



**Rehabilitation  
& Performance**  
INSTITUTE

***The***  
***Elbow, Hand,***  
***& Wrist***



## ***The Elbow, Hand, & Wrist***

### **ASSESS**

#### **ELBOW**

**SFMA:** Utilize upper extremity one and two breakouts (see shoulder for example), as well as cervical patterns.

#### **Inspection**

- Note deformities, swelling, temperature, moisture, color, atrophy, hypertrophy
- Note varus or valgus carrying angle

#### **Active Movements**

- Assess elbow flexion, extension, pronation, supination
  - Test pronation and supination with elbow bent to 90 and extended

#### **Passive Movements**

- Same as for active but note end feel and sequence of pain and limitation

#### **Resisted Tests**

- Test throughout ROM in 3 positions. Start with neutral and then maximally shorten and lengthened positions

#### **Neuro Screen**

- Myotomes
  - C5/6: resisted flexion and supination; C7: resisted extension; C8, T1: resisted pronation
- Dermatomes-tests of peripheral Nerves
  - C5-lateral arm-sensory branches of the axillary and radial N.
  - C6-lateral anterior forearm-sensory branches of the musculocutaneous N.
  - C8-distal medial forearm-medial cutaneous N of the forearm.
  - T1-medial arm-medial cutaneous N of the forearm.
- Reflexes
  - C5-biceps

- C6-brachioradialis
- C7-triceps
- Neurologic Tests (radial, ulnar, Median-RUM)
  - Thumb cannot abduct (pollicis longus and brevis paralysis)
  - Finger flexion impaired
  - Wrist extension impaired
  - Radial Nerve
    - Motor-wrist drop. Held in wrist flexion.
    - Sensory- impaired sensation dorsum of hand and radial aspect, especially in thumb web and index finger.
  - Ulnar Nerve
    - Motor-Positive Froments sign-paper between index finger and thumb
    - Sensory-4<sup>th</sup> and 5<sup>th</sup> digits on both dorsal and palmar surfaces.
  - Median Nerve
    - Motor-Flat hand deformity-unable to have each finger touch the thumb
    - Sensory-impaired sensation radial aspect of palm and palmar surface of thumb and first 2 digits (purest at palmar surface of tip of index finger).

### Special tests

- Lateral Epicondylalgia
  - Isometric contraction of wrist extension
  - Grip Strength
  - Cozen Test
  - Mill Test
  - Third finger resistance test
- Medial Epicondylalgia
  - Palpation of the medial epicondyle
  - Decreased grip strength
  - Passive position test
- Cubital Tunnel Syndrome (ulnar neuritis)
  - Tinel at the cubital tunnel
  - Pressure provocation test
  - Scratch collapse test
  - Froment's Sign
- Pronator syndrome
  - Pronator compression test
  - Compression at pronator with resisted pronation while passively extending the elbow
  - Compression at flexor digitorum superficialis test
  - Sensory changes in median N distribution of hand
- AIN Syndrome: Pinch (OK) sign
  - Weakness of the pronator teres
  - No sensory symptoms

- Froment's pinch-median N-profundus and FPL
- Froment's sign-Ulnar N-Adductor pollicis
- LCL (varus) Stress test-tests for radial lateral collateral ligament insufficiency
- Ulnar Collateral Ligament Insufficiency
  - MCL (valgus) stress Test
  - Milking Test
  - Moving valgus stress test
- Posteriolateral rotary instability test
- Chair sign-for posteriolateral rotary instability
- Tinel's Sign-Ulnar N.
- Waldswort's Test-Ulnar N
- Wartenberg's Sign

Specific Mobility Testing: refer to manual therapy section

## **WRIST & HAND**

### **Initial Observation**

- Note protective positioning
- The way the pt shakes hands, firmness of grasp
- Symmetrical hand movements

### **Visual inspection**

- Note deformities, pathological changes, moisture, color, scars, atrophy, hypertrophy
- Calluses
- Shape and size of thenar and hypothenar eminences
- Position of fingers
- Nails (color, shape, pitting)

### **Function** (active and passive ROM-note end feel with passive ROM)

- Distal Radioulnar Joint
  - Active/passive-supination, pronation, wrist flexion, extension, Radial and ulnar deviation
  - Perform each motion elbow flexed and elbow extended
- Hand and fingers
  - Active/passive-make fist in supinated position, spread fingers, then extend wrist, opposition of little finger, abduct and adduct all fingers
- Thumb
  - Active/passive-flexion, extension, adduction, abduction, opposition, circumduction

### **Resisted Testing**

- Test each muscle in 3 positions-start at neutral, then at both inner and outer ranges.

## Neuro Screen

- Sensation
  - Peripheral nerves
    - Median-palmar thumb, 2-3 digits and lateral aspect of 4<sup>th</sup> digit
    - Ulnar –palmar and dorsal medial 4<sup>th</sup> digit and 5<sup>th</sup> digit
    - Radial-dorsal lateral 4<sup>th</sup> digit, 2-3 digits and thumb
  - Neurologic Level
    - C6-thumb
    - C7-dorsal aspect 3<sup>rd</sup> digit
    - C8-lateral 5<sup>th</sup> digit
    - T1-medial aspect of forearm
- Reflexes
  - Hoffman Sign (C7-T1) –flick the 2<sup>nd</sup> finger nail will cause hyperreflexive flexion of the thumb
- Myotomes
  - Elbow extension and/or wrist flexion: C7
  - Thumb extension and/or ulnar deviation: C8
  - Abduction and/or adduction of hand intrinsics: T1

## Special Tests

- Bunnel-littler Test-tests for intrinsic tightness
- Allen Test-Tests for radial and ulnar vascularization
- DIP Tightness differentiation test-differentiates retinacular tightness vs. capsular tightness
- Extensor Digitorum Contracture Test-
- Finger Fracture Percussion Test
- Finkelstein Test-DeQuervain's Disease (100% Sn and Sp)
- Froment's Sign-Ulnar N Loss
- Scratch/collapse test-nerve lesion (99% Sp, 64% Sn)
- Phalen's Test-Carpal tunnel test (73% Sp, 68% Sn)
- Reverse Phalen's-carpal tunnel test
- Smiths Pinch test-carpal tunnel test
- Tinel's Sign-Carpal tunnel test (50% Sn, 77% Sp)
- Carpal Tunnel Test Cluster
  - Hand shaking improves symptoms (Flick Sign)
  - Wrist-ratio Index > 0.67 (indicator of carpal canal volume)
  - Symptom severity scale > 1.9
  - Diminished sensation thumb (median n.)
  - Age > 45 years
    - All 5 positive Sn .18, Sp .99
- Tear Drop test –tests for AIN syndrome
- Shrivell Test-tests for denervation

- Weber's 2 point discrimination test
- CMC Grind Test-tests for OA of first CMC (93% Sp, 53% Sn)
- Ulnar collateral Ligament Stress test-Gamekeepers thumb
- Scaphoid Shift test or Watsons Test-Scapholunate dissociation(69% Sn,66% Sp)
- Lunotriquetral Shear/ Ballottement -Lunotriquetral Dissociation(64% Sn,44% Sp)
- Ulnar Fovea Sign-disruption on the Distal Radioulnar joint
- Triangular fibrocartilage complex load -TFCC Lesion
- Ulnocarpal instability
- Piano key sign-DRUJ instability

#### **Mobility Testing**

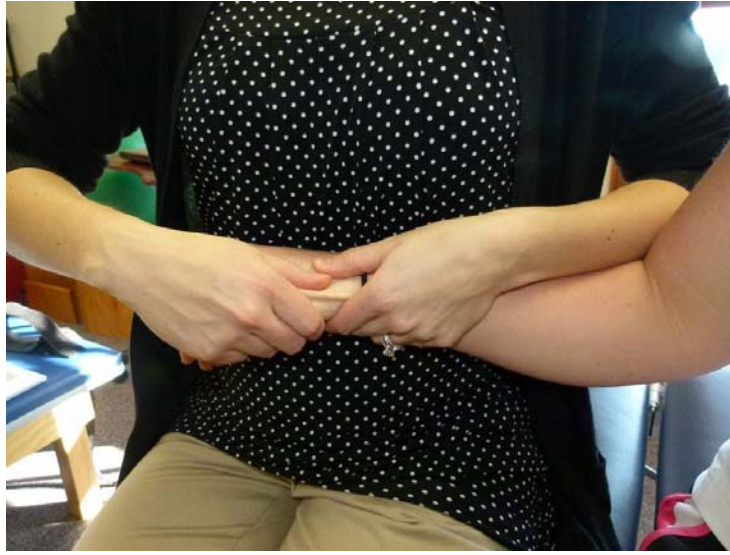
- Refer to manual therapy section

## **RESET THE SYSTEM**

### ***Finger, Hand, and Wrist Mobilizations***

#### **1st CMC Joint (Saddle Jt)**

- Dorsal glide for ABD (*Remember: DAB*)
- Palmar glide for ADD (*Remember: PAD*)



