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Upper Extremity Strength Characteristics in Female Recreational Tennis Players With and Without Lateral Epicondylalgia

Epidemiological reports suggest that up to 40% of tennis players experience lateral elbow pain at some time during their lifetime.^{2,26} Lateral epicondylalgia is one of the most common injuries in tennis players of all skill levels and can result in prolonged symptoms and reduced athletic performance.¹⁵ Lateral epicondylalgia is characterized as a chronic overuse injury that is likely the result

of multiple factors.²⁶ However, high demands on the wrist extensor musculature from repeated muscular contractions in extreme positions of the upper extremity may contribute to the pathophysiology that leads to symptoms of lateral epicondylalgia. Both extrinsic and intrinsic factors contributing to injury may be present prior to the actual injury or onset of symptoms. Extrinsic risk factors can include errors in technique, environmental conditions, and equipment that alters the external forces applied to the upper extremity.²⁶ Intrinsic risk factors can include altered joint arthrokinematics, muscular imbalances, or muscular weakness in the upper extremity that may expose an individual to microtrauma of the involved tissues.¹³

Grip strength weakness^{11,12} and general weakness of the arm^{1,10,31} have been reported in individuals with acute symptoms of lateral epicondylalgia. This is consistent with the finding that, during the tennis stroke, the musculoskeletal components of the scapula, shoulder, elbow, and wrist are essential links in the kinetic chain that transfers energy from the force-generating legs and trunk to the more rapidly moving segments of the wrist and hand.¹⁸ Therefore, it is impor-

● **STUDY DESIGN:** Descriptive, cross-sectional.

● **OBJECTIVES:** To compare static strength characteristics of the upper extremity musculature in female recreational tennis players with lateral epicondylalgia to those of nonsymptomatic tennis players and a control group of women who did not play tennis.

● **BACKGROUND:** There is a paucity of research describing the relationship between lateral epicondylalgia and strength characteristics of the upper extremity musculature, despite the functional relationship between the shoulder, elbow, and wrist.

● **METHODS:** Sixty-three women were recruited into 3 groups (n = 21 per group): symptomatic tennis players (STP) with lateral epicondylalgia, nonsymptomatic tennis players, and controls. Data collection was performed during a single session, during which the strength of selected muscle groups of the dominant upper extremity was measured using a combination of force transducers. Strength ratios of selected muscle groups were then calculated.

● **RESULTS:** The STP group reported median pain level of 3/10 on a numeric pain rating scale and a

symptom duration of 16 weeks. The STP group had weaker lower trapezius strength (mean difference, -9.0 N; 95% confidence interval [CI]: -13.5, -4.4) and wrist extensor strength (-12.7 N; 95% CI: -24.4, -1.1), and a higher shoulder internal/external rotation strength ratio (0.19; 95% CI: 0.02, 0.35) and upper/lower trapezius strength ratio (1.32; 95% CI: 0.41, 2.23), compared to those of the nonsymptomatic group. Compared to the control group, the STP group demonstrated a significantly higher shoulder internal/external rotation strength ratio (0.21; 95% CI: 0.04, 0.38) and wrist flexion/extension strength ratio (0.14; 95% CI: 0.01, 0.27).

● **CONCLUSION:** In this group of recreational female tennis players, significant differences in strength and strength ratio characteristics were identified. Although the design of the study precludes establishing a cause-and-effect relationship, the results suggest further study and treatment of the muscle groups of interest. *J Orthop Sports Phys Ther* 2012;42(12):1025-1031, Epub 5 September 2012. doi:10.2519/jospt.2012.4095

● **KEY WORDS:** lateral epicondylitis, shoulder, tennis elbow, wrist

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tant to consider that musculature that may not be directly associated with the symptomatic site may be involved mechanically in the development of symptoms at the lateral elbow. The purpose of this study was to measure static strength of the upper extremity musculature as a potential pathobiomechanical factor in the etiology of lateral epicondylalgia in female tennis players.

