, which of the following is the correct order of mesocycles?

A. Sport-specific, endurance, power, strength
B. Strength, endurance, power, sport-specific
C. Endurance, hypertrophy, strength, power
D. Hypertrophy, endurance, strength, power

Answer Key

QUESTION 1. Correct answer: **A** (see Phase I)

QUESTION 2. Correct answer: **C** (see Phase II, Chronic training variables applied)

QUESTION 3. Correct answer: **B** (see Phase II, Specific exercises used)

QUESTION 4. Correct answer: **B** (see Phase III, Exercises to continue)

QUESTION 5. Correct answer: **C** (see Phase I, Training variables)