*Make sure your fingers are close to the joint line.*

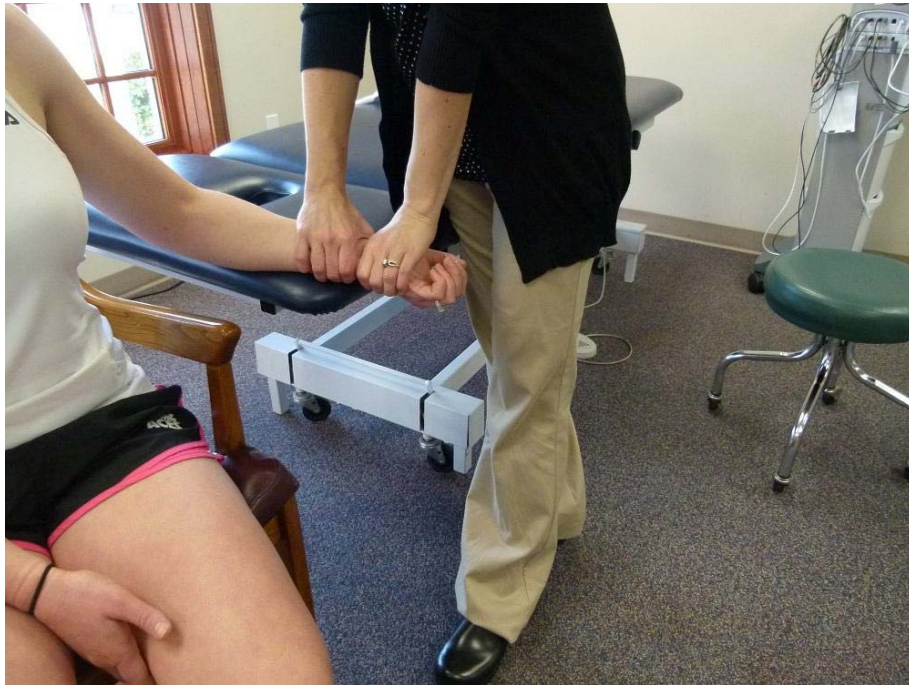
- Ulnar glide for FLEX
- Radial glide for EXT



*Keep patient's extremity close to your body for support.  
Use a pillow as a buffer as needed.*

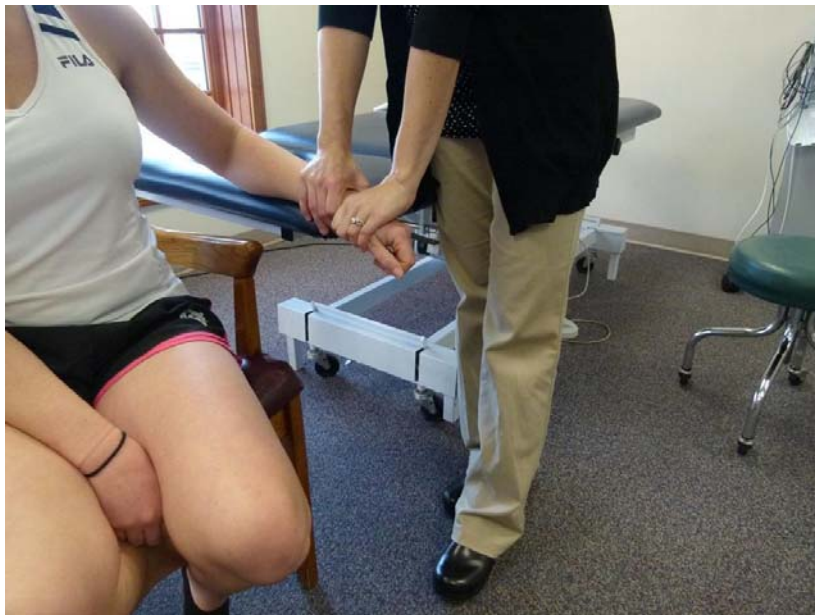
**Wrist Complex** (Convex on Concave)

- Dorsal glide for Flex



*Operator should maintain an extended elbow.  
Slight distraction is applied during gliding articulation.*

- Palmar glide for Ext



*Patient's forearm should not be fully pronated as this tends to tighten the dorsal radiocarpal ligaments.*

- Distal carpal row moves with RD, proximal carpal row moves with UD
- Ulnar glide for RD



- Radial glide for UD



*Alternative positioning good for patient to achieve mobilization with gravity assistance. Patient should not have shoulder mobility problems.*

**Considerations:**

Mechanoreceptors=Type II

Open-packed position= MCP/IP: slight flexion; Wrist: Extension-UD

## ***Elbow Mobilizations***

### **Radiohumeral (Concave on Convex)**

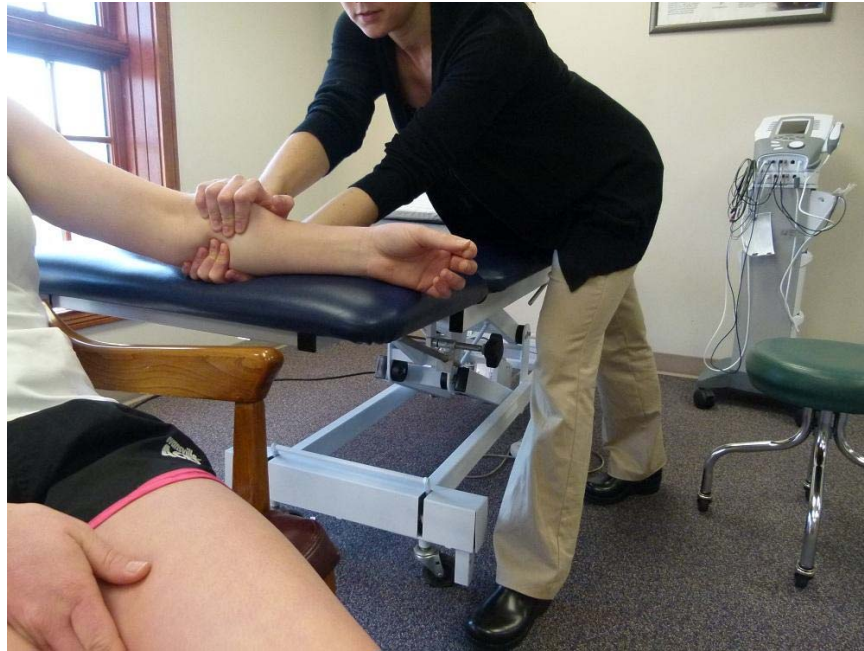
- Distraction and compression



*Clinician stabilizes the humerus and grips onto the radial head.  
Stabilize forearm in neutral position in between clinician elbow and side. Distract by rotating clinician  
body away and pulling on radial head.*

**Proximal Radioulnar (Convex on Concave)**

- Anterior glide for supination
- Posterior glide for pronation (*Key to Remember*)



*Make sure clinician is stabilizing the ulna ONLY and then mobilizing the radius on the ulna in the appropriate position.*

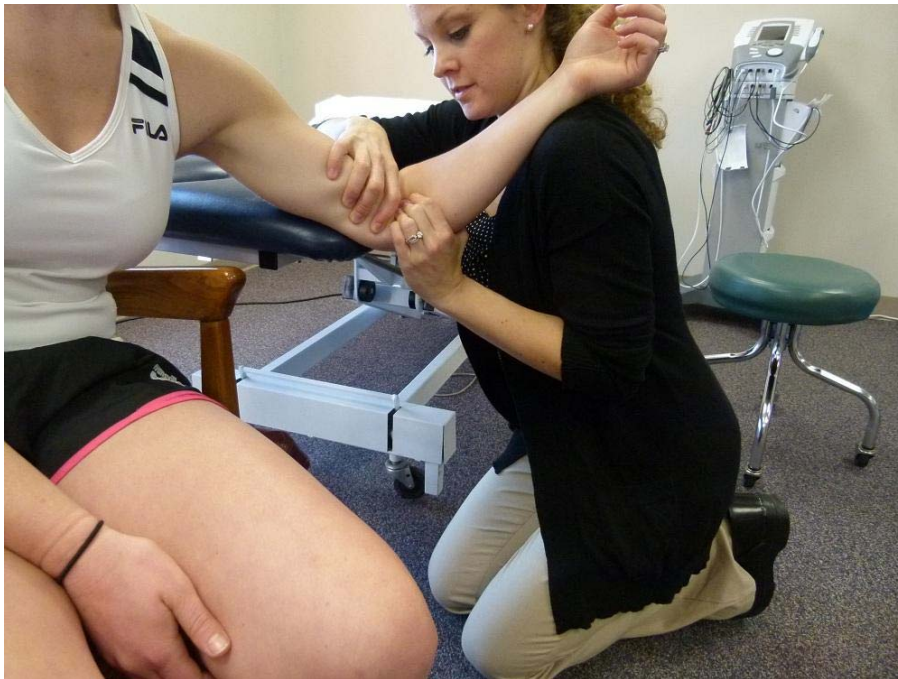
**Distal Radioulnar (Concave on Convex)**

- Opposite of Proximal



**Humeroulnar (Concave on Convex)**

- Distraction 45 degrees to longitudinal axis- Helps to achieve elbow extension



*Stabilize humerus and grip the ulna ONLY to distract. Should maintain 45 degrees to longitudinal axis, thus separating the olecranon from the trochlea. Work into extension.*

**Considerations:**

- Mechanoreceptor=type II
- Work into the restricted range (don't just stay in open-packed position throughout rehab)
- Know where you are blocking for effective mobilization
- Open-packed position= 70 deg flexion, neutral forearm

**Other Considerations:**

- Functional Dry Needling
- Scraping/ Graston Technique for STM
- Radial Head Manipulation\*



## **REINFORCE THE CORRECTION**

### **Basic Reinforcement Interventions:**

- Foam Roller- Reinforces any soft tissue work and helps remove additional TEDs
  - Along posterior capsule of shoulder, latissimus dorsi, aid in pectoralis stretching
- Stretches- assisting with various TEDs
  - Wrist flexors, wrist extensors, pronators, supinators, biceps, triceps

### **Functional Taping**

- McConnell taping
  - Base of adhesive covering followed by a top layer of adhesive to redirect and change biomechanical forces
- Kinesiotaping
  - Can be used to facilitate or inhibit a movement pattern and aid in proprioception depending on its application
- Make sure you know why you are using the tape.
  - To reduce, restrict, or minimize movement?
  - To facilitate proprioceptive input and joint arthrokinematics at a segment?
- *\*NOTE\* When utilizing the tape, make sure you realize that the tape is providing a temporary increase in performance. The patient must continue to rehabilitate and strengthen the joint where they need taping in order to perform.*