METHODS

Subjects

SUBJECTS WERE RECRUITED FROM advertisements in the recreational tennis community. Sixty-three female participants (mean \pm SD age, 44.9 \pm 8.1 years; age range, 20-63 years) satisfied the eligibility criteria for inclusion. Subjects were recruited into 3 groups of equal size ($n = 21$ per group): tennis players with symptoms of lateral epicondylalgia in the dominant extremity (STP group), tennis players without symptoms of lateral epicondylalgia (NSTP group), and a control group consisting of active women who did not play tennis. Demographic and pain data were collected on all participants by questionnaire. The study was approved by the Institutional Review Board of Nova Southeastern University, and written informed consent was obtained from all participants.

Inclusion and Exclusion Criteria and Group Assignment

All participants were required to be women between 18 and 65 years of age. The participants in the 2 groups of tennis players were required to be actively involved in recreational tennis play at least twice a week for a minimum of 10 weeks immediately prior to data collection, unless the symptomatic players had decreased playing within that time period because of lateral elbow pain. The participants in the control group were recreationally active women who did not play tennis.

To qualify for inclusion in the STP group, at least 3 of 4 of the following cri-

teria^{14,37} were required: pain in the lateral elbow region within 90 days immediately prior to data collection, tenderness to palpation local to the lateral epicondyle at the time of evaluation, pain local to the lateral epicondyle during resisted wrist extension performed with the elbow in extension at the time of evaluation, and pain occurring local to the lateral epicondyle with stretching of the wrist extensors. All 4 diagnostic criteria were required to be negative for a participant to be included in one of the asymptomatic groups.

Participants were excluded if they participated in professional tennis activities or sports activities that required extremes of dominant upper extremity motion, were not fluent in English, were pregnant, were under medical care for cervical pathology, had a history of rheumatoid disease or neurologic impairment, had recent surgery to the upper quarter, or had any previous surgery to the elbow or shoulder. Additionally, they were excluded if the screening tests for differential diagnosis were positive, indicating possible cervical radiculopathy, radial tunnel syndrome, or intra-articular elbow pathology.

The following tests were also used to determine inclusion in the study: (1) the Spurling test to rule out cervical pathology (reported positive and negative likelihood ratios of 9.63 and 0.25, respectively)³⁵; (2) passive range of motion of the elbow to assess for crepitus, joint sounds, or motion limitations, which suggest an intra-articular pathology²⁸; (3) the chair test, as described by Regan and Lapner,³³ to assess for lateral collateral ligament integrity (the diagnostic utility of which has not been established); and (4) palpation and resisted supination to determine the presence of radial tunnel syndrome.³⁷ The most common physical findings for radial tunnel syndrome include tenderness over the radial nerve at the supinator muscle level and pain on resisted supination 4 cm distal to the lateral epicondyle.³⁶ Despite the lack of published diagnostic utility data for these

tests, indications of pain in the proximal muscle of the forearm (rather than at the lateral epicondyle) and pain with resisted supination were used as screening tools to rule out radial tunnel syndrome. When the screening tests were negative, each participant was physically examined for lateral epicondylalgia to confirm group assignment. The examination procedures and data collection were conducted by a licensed physical therapist who was certified in hand therapy and had 19 years of clinical experience.

Instrumentation

The microFET2 (Hoggan Health Industries, Inc, West Jordan, UT) handheld dynamometer (HHD), which has a manufacturer-reported accuracy within $\pm 2\%$, was used for data collection. The dynamometer was factory calibrated prior to the study.

Procedure

Strength tests were performed in the order listed below, with a maximal isometric hold time (make test) of approximately 6 seconds, using standardized instructions.¹⁹ Three repetitions were performed for each muscle group. Participants were provided with 10 seconds of rest between trials and at least 3 minutes between the testing of muscle groups. The peak strength value of each of the 3 trials was recorded and subsequently averaged for analysis.

For all seated tests, the nontested arm was on the subject's lap, and a stabilization belt was applied around the participant's chest and chair to prevent trunk movement. The participant was seated in an armless chair with the trunk supported and the feet flat on the floor.