*For Example- Mulligan Lateral Epicondylalgia Taping (YouTube)*

## **RELOAD THE SYSTEM**

***Once mobility is established at the dysfunctional joint, treat as a SMCD and reload the system so that the patient can utilize their new mobility in a functional manner.***

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# Scapular Muscle Performance in Individuals With Lateral Epicondylalgia

**L**ateral epicondylalgia (LE), originally described as lawn tennis elbow,<sup>35</sup> is characterized by pain in the region of the lateral epicondyle of the humerus.<sup>28</sup> While a high percentage of recreational tennis players develop the pathology,<sup>20</sup> LE is also a common condition with significant negative consequence in the general population. The prevalence of LE has been reported to be as high as 12.2% in occupational settings.<sup>45</sup> In addition, 27% of patients

with LE report severe limitations with activities of daily living,<sup>52</sup> such as lifting bags or boxes.<sup>53</sup>

The effectiveness of conservative treatment approaches remains less than optimal secondary to high recurrence

rates. Cortisone injections are effective in pain management, but only up to 8 weeks from the time of the injection.<sup>11,22,38,39</sup> A recent study reported a recurrence rate of 29% to 38% in individuals receiving conservative treatment.<sup>10</sup> In the only study with a 2-year follow-up after physical therapy intervention, more than half the patients reported ongoing pain and function loss secondary to the return of LE symptoms.<sup>37</sup>

It has been suggested that assessing scapular muscle impairments should be an important component of the evaluation of individuals with LE. Lucado et al<sup>29</sup> recently reported diminished lower trapezius (LT) muscle strength in a group of female tennis players with LE compared to a matched group of asymptomatic female tennis players. In a healthy population of throwing athletes, fatigue of the scapular stabilizers has been shown to produce alterations of elbow kinematics,<sup>28,48</sup> implying that scapular muscle fatigue could predispose individuals to throwing injuries at the elbow region. Another study<sup>44</sup> reported that induced pain at the upper trapezius (UT) produces an increase in wrist extensor electromyographic (EMG) signal intensity in healthy individuals, which could potentially lead to overuse injury, such as LE, at the elbow. Anecdotally, our clinical experience suggests that overuse of the UT and underuse of the LT may result in UT pain.

● **STUDY DESIGN:** Descriptive, laboratory-based, cross-sectional study.

● **OBJECTIVES:** To describe scapular musculature strength, endurance, and change in thickness in individuals with unilateral lateral epicondylalgia (LE) compared to the uninvolved limb and the corresponding limb of a matched comparison group.

● **BACKGROUND:** Reported poor long-term outcomes for the nonsurgical management of individuals with LE suggest a less-than-optimal rehabilitation process. Knowledge of scapular muscle function in a working population of individuals with LE may help to further refine conservative management of this condition.

● **METHODS:** Twenty-eight patients with symptomatic LE and 28 controls matched by age and sex were recruited to participate in the study. Strength of the middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA) was measured with a handheld dynamometer. A scapular isometric muscle endurance task was performed in prone. Changes in muscle thickness of the SA and LT were measured with ultrasound imaging. Analysis-of-variance models were used to

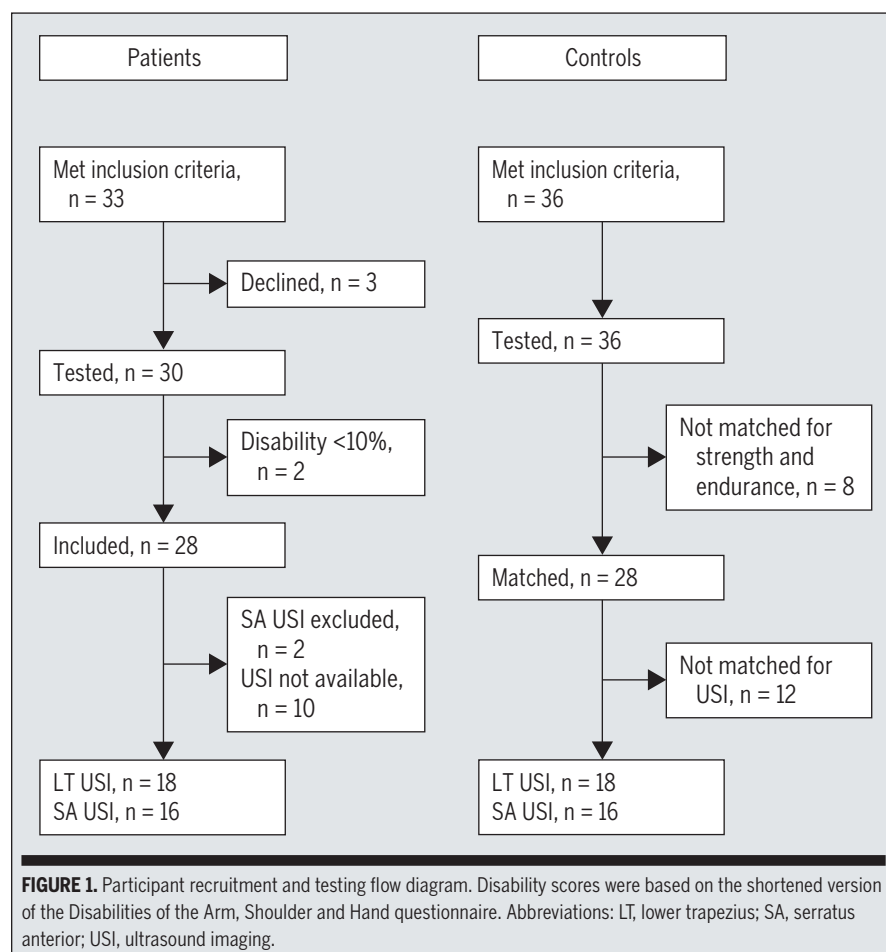
determine within- and between-group differences.

● **RESULTS:** The involved side of the group with LE had significantly lower values for MT strength ( $P = .031$ ), SA strength ( $P < .001$ ), LT strength ( $P = .006$ ), endurance ( $P = .003$ ), and change in SA thickness ( $P = .028$ ) when compared to the corresponding limb of the control group. The involved side of the group with LE had significantly lower strength of the LT ( $P = .023$ ) and SA ( $P = .016$ ) when compared to the uninvolved limb; however, these differences were small and of potentially limited clinical significance.

● **CONCLUSION:** When compared to a matched comparison group, there were impairments of scapular musculature strength and endurance in patients with LE, suggesting that the scapular musculature should be assessed and potentially treated in this population. Cause and effect cannot be established, as the weakness of the scapular musculature could be a result of LE. *J Orthop Sports Phys Ther* 2015;45(5):414-424. Epub 10 Jan 2015. doi:10.2519/jospt.2015.5290

● **KEY WORDS:** *serratus anterior, strength, trapezius, ultrasound imaging*

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Although it appears that scapular musculature strength and endurance have a potential influence on patients with LE, data are limited to a population of female tennis players<sup>29</sup> and a case report.<sup>5</sup> Because there is a high prevalence of LE in the working population<sup>45</sup> and most studies report that males develop the condition just as frequently as females,<sup>21</sup> there is a need to investigate scapular muscle strength in a more inclusive group of patients. In addition, although the study by Suzuki et al<sup>48</sup> implies that fatigued scapular muscles may contribute to elbow pathology, no studies have directly investigated scapular muscle endurance in patients with LE.

The primary purpose of this study was to compare scapular musculature strength, endurance, and change in thickness from resting to contraction, as

measured by ultrasound imaging (USI), in patients with unilateral LE with those of the corresponding limb of a matched comparison group. The secondary purpose was to compare the same variables between the involved and uninvolved limbs of the group with unilateral LE.

## METHODS

### Participants

A CONVENIENCE SAMPLE OF 28 PATIENTS with unilateral LE (15 women, 13 men) and 28 age- and sex-matched controls agreed to participate in the study (FIGURE 1). Patients were recruited from 1 of 5 outpatient rehabilitation clinics in central Kentucky, and controls were recruited from the central Kentucky region.

Patients were recruited to participate

in this study if they were seeking medical attention from a therapist at 1 of 5 outpatient clinics, reported a primary symptom of unilateral lateral elbow pain, were between the ages of 18 and 65, and presented with at least 2 positive clinical tests for LE. The clinical tests performed for symptoms of LE were palpation of the lateral epicondyle and the associated common wrist extensor unit, passive stretching of the wrist extensors (Mill's sign), strength assessment with a hand-grip dynamometer, manual resistance against maximal volitional contraction of the wrist extensors (Cozen's sign), and manual resistance applied to extension of the middle digit (Maudsley's test).<sup>8,18</sup> The clinical tests were considered positive if there was reproduction of pain at the lateral epicondyle.

Patients were excluded from the study if they reported any of the following as part of their medical history: peripheral neuropathy secondary to diabetes, progressive neurological disorder, cancer, infection in the spine or upper extremity, upper motor neurological disorder (eg, stroke, traumatic brain injury), or fibromyalgia. Patients were also excluded if they had surgery on the upper quadrant within the previous 6 months or if they had a score of less than 10% on the shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire (QuickDASH). This last exclusion was based on a previous study indicating that Disabilities of the Arm, Shoulder and Hand questionnaire scores typically range from 0% to 10.1% in an asymptomatic general population.<sup>25</sup>

For those in the comparison group, the tests for LE were performed, and the disability score was also recorded during the initial intake. Potential participants for the control group were excluded from the study if they reported any upper-quadrant musculoskeletal conditions within the past 6 months, had trunk or upper-quadrant surgery in the previous 6 months, tested positive for any of the tests for LE, or had a disability score of greater than 10% as measured by the QuickDASH.<sup>25</sup>

To be included in the study, all potential participants had to demonstrate the ability to tolerate and maintain the instructed test positions. All participants gave their written informed consent to take part in the study, and the study protocol was approved by the University of Kentucky Institutional Review Board. Participants' rights were protected.

## Procedures

All measures of scapular muscle strength were performed by the primary investigator, who was not blinded to the participant's group assignment or to the knowledge of the involved limb for the patients with LE. Before the first dependent variable was measured, a baseline resting heart rate was obtained. After each group of dependent variables was measured, a 5-minute rest was given to participants to allow time for recovery.<sup>41,47</sup> Heart rate was measured immediately after data collection of each group of dependent variables and then after the allotted 5-minute rest to ensure that the participant had recovered to baseline values. Extra rest was given if the participant did not return to baseline values.

Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA) was used to generate a random list of numbers to determine the order for scapular muscle testing (thickness measures with USI, handheld dynamometer [HHD] testing, and endurance testing). The order of each outcome measure within each scapular test and the first limb tested (dominant versus nondominant) were also determined from a random list of numbers.

**Strength Testing** Prior to the study, a Nicholas Manual Muscle Tester HHD (model 01160; Lafayette Instrument Company, Lafayette, IN) was calibrated by placing weights of 15 lb (6.8 kg), 25 lb (11.3 kg), and 50 lb (22.7 kg) on the dynamometer and then calculating the absolute difference between the expected value of the weight and the observed value on the dynamometer. The largest difference between measures was 0.14 kg.



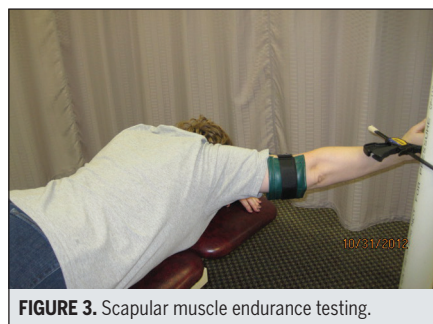
**FIGURE 2.** Positioning for strength testing using the handheld dynamometer. (A) Middle trapezius; (B) lower trapezius; (C) serratus anterior.

Previously established methods for measuring strength of scapular muscles using an HHD have demonstrated good between-day intrarater reliability (intraclass correlation coefficient = 0.75–0.97)<sup>7,32</sup>; however, no validity data have been reported for measuring middle trapezius (MT) or serratus anterior (SA) strength. Maximal volitional contractions for both the left and right upper extremities were assessed. Each patient performed a practice trial on the affected upper extremity for each test before data were recorded. The investigator instructed the participant to slowly push into the dynamometer and increase force production to the maximum force by the end of the 5 seconds used for testing. The maximal volitional contraction was recorded by the assessor. The following muscles were tested: MT, LT, and SA.<sup>32</sup> Three trials were performed for each muscle, and

the average value of the 3 trials was used for statistical analysis.

The SA was tested by positioning the participant supine with the shoulder and elbow flexed to 90°. The dynamometer was placed on the olecranon of the elbow. The patient was asked to protract the scapula, and resistance was given along the humeral axis (**FIGURE 2**). For the MT, the participant was positioned prone with the elbow flexed and shoulder held to 90° of abduction. The dynamometer was placed on the spine of the scapula, in between the acromion and the medial superior border of the scapula. The participant was instructed to lift the arm upward while resistance with the dynamometer was being applied in the lateral direction (**FIGURE 2**). Finally, the LT was tested by positioning the participant prone with the arm extended and shoulder held in 135° of abduction. The





**FIGURE 3.** Scapular muscle endurance testing.

dynamometer was placed in the middle of the scapula, in between the acromion and the medial superior border. While the participant lifted his or her arm upward, resistance with the dynamometer was applied in the lateral and superior directions (**FIGURE 2**). For both the MT and LT, the investigator was positioned on the opposite side of the limb to be tested.<sup>16,32</sup>

**Scapular Muscle Endurance** Lying prone, the participant was asked to place his or her forehead on the contralateral limb. The limb to be tested was passively positioned to 135° of shoulder abduction. The test position was chosen because EMG analysis demonstrates that the LT, MT, UT, and SA are active in this position.<sup>9,15,36</sup> A cuff weight of 1% of the participant's body weight (to the nearest 0.23 kg) was strapped just proximal to the elbow. A level was positioned at a height parallel to the trunk and at 135° of shoulder horizontal abduction. The participant was then asked to elevate and hold his or her arm to the established level for as long as possible (**FIGURE 3**). The test was terminated when the participant voluntarily lowered his or her upper extremity or if the distal radius was no longer contacting the level.<sup>26,49</sup> A single trial was performed and its value used for statistical analysis.

**Muscle Thickness** The primary investigator received formal training through The Burwin Institute of Diagnostic Medical Ultrasound. Data were collected on 18 of the 28 available patients and controls. Participants were not preferentially chosen by the researchers; the choice was based on the participants' time constraints or equipment availability.

Methods for positioning and landmark



**FIGURE 4.** (A) Resting position of the participant and probe placement for ultrasound imaging of the lower trapezius.<sup>12</sup> (B) Resting position of the participant and probe placement for ultrasound imaging of the serratus anterior.<sup>12</sup>

identification were based on a recently published reliability study.<sup>12</sup> Participants were seated comfortably on a chair without a back rest. A neutral spine posture was established by instructing the participant to sit upright and then slump 3 times. After the third movement, the researcher asked the participant to rest comfortably between the 2 motions.<sup>30</sup> The participant was then asked to place his or her forearm on an adjustable table that was adjusted to place the arm at 85° of shoulder elevation and 45° of shoulder horizontal adduction (**FIGURE 4**). Horizontal adduction was maintained throughout testing by placing a mark for arm position, which was continuously monitored during testing. A felt-tip pen was used to mark the level of the thoracic spine that coincided with the inferior angle of the scapula so that the ultrasound transducer could be placed in a consistent position for all measures.<sup>40</sup> Additionally, a mark was placed on the lateral torso at the level of the inferior angle of the scapula between the pectoralis major and the latissimus dorsi, indicating the location of the SA.<sup>4</sup>

Computerized ultrasonography (LOG-IQ e; GE Healthcare, Waukesha, WI) was used by the primary investigator to produce a cross-sectional image of the LT and SA at rest and during arm lifting (**FIGURE 4**). In B-mode, a 40-mm, 8-MHz linear transducer was placed transversely

over the mark previously made to identify the LT and vertically along the mark used to identify the SA. A 2.27-kg (5-lb) weight was strapped around the arm of each participant, just proximal to the elbow. This load was found to be equivalent to holding a 0.91-kg (2-lb) weight in the hand. In pilot work performed prior to this investigation, a load of 0.91 kg held in the hand was observed to produce a consistent visual increase in muscle thickness of the LT and SA when compared to the resting state.

Initially, an image was taken with the muscle in a resting state. Second, the participant was asked to elevate his or her arm with the elbow extended to 0°, shoulder horizontally adducted to 45° from the frontal plane, shoulder flexed at 90°, and shoulder externally rotated (thumb-up position). This position is known to produce high SA and moderate LT activity<sup>15,16,36</sup> and was chosen over shoulder protraction because elevation of the arm in the scapular plane is a more functional position. The arm was then held for approximately 2 seconds to allow an ultrasound image to be taken. A second resting and lifting image was subsequently taken for the same arm and muscle using the same procedure. The same procedure was then followed to test the same muscle on the contralateral limb. The entire procedure was then

repeated for testing of the other muscle for both limbs.

Muscle thickness measurements were performed using procedures based on a previous study.<sup>12</sup> Two images were taken of each muscle for both the relaxed condition and contracted condition.<sup>27</sup> Linear measurements of LT thickness were made 2 cm from the spinous process landmark.<sup>40</sup> Linear measurements of SA thickness were made from the inside border of the rib, up to the inside edge of the muscle border. The rib served as the on-screen anatomical reference. The average of 5 thickness measures, spanning the width of the rib, was recorded.<sup>12</sup> Prior to statistical analysis, the measures obtained from the 2 images of the same person, condition, and muscle were averaged together for 1 data point.

Two patients were excluded from the SA USI analysis secondary to poor image quality taken during data collection. Therefore, a total of 18 patients (11 women, 7 men) were included in the LT USI data analysis and 16 patients (10 women, 6 men) were included in the SA USI data analysis. Eighteen controls were matched by age and sex to the patient population. An average of the 2 measures of LT absolute thickness was the dependent measure in one model, and SA absolute thickness was the dependent measure in the other model.

### Statistical Analysis

An a priori power analysis was completed based on previous measures of scapular muscle strength, which indicated that a minimal detectable change (MDC) of 3.6 kg can identify true difference between tests for the SA. An effect size of 0.60 was calculated by dividing the MDC value of 3.6 kg by the reported standard deviation of 6.0 kg for the SA. The SA effect size of 0.60 was chosen for the power analysis because this value was smaller than the effect sizes of the LT and MT.<sup>32</sup> Using an effect size of 0.60, a sample size of 28 participants in each group provided a true power of 86% at an alpha level of .05.

Statistical analysis was performed using SPSS Version 20 for Windows (SPSS Inc, Chicago, IL). Descriptive data for mechanism of injury and duration of symptoms were calculated for patients with LE. In addition, descriptive data were calculated for the QuickDASH and all dependent variables for both groups. To evaluate similarity between the control and patient groups, paired *t* tests were used to compare age, body mass, height, and shoulder activity levels.

**Between-Group Comparisons for Strength and Endurance Variables** The involved limb in the patient group was compared to the matched limb in the control group, based on arm dominance of the patient. For each dependent measure (MT strength, LT strength, SA strength, and endurance), separate linear mixed models were run, using a within-group factor of group (patient or control) and a between-group factor of limb dominance (whether the involved limb of the patient group and the matched limb of the control group were dominant or nondominant). Dominance of the analyzed limb had to be considered for both groups due to a previously established statistical difference due to limb dominance in healthy individuals. Finally, because our control participants were not matched according to height and weight, these 2 variables were used as covariates in each model. A *P* value of .05 was set a priori. In the case of an interaction, a least-significant-difference (LSD) post hoc analysis was performed. If no significant interaction was present, the model was run again without the interaction, so that the other factors could be interpreted.

**Between-Group Comparisons for Muscle Thickness Variables** Similar to the above strength and endurance analysis, only 1 limb was analyzed per group (the involved limb of the patient group and the matched limb, based on arm dominance of the patient, of the control group). The other element of the primary purpose was to investigate the differences in muscle thickness (contracted thickness minus resting thickness) of the

LT and SA between patients with LE and controls. Separate linear mixed models were run using 2 within-group factors: (1) condition (rest and contraction) and (2) group (patient and control). Dominance (whether the involved limb from the patient group and matched limb from the control group were dominant or nondominant) was used as a between-group factor. Height and weight were also used as covariates in each model. A *P* value of .05 was set a priori. In the case of an interaction, an LSD post hoc analysis was performed. If no significant interaction was present, the model was run again without the interaction, so that the rest of the factors could be interpreted.

**Within-Group Comparisons (LE Group) for Strength and Endurance Variables** For each dependent measure (MT strength, LT strength, SA strength, and endurance), separate linear mixed models were run using a within-group factor of limb (uninvolved or involved) and a between-group factor of dominance (dominant involved or nondominant involved). A *P* value of .05 was set a priori. In the case of an interaction, an LSD post hoc analysis was performed. If no significant interaction was present, the model was run again without the interaction so that the other factors could be interpreted.

**Within-Group Comparisons (LE Group) for Muscle Thickness Variables** The other element of the secondary purpose was to investigate the differences in muscle thickness of the LT and SA between involved and uninvolved limbs. Separate linear mixed models were run using 2 within-group factors: (1) condition (rest and contraction) and (2) limb (uninvolved and involved). Dominance (dominant involved or nondominant involved) was used as a between-group factor. A *P* value of .05 was set a priori. In the case of an interaction, an LSD post hoc analysis was performed. If no significant interaction was present, the model was run again without the interaction so that the other factors could be interpreted.

TABLE 1

## CHARACTERISTICS OF PARTICIPANTS WITH STRENGTH AND ENDURANCE DATA\*

Variable	Patients With LE (n = 28)	Controls (n = 28)
Age, y	46.8 ± 8.8	46.1 ± 9.2
Body mass, kg <sup>†</sup>	83.8 ± 15.9	73.3 ± 13.3
Height, m	1.70 ± 0.10	1.71 ± 0.09
Shoulder activity level (0-20) <sup>‡</sup>	10.3 ± 4.1	10.8 ± 4.2
QuickDASH, % <sup>†</sup>	40.6 ± 16.3	2.6 ± 3.5

Abbreviations: LE, lateral epicondylalgia; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire.

\*Values are mean ± SD.

<sup>†</sup>Significant difference between groups ( $P < .05$ ).

<sup>‡</sup>Shoulder activity level is based on a scale from 0 (no shoulder activity) to 20 (highest shoulder activity).

TABLE 2

## CHARACTERISTICS OF PARTICIPANTS WITH MUSCLE THICKNESS DATA\*

Variable	Patients With LE (n = 18)	Controls (n = 18)
Age, y	48.2 ± 9.8	48.0 ± 10.2
Body mass, kg <sup>†</sup>	83.9 ± 17.3	69.9 ± 13.0
Height, m	1.67 ± 0.11	1.71 ± 0.08
Shoulder activity level (0-20) <sup>‡</sup>	10.5 ± 3.9	11.5 ± 4.0
QuickDASH, % <sup>†</sup>	38.4 ± 16.8	2.0 ± 3.1

Abbreviations: LE, lateral epicondylalgia; QuickDASH, shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire.

\*Values are mean ± SD.

<sup>†</sup>Significant difference between groups ( $P < .05$ ).

<sup>‡</sup>Shoulder activity level is based on a scale from 0 (no shoulder activity) to 20 (highest shoulder activity).

## RESULTS

**AGE, HEIGHT, AND SHOULDER ACTIVITY** levels were not statistically different between groups. Those with LE were found to have higher QuickDASH scores ( $P < .001$ ) than those in the control group (TABLES 1 and 2). Among patients with LE, 79% reported an insidious onset, whereas 21% reported a specific event that caused the injury. In patients with LE, the median (interquartile range) duration of symptoms was 12 (8-22) weeks, and 15 of 28 (53%) participants reported the affected side as their dominant side. The descriptive (unadjusted) data for strength, endurance, and USI measures are provided in TABLES 3 through 5.

## Comparisons Between Groups

**Strength** There were no significant interactions between group and dominance when accounting for the participants' height and weight ( $P > .503$ ). There were no differences in limb dominance regardless of group ( $P > .535$ ). However, the control group was stronger than the LE group for the LT ( $P = .006$ ), MT ( $P = .031$ ), and SA ( $P < .001$ ) (FIGURE 5).

**Endurance** Similar to strength, there were no significant interactions between group and dominance when accounting for participants' height and weight ( $P = .775$ ), and there were no differences in limb dominance regardless of group ( $P = .740$ ). The control group had greater endurance than the LE group ( $P = .003$ ) (FIGURE 6).

**Muscle Thickness** For the SA, there was no significant 3-way interaction between muscle type, group, and dominance ( $P = .11$ ). There was a significant 2-way interaction ( $P = .028$ ) between SA thickness condition and group when accounting for the participants' height and weight. The marginal means indicate that those in the control group had a greater change in SA thickness (1.4 mm) relative to patients with LE (0.7 mm) (TABLE 6). Post hoc analysis revealed a significant increase in thickness from rest to a contracted condition for the LE ( $P < .001$ ) and control ( $P = .015$ ) groups. No significant differences were found between patients with LE and the control group for resting SA thickness ( $P = .919$ ) or contracting thicknesses ( $P = .248$ ). The statistical analysis for the LT muscle indicated no 3-way ( $P = .155$ ) or 2-way interaction for group and type ( $P = .580$ ). There was a significant increase in thickness from rest to a contracted condition regardless of group ( $P < .001$ ) (TABLE 6).

## LE Involved-to-Uninvolved Comparison

**Strength** There were no significant interactions between limb and dominance ( $P > .381$ ). There were no differences in dominance regardless of group ( $P > .524$ ). In addition, there was no significant difference in involved versus uninvolved muscle strength for the MT ( $P = .26$ ). However, the involved limb was weaker than the uninvolved limb when measuring SA strength ( $P = .016$ ) and LT strength ( $P = .023$ ) (FIGURE 7).

**Endurance** Similar to our within-group results for strength, there was no interaction between limb and dominance ( $P = .178$ ), and no differences in dominance regardless of whether the limb was involved or uninvolved ( $P = .587$ ). There were no differences in endurance times when comparing the uninvolved and involved limbs (noninvolved,  $64 \pm 41$  seconds; involved,  $54 \pm 34$  seconds;  $P = .096$ ).

**Muscle Thickness** For both the SA and LT, there were no significant 3-way interactions between muscle type, limb, and dominance ( $P > .071$ ) or 2-way interac-

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tions between type and limb ( $P>.444$ ). There was a significant increase in thickness from rest to a contracted condition regardless of group ( $P<.001$ ) for both muscles (TABLE 7).

## DISCUSSION

TO OUR KNOWLEDGE, THIS IS THE first study to investigate scapular muscle characteristics in a general population of patients with LE. Consistent with our primary hypothesis, SA strength, LT strength, MT strength, scapular muscle endurance, and change in SA muscle thickness in patients with LE were significantly less than those in the matched comparison group. The findings suggest that therapists should consider factors that impact scapular muscle performance (strength and endurance) in patients with LE.

While our results indicated that scapular muscle strength and endurance were impaired in patients with LE compared to matched controls, when comparing the patients' involved limb to their uninvolved limb, the differences, although statistically significant and only for SA and LT strength, do not exceed measurement error using an HHD. These 2 findings are consistent with previous cross-sectional studies of patients with LE.<sup>1,29</sup> Most closely related to our study, Lucado et al<sup>29</sup> found significantly lower LT strength in female tennis players with LE compared to healthy female tennis players. In a second study, Alizadehkhayat et al<sup>1</sup> assessed isometric strength for select shoulder muscles in patients with LE, comparing the results to matched controls and also to the patient's uninvolved side. Similar to our study, the authors<sup>1</sup> found that there were deficits in strength when comparing patients with LE to matched controls, but no meaningful differences in shoulder strength between the uninvolved and involved limbs.

The current study also demonstrates diminished scapular muscle endurance in patients with LE. There has been very little literature published with which to

TABLE 3 SCAPULAR MUSCLE STRENGTH AND ENDURANCE*			
Measure	Patients With LE (n = 28)		Controls (n = 28)
	Uninvolved	Involved	Matched Limb <sup>†</sup>
LT strength, N	123 ± 25	109 ± 37	125 ± 29
MT strength, N	146 ± 27	139 ± 38	149 ± 25
SA strength, N	205 ± 51	185 ± 66	244 ± 49
Endurance, s	64 ± 41	54 ± 34	85 ± 34

Abbreviations: LE, lateral epicondylalgia; LT, lower trapezius; MT, middle trapezius; SA, serratus anterior.  
 \*Values are unadjusted mean ± SD. Unadjusted means are raw data and do not consider arm dominance, weight, and height.  
<sup>†</sup>Matched to a patient with LE. Matching was based on arm dominance.

TABLE 4 SCAPULAR MUSCLE THICKNESS						
Muscle	Patients With LE			Controls*		
	Relaxed <sup>†</sup>	Contracted <sup>†</sup>	Difference	Relaxed <sup>†</sup>	Contracted <sup>†</sup>	Difference
SA (n = 16)	5.9 ± 2.4	6.6 ± 2.3	0.7	4.9 ± 1.6	6.3 ± 1.6	1.4
LT (n = 18)	5.1 ± 2.0	6.5 ± 2.1	1.4	4.3 ± 2.0	5.6 ± 2.0	1.3

Abbreviations: LE, lateral epicondylalgia; LT, lower trapezius; SA, serratus anterior.  
 \*Values represent a matched limb to a patient with LE. Matching was based on arm dominance.  
<sup>†</sup>Values are unadjusted mean ± SD mm. Unadjusted means are raw data and do not consider arm dominance, weight, and height.

TABLE 5 WITHIN-GROUP COMPARISON OF SCAPULAR MUSCLE THICKNESS FOR THE GROUP WITH LATERAL EPICONDYLALGIA						
Muscle	Uninvolved Limb			Involved Limb		
	Relaxed*	Contracted*	Difference	Relaxed*	Contracted*	Difference
SA (n = 16)	5.9 ± 2.3	6.6 ± 2.5	0.7	5.9 ± 2.4	6.6 ± 2.3	0.7
LT (n = 18)	5.3 ± 2.0	6.4 ± 2.3	1.1	5.1 ± 2.0	6.5 ± 2.1	1.4

Abbreviations: LT, lower trapezius; SA, serratus anterior.  
 \*Values are unadjusted mean ± SD mm. Unadjusted means are raw data and do not consider arm dominance, weight, and height.

compare our endurance results. Alizadehkhayat et al<sup>3</sup> found no significant differences in rotator cuff muscle endurance compared to a control group. The differences in findings between studies may be attributed to the type of endurance task performed. Alizadehkhayat et al<sup>1</sup> investigated repetitive isotonic shoulder contractions, whereas the current study used

a sustained isometric contraction to measure fatigue. The 2 types of endurance tests physiologically differ. Intramuscular tissue pressure increases during sustained isometric contractions, and intramuscular tissue pressure is known to interfere with muscular blood flow.<sup>14,43</sup> The impeded blood flow could result in muscle ischemia, thus altering muscle



TABLE 6

### BETWEEN-GROUP COMPARISON OF MARGINAL MEAN VALUES OF SCAPULAR MUSCLE THICKNESS

Muscle	Patients With LE			Controls*		
	Relaxed <sup>†</sup>	Contracted <sup>†</sup>	Difference	Relaxed <sup>†</sup>	Contracted <sup>†</sup>	Difference
SA (n = 16)	5.4 ± 1.6	6.1 ± 2.0	0.7 <sup>‡</sup>	5.4 ± 1.2	6.8 ± 1.6	1.4 <sup>§</sup>
LT (n = 18)	4.6 ± 1.7	6.0 ± 1.9	1.4 <sup>‡</sup>	4.8 ± 1.4	6.1 ± 1.7	1.3 <sup>‡</sup>

Abbreviations: LE, lateral epicondylalgia; LT, lower trapezius; SA, serratus anterior.

\*Values represent a matched limb to a patient with LE. Matching was based on arm dominance.

<sup>†</sup>Values are mean ± SD mm adjusted for arm dominance, height, and weight.

<sup>‡</sup>Significant increase from rest to contraction.

<sup>§</sup>Significant 2-way interaction ( $P = .028$ ) between the SA thickness condition and group, showing that the controls had a greater change in thickness with contraction.

TABLE 7

### WITHIN-GROUP COMPARISON OF MARGINAL MEAN VALUES OF SCAPULAR MUSCLE THICKNESS FOR THE GROUP WITH LATERAL EPICONDYLALGIA

Muscle	Uninvolved Limb			Involved Limb		
	Relaxed*	Contracted*	Difference	Relaxed*	Contracted*	Difference
SA (n = 16)	5.9 ± 2.3	6.6 ± 2.5	0.7 <sup>†</sup>	5.9 ± 2.5	6.8 ± 2.9	0.9 <sup>†</sup>
LT (n = 18)	5.1 ± 2.1	6.5 ± 2.3	1.4 <sup>†</sup>	5.0 ± 1.9	6.4 ± 2.7	1.4 <sup>†</sup>

Abbreviations: LT, lower trapezius; SA, serratus anterior.

\*Values are mean ± SD mm adjusted for arm dominance.

<sup>†</sup>Significant increase from rest to contraction ( $P < .001$ ).

performance.<sup>31,46</sup> Diminished oxygen delivery will accelerate muscle fatigue compared to the isotonic test, where the muscle acts as a natural pump for blood flow. Thus, the differences observed in isometric endurance times in the current study may be a difference in muscle perfusion efficiency between patients with LE and controls.

The position of this endurance test (prone shoulder abduction at 135°) was chosen by the investigators because it is known to produce a high amount of LT activity.<sup>15,16,36</sup> However, it could be argued that because other posterior shoulder muscles are also active in this position, the described test may not be a true measure of LT endurance. Therefore, future research is needed to better determine which of the posterior shoulder muscles are most affected by this test position. Previous studies have compared rate of

median frequency shifts between muscles to show which muscle is fatigued at a greater rate.<sup>34</sup> Although factors like muscle strength and the contribution of synergistic muscles would have to be considered, comparing rates of median frequency shifts could be used to determine which of the several posterior shoulder muscles are fatiguing the fastest.

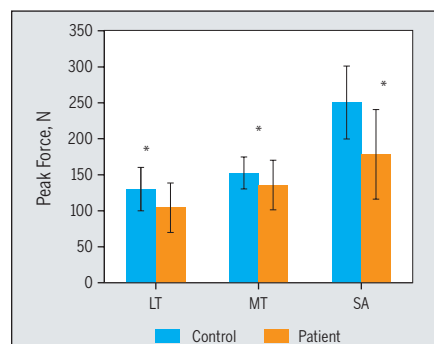
Our findings have implications for clinical practice. The differences in LT strength (26 N) and SA strength (72 N) between patients with LE and controls meet or exceed the MDC values from previously published data.<sup>32</sup> The mean values indicate that the differences are beyond measurement error of the device used. Although MDC values for the described scapular muscle endurance test have never been published, the mean difference between patients with LE and controls is large (31 seconds) and statis-

tically significant. As a result, addressing LT strength, SA strength, as well as scapular muscle endurance should be considered in patients with LE.

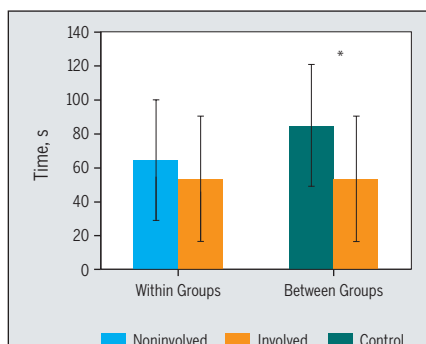
In contrast to the above finding, there were no measurable differences between patients' involved and uninvolved limbs. Because a limb-to-limb comparison in the clinical setting is often the most convenient approach to assess patients, scapular muscle impairments may be missed. Therefore, to determine the presence of deficits, clinicians should compare strength and endurance findings in patients with LE to normative data, which have yet to be established.

The assessment of scapular muscle strength and endurance is potentially important in patients with LE to provide clinicians with objective information to make a clinical decision as to whether treatment is indicated. Based on this study design, we are unable to definitively determine if treating scapular muscle strength and endurance deficits will improve outcomes in patients with LE. However, Bhatt et al<sup>5</sup> reported successful treatment of a 54-year-old woman with only strengthening exercises targeting the MT and LT muscles. It has also been reported that after successful remission of pain symptoms, patients previously diagnosed with LE continue to present with shoulder weakness.<sup>2</sup> During functional arm motions, kinetic energy is transferred from proximal to more distal segments of the arm. With an impaired ability to stabilize the scapula, increased energy demands are theoretically required of tissues in the distal upper extremity when performing a functional activity.<sup>17,42</sup> Theoretically, the scapulothoracic muscle impairments found in this study could perpetuate the LE or predispose patients to reinjury if left unaddressed.

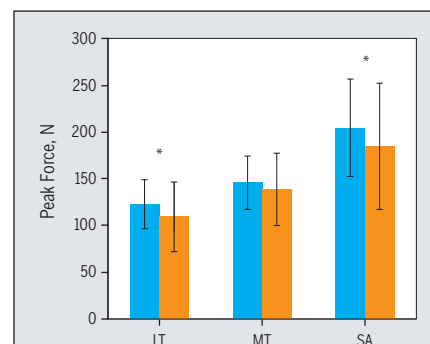
The design of this study does not allow for definitive conclusions that scapular muscle weakness is a causative factor for the development of LE. One other possible theory is that lateral epicondyle pain triggers a centrally mediated mecha-



**FIGURE 5.** Scapular muscle strength. Values are marginal mean  $\pm$  SD (adjusted for height and weight). Measures represent the involved limb of the patients with lateral epicondylalgia and a matched limb of the control group. The matched limb of the control group was based on arm dominance. LT control, 130  $\pm$  29 N; LT patient, 104  $\pm$  33 N; MT control, 152  $\pm$  22 N; MT patient, 135  $\pm$  33 N; SA control, 250  $\pm$  50 N; SA patient, 178  $\pm$  62 N. \*Significant difference between groups ( $P < .01$ ). Abbreviations: LT, lower trapezius; MT, middle trapezius; SA, serratus anterior.



**FIGURE 6.** Scapular muscle endurance. Values are marginal mean  $\pm$  SD. The within-group comparison is between the uninvolved and involved limbs of the patients with lateral epicondylalgia. The between-group comparison is between the involved limb of the patients with lateral epicondylalgia and a matched limb of the control group. The matched limb of the control group was based on arm dominance. The means represented are adjusted for height and weight. Within-group noninvolved, 64  $\pm$  35 seconds; within-group involved, 53  $\pm$  37 seconds; between-group control, 84  $\pm$  35 seconds; between-group involved, 53  $\pm$  37 seconds. \*Significant difference between groups ( $P < .01$ ).



**FIGURE 7.** Scapular muscle strength for patients with lateral epicondylalgia. Values are mean  $\pm$  SD. LT noninvolved, 123  $\pm$  25 N; LT involved, 109  $\pm$  37 N; MT noninvolved, 146  $\pm$  27 N; MT involved, 139  $\pm$  38 N; SA noninvolved, 205  $\pm$  51 N; SA involved, 185  $\pm$  66 N. \*Significant difference between groups ( $P < .01$ ). Abbreviations: LT, lower trapezius; MT, middle trapezius; SA, serratus anterior.

nism, resulting in the observed scapular muscle weakness. To that end, muscle inhibition from a regional source of pain has been reported for the quadriceps,<sup>19,51</sup> hamstrings,<sup>24</sup> and masseter<sup>33</sup> muscles. In addition, pain of the common wrist extensors may cause the patient to use the upper extremity less and in a more guarded range of motion. Over time, disuse would result in a decrease in shoulder active range of motion and weakness of the shoulder musculature.

Future studies are needed to more completely define the clinical significance of scapular muscle deficits in patients with LE, because it could be argued that the differences in muscle strength may be differences solely of scapular and thoracic posture. Future studies should assess the spinal curvature and position of the scapula in both populations and then see if the testing position equally impacts both groups. In addition, it would be interesting to determine if treating scapular muscle deficits will improve both short- and long-term outcomes in patients with LE. Prospective studies are also warranted to determine if scapular muscle weakness is present prior to the development of LE

and if scapular muscle weakness is a potential risk factor for LE.

Our USI results highlight that the change in SA thickness from rest to contraction was significantly different between patients with LE and controls, but no differences were found comparing the involved SA with the uninvolved SA. In addition, using this methodology, the change in LT does not appear to behave differently in patients with LE compared to normal controls or when comparing a patient's involved LT with the uninvolved LT. Preliminarily, the differences observed between patients with LE and controls for the change scores from rest to contraction are encouraging and warrant further investigation, but there are a number of limitations to the interpretation of USI of muscle actions.<sup>55</sup>

Similar to our USI findings, it has been consistently reported that individuals with cervical pain, shoulder pain, and postural deficits demonstrate diminished SA activity compared to controls, while results for LT activity have been inconsistent.<sup>13,23,50,54</sup> Overall, the findings in our study and in previous studies may

indicate that individuals with upper-quarter pain or postural deficits often present with diminished SA function. Future research should examine whether the observed SA deficits are a result of a specific pathology or are a predetermining factor in the development of conditions like cervical, shoulder, and lateral elbow pain.

## Limitations

Despite efforts made to eliminate extraneous factors influencing the results of our study, there are several limitations that should be considered. First, all measures of scapular muscle strength were performed by the primary investigator, and the investigator was not blinded to group assignment or to the involved limb in patients with LE, thus introducing potential investigator bias. In addition, it has been demonstrated by EMG analysis that the SA strength test used in this study does not isolate SA function, and therefore it may be better to regard the test as an indication of scapulothoracic protraction weakness.<sup>32</sup> Second, a submaximal endurance task, as completed in this study, is thought to be influenced by an individual's ability to self-regulate. Self-regulation can cause an individual

to override a feeling of fatigue, through the central nervous system, to sustain an endurance task.<sup>6</sup> Therefore, it is possible that individuals with LE have a diminished ability to self-regulate, thus reducing the endurance times. Third, because the patients had pain and no systematic differences were detected between limbs, it is possible that pain is a central driving factor for maximal volitional contraction, endurance, and muscle thickness measures. Fourth, the power analysis suggested that 28 participants be recruited for this study, but only 18 were available for the USI assessment. Finally, it is difficult to ascertain the exact meaning of change in muscle thickness using USI, because of the inconsistent findings reported by previous authors examining the correlations between change in muscle thickness and muscle activity.<sup>55</sup>

## CONCLUSION

**P**ATIENTS WITH LE DEMONSTRATED significant weakness of the LT and SA as well as a significant decline in scapular muscle endurance when compared to an asymptomatic control group. Assessment of SA strength, LT strength, and posterior shoulder muscle endurance is recommended in patients with LE. Future studies should seek to investigate the short- and long-term efficacy of treating scapular muscle deficits as part of a comprehensive treatment program for individuals with LE. ●

## KEY POINTS

**FINDINGS:** Patients with LE demonstrated significant weakness of the LT and SA as well as a significant decline in scapular muscle endurance when compared to an asymptomatic control group. The differences between the uninvolved and involved limbs were not clinically meaningful.

**IMPLICATIONS:** Scapular muscle strength and endurance deficits should be considered in the management of patients with lateral elbow pain.

**CAUTION:** This was a cross-sectional

study of a small group of patients with LE; therefore, the data do not indicate a causal relationship between LE and scapular muscle weakness.

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## REFERENCES

1. Alizadehkhayat O, Fisher AC, Kemp GJ, Frostick SP. Strength and fatigability of selected muscles in upper limb: assessing muscle imbalance relevant to tennis elbow. *J Electromyogr Kinesiol.* 2007;17:428-436. <http://dx.doi.org/10.1016/j.jelekin.2006.04.007>
2. Alizadehkhayat O, Fisher AC, Kemp GJ, Vishwanathan K, Frostick SP. Assessment of functional recovery in tennis elbow. *J Electromyogr Kinesiol.* 2009;19:631-638. <http://dx.doi.org/10.1016/j.jelekin.2008.01.008>
3. Alizadehkhayat O, Fisher AC, Kemp GJ, Vishwanathan K, Frostick SP. Upper limb muscle imbalance in tennis elbow: a functional and electromyographic assessment. *J Orthop Res.* 2007;25:1651-1657. <http://dx.doi.org/10.1002/jor.20458>
4. Basmajian J. *Biofeedback: Principles and Practice for Clinicians*. Baltimore, MD: Williams & Wilkins; 1989.
5. Bhatt JB, Glaser R, Chavez A, Yung E. Middle and lower trapezius strengthening for the management of lateral epicondylalgia: a case report. *J Orthop Sports Phys Ther.* 2013;43:841-847. <http://dx.doi.org/10.2519/jospt.2013.4659>
6. Bray SR, Martin Ginis KA, Woodgate J. Self-regulatory strength depletion and muscle-endurance performance: a test of the limited-strength model in older adults. *J Aging Phys Act.* 2011;19:177-188.
7. Çelik D, Dirican A, Baltaci G. Intrarater reliability of assessing strength of the shoulder and scapular muscles. *J Sport Rehabil.* 2012;technical notes 3:1-5.
8. Cleland JA, Flynn TW, Palmer JA. Incorporation of manual therapy directed at the cervicothoracic spine in patients with lateral epicondylalgia: a pilot clinical trial. *J Man Manip Ther.* 2005;13:143-151. <http://dx.doi.org/10.1179/106698105790824932>
9. Cools AM, Dewitte V, Lanszweert F, et al. Rehabilitation of scapular muscle balance: which exercises to prescribe? *Am J Sports Med.* 2007;35:1744-1751. <http://dx.doi.org/10.1177/03635465070303560>
10. Coombes BK, Bisset L, Brooks P, Khan A, Vicenzino B. Effect of corticosteroid injection, physiotherapy, or both on clinical outcomes in patients with unilateral lateral epicondylalgia: a randomized controlled trial. *JAMA.* 2013;309:461-469. <http://dx.doi.org/10.1001/jama.2013.129>
11. Coombes BK, Bisset L, Vicenzino B. Efficacy and safety of corticosteroid injections and other injections for management of tendinopathy: a systematic review of randomised controlled trials. *Lancet.* 2010;376:1751-1767. [http://dx.doi.org/10.1016/S0140-6736\(10\)61160-9](http://dx.doi.org/10.1016/S0140-6736(10)61160-9)
12. Day JM, Uhl T. Thickness of the lower trapezius and serratus anterior using ultrasound imaging during a repeated arm lifting task. *Man Ther.* 2013;18:588-593. <http://dx.doi.org/10.1016/j.math.2013.07.003>
13. Diederichsen LP, Nørregaard J, Dyhre-Poulsen P, et al. The activity pattern of shoulder muscles in subjects with and without subacromial impingement. *J Electromyogr Kinesiol.* 2009;19:789-799. <http://dx.doi.org/10.1016/j.jelekin.2008.08.006>
14. Edwards RH, Hill DK, McDonnell M. Myothermal and intramuscular pressure measurements during isometric contractions of the human quadriceps muscle. *J Physiol.* 1972;224:58P-59P.
15. Ekstrom RA, Donatelli RA, Soderberg GL. Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *J Orthop Sports Phys Ther.* 2003;33:247-258. <http://dx.doi.org/10.2519/jospt.2003.33.5.247>
16. Escamilla RF, Yamashiro K, Paulos L, Andrews JR. Shoulder muscle activity and function in common shoulder rehabilitation exercises. *Sports Med.* 2009;39:663-685. <http://dx.doi.org/10.2165/00007256-200939080-00004>
17. Feltner ME, Dapena J. Three-dimensional interactions in a two-segment kinetic chain, part 1: general model. *Int J Sport Biomech.* 1989;5:403-419.
18. Fernández-Carnero J, Cleland JA, Arbizu RL. Examination of motor and hypoalgesic effects of cervical vs thoracic spine manipulation in patients with lateral epicondylalgia: a clinical trial. *J Manipulative Physiol Ther.* 2011;34:432-440. <http://dx.doi.org/10.1016/j.jmpt.2011.05.019>
19. Graven-Nielsen T, Lund H, Arendt-Nielsen L, Danneskiold-Samsøe B, Bliddal H. Inhibition of maximal voluntary contraction force by experimental muscle pain: a centrally mediated mechanism. *Muscle Nerve.* 2002;26:708-712. <http://dx.doi.org/10.1002/mus.10225>
20. Gruchow HW, Pelletier D. An epidemiologic study of tennis elbow. Incidence, recurrence, and effectiveness of prevention strategies. *Am J Sports Med.* 1979;7:234-238.
21. Hamilton PG. The prevalence of humeral epicondylitis: a survey in general practice. *J R Coll Gen Pract.* 1986;36:464-465.
22. Han SH, An HJ, Song JY, et al. Effects of corticosteroid on the expressions of neuropeptide and cytokine mRNA and on tenocyte viability in lateral epicondylitis. *J Inflamm (Lond).* 2012;9:40. <http://dx.doi.org/10.1186/1476-9255-9-40>
23. Helgadóttir H, Kristjánsson E, Einarsson E, Karduna A, Jonsson H, Jr. Altered activity of the

serratus anterior during unilateral arm elevation in patients with cervical disorders. *J Electromyogr Kinesiol*. 2011;21:947-953. <http://dx.doi.org/10.1016/j.jelekin.2011.07.007>

24. Henriksen M, Rosager S, Aaboe J, Graven-Nielsen T, Bliddal H. Experimental knee pain reduces muscle strength. *J Pain*. 2011;12:460-467. <http://dx.doi.org/10.1016/j.jpain.2010.10.004>
25. Hunsaker FG, Cioffi DA, Amadio PC, Wright JG, Caughlin B. The American Academy of Orthopaedic Surgeons outcomes instruments: normative values from the general population. *J Bone Joint Surg Am*. 2002;84-A:208-215.
26. Johnson EG, Godges JJ, Lohman EB, Stephens JA, Zimmerman GJ, Anderson SP. Disability self-assessment and upper quarter muscle balance between female dental hygienists and non-dental hygienists. *J Dent Hyg*. 2003;77:217-223.
27. Koppenhaver SL, Parent EC, Teyhen DS, Hebert JJ, Fritz JM. The effect of averaging multiple trials on measurement error during ultrasound imaging of transversus abdominis and lumbar multifidus muscles in individuals with low back pain. *J Orthop Sports Phys Ther*. 2009;39:604-611. <http://dx.doi.org/10.2519/jospt.2009.3088>
28. Lahz JR. Pathology and treatment of tennis elbow. *J Bone Joint Surg Br*. 1948;30B:223.
29. Lucado AM, Kolber MJ, Cheng MS, Echternach JL, Sr. Upper extremity strength characteristics in female recreational tennis players with and without lateral epicondylalgia. *J Orthop Sports Phys Ther*. 2012;42:1025-1031. <http://dx.doi.org/10.2519/jospt.2012.4095>
30. Lynch SS, Thigpen CA, Mihalik JP, Prentice WE, Padua D. The effects of an exercise intervention on forward head and rounded shoulder postures in elite swimmers. *Br J Sports Med*. 2010;44:376-381. <http://dx.doi.org/10.1136/bjsm.2009.066837>
31. McDermott MM, Tian L, Ferrucci L, et al. Associations between lower extremity ischemia, upper and lower extremity strength, and functional impairment with peripheral arterial disease. *J Am Geriatr Soc*. 2008;56:724-729. <http://dx.doi.org/10.1111/j.1532-5415.2008.01633.x>
32. Michener LA, Boardman ND, Pidcoe PE, Frith AM. Scapular muscle tests in subjects with shoulder pain and functional loss: reliability and construct validity. *Phys Ther*. 2005;85:1128-1138.
33. Minami I, Akhter R, Albersen I, et al. Masseter motor unit recruitment is altered in experimental jaw muscle pain. *J Dent Res*. 2013;92:143-148. <http://dx.doi.org/10.1177/0022034512470832>
34. Minning S, Eliot CA, Uhl TL, Malone TR. EMG

analysis of shoulder muscle fatigue during resisted isometric shoulder elevation. *J Electromyogr Kinesiol*. 2007;17:153-159. <http://dx.doi.org/10.1016/j.jelekin.2006.01.008>

35. Morris H. The rider's sprain. *Lancet*. 1882;120:133-134. [http://dx.doi.org/10.1016/S0140-6736\(02\)26282-0](http://dx.doi.org/10.1016/S0140-6736(02)26282-0)
36. Moseley JB, Jr., Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med*. 1992;20:128-134.
37. Nilsson P, Baigi A, Swärd L, Möller M, Månsson J. Lateral epicondylalgia: a structured programme better than corticosteroids and NSAID. *Scand J Occup Ther*. 2012;19:404-410. <http://dx.doi.org/10.3109/11038128.2011.620983>
38. Olausson M, Holmedal O, Lindbæk M, Brage S. Physiotherapy alone or in combination with corticosteroid injection for acute lateral epicondylitis in general practice: a protocol for a randomised, placebo-controlled study. *BMC Musculoskelet Disord*. 2009;10:152. <http://dx.doi.org/10.1186/1471-2474-10-152>
39. Orchard J. Corticosteroid injection for lateral epicondylalgia is helpful in the short term, but harmful in the longer term; data for non-corticosteroid injections and other tendinopathies are limited. *Evid Based Med*. 2011;16:116-117. <http://dx.doi.org/10.1136/ebm1202>
40. O'Sullivan C, Bentman S, Bennett K, Stokes M. Rehabilitative ultrasound imaging of the lower trapezius muscle: technical description and reliability. *J Orthop Sports Phys Ther*. 2007;37:620-626. <http://dx.doi.org/10.2519/jospt.2007.2446>
41. Petrofsky JS. Quantification through the surface EMG of muscle fatigue and recovery during successive isometric contractions. *Aviat Space Environ Med*. 1981;52:545-550.
42. Putnam CA. Sequential motions of body segments in striking and throwing skills: descriptions and explanations. *J Biomech*. 1993;26 suppl 1:125-135.
43. Saltin B, Sjøgaard G, Gaffney FA, Rowell LB. Potassium, lactate, and water fluxes in human quadriceps muscle during static contractions. *Circ Res*. 1981;48:118-124.
44. Samani A, Fernández-Carnero J, Arendt-Nielsen L, Madeleine P. Interactive effects of acute experimental pain in trapezius and sore wrist extensor on the electromyography of the forearm muscles during computer work. *Appl Ergon*. 2011;42:735-740. <http://dx.doi.org/10.1016/j.apergo.2010.11.008>
45. Shirir R, Viikari-Juntura E. Lateral and medial epicondylitis: role of occupational factors. *Best Pract Res Clin Rheumatol*. 2011;25:43-57. <http://dx.doi.org/10.1016/j.jberh.2011.01.013>

[dx.doi.org/10.1016/j.jberh.2011.01.013](http://dx.doi.org/10.1016/j.jberh.2011.01.013)

46. Smeele KM, Eerbeek O, Schaart G, et al. Reduced hexokinase II impairs muscle function 2 wk after ischemia-reperfusion through increased cell necrosis and fibrosis. *J Appl Physiol* (1985). 2012;113:608-618. <http://dx.doi.org/10.1152/japplphysiol.01494.2011>
47. Stull GA, Clarke DH. Patterns of recovery following isometric and isotonic strength decrement. *Med Sci Sports*. 1971;3:135-139.
48. Suzuki H, Swanik K, Bliven KH, Kelly JD, 4th, Swanik CB. Alterations in upper extremity motion after scapular-muscle fatigue. *J Sport Rehabil*. 2006;15:71-88.
49. Tate A, Turner GN, Knab SE, Jorgensen C, Strittmatter A, Michener LA. Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. *J Athl Train*. 2012;47:149-158.
50. Thigpen CA, Padua DA, Michener LA, et al. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *J Electromyogr Kinesiol*. 2010;20:701-709. <http://dx.doi.org/10.1016/j.jelekin.2009.12.003>
51. Verbunt JA, Seelen HA, Vlaeyen JW, et al. Pain-related factors contributing to muscle inhibition in patients with chronic low back pain: an experimental investigation based on superimposed electrical stimulation. *Clin J Pain*. 2005;21:232-240.
52. Walker-Bone K, Palmer KT, Reading I, Coggon D, Cooper C. Occupation and epicondylitis: a population-based study. *Rheumatology (Oxford)*. 2012;51:305-310. <http://dx.doi.org/10.1093/rheumatology/ker228>
53. Walker-Bone K, Palmer KT, Reading I, Coggon D, Cooper C. Prevalence and impact of musculoskeletal disorders of the upper limb in the general population. *Arthritis Rheum*. 2004;51:642-651. <http://dx.doi.org/10.1002/art.20535>
54. Weon JH, Oh JS, Cynn HS, Kim YW, Kwon OY, Yi CH. Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. *J Bodyw Mov Ther*. 2010;14:367-374. <http://dx.doi.org/10.1016/j.jbmt.2009.06.006>
55. Whittaker JL, Stokes M. Ultrasound imaging and muscle function. *J Orthop Sports Phys Ther*. 2011;41:572-580. <http://dx.doi.org/10.2519/jospt.2011.3682>



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