Shoulder Internal/External Rotation

Strength testing for shoulder internal rotation (IR) and external rotation (ER) was conducted using a previously established protocol and equipment.^{19,20} A preconstructed arm support, placed in the participant's axillary region, maintained the tested arm in 30° of elevation in the scapular plane, and a PVC stabili-

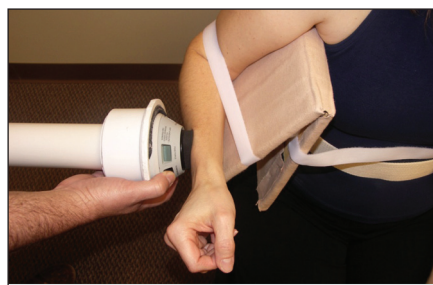


FIGURE 1. Strength test for shoulder external rotation.

zation device, positioned on the wall at a level that accommodated the desired testing angle, held the contact surface of the HHD against the participant's arm (**FIGURE 1**). IR was tested with the contact surface of the HHD placed on the volar aspect of the distal forearm, and ER was tested with the contact surface of the HHD placed on the dorsal aspect of the distal forearm.

Shoulder Abduction The strength of the shoulder abductors was tested in a seated position, with the arm adducted by the side of the trunk.²⁰ The stabilization device was positioned with the HHD just proximal to the lateral epicondyle.

Upper Trapezius Upper trapezius (UT) testing was conducted according to a previously established protocol.²⁰ The participant was seated in a chair, with the trunk stabilized and the elbow of the tested side actively flexed to 90°. The tester stood behind the participant and, using a stable stool, placed the HHD on the superior lateral aspect of the scapula, with a nonslip padding interposed between the skin and HHD. The participant was instructed to shrug the shoulder.

Wrist Flexion/Extension Participants were seated with the shoulder abducted to approximately 20° of neutral rotation, the elbow flexed to 90°, and the forearm resting in neutral rotation on an adjustable-height table on the tested side. The wrist was positioned in neutral extension/flexion, with the fingers in slight flexion. For wrist flexion, the examiner manually stabilized the distal forearm just proximal to the wrist with 1 hand and applied the HHD to the palm of the participant's hand, so that the midpoint of the HHD



FIGURE 2. Strength test of lower trapezius muscle.

contact surface corresponded with the midline of the third metacarpal. The participant was instructed to flex the wrist. For wrist extension, the testing position was identical, except that the examiner applied the HHD to the dorsal aspect of the hand, so that the midpoint of the HHD contact surface corresponded with the midline of the third metacarpal. The participant was instructed to extend the wrist.

Lower Trapezius The participant was in a prone position on the testing table³⁰ and was instructed to raise the arm off the table toward the ceiling, while pulling the scapula downward in the direction of scapular depression.²⁰ The examiner applied the HHD to the lateral aspect of the distal radius (**FIGURE 2**).

Elbow Flexion/Extension Strength of the elbow flexors and extensors was tested in a supine position using a previously established protocol.⁴ The participant was instructed to place the tested arm along the trunk and to flex the elbow to 90°. The forearm and wrist were held in a neutral position. The examiner manually stabilized the distal humerus just proximal to the elbow joint with 1 hand and applied the HHD to the lateral aspect of the distal radius just proximal to the wrist for elbow flexion. The procedure was repeated for extension, with the HHD applied just proximal to the wrist on the ulnar surface of the forearm.

Data Analysis

Statistical analysis included measures of central tendency and variability of the

descriptive data for each of the groups using SPSS Version 18.0 (SPSS Inc, Chicago, IL). An a priori power analysis indicated that, with an alpha level of .05 and a conventional large effect size of 0.40 for a power of .80, a minimum sample of 21 per group was required.³² Outcomes data were compared among the 3 groups using a 1-way analysis of variance for each variable. Post hoc analyses were conducted using the Bonferroni test. The significance level was set at the .05 level, using a 2-tailed test for all hypotheses.

Using the strength data, agonist-antagonist ratios were calculated for shoulder IR/ER, UT/lower trapezius (LT), shoulder abduction/ER, elbow flexion/extension, and wrist flexion/extension. The data of the 3 individual strength trials and the calculated strength ratios were used to document intrarater within-session reliability of the strength measurements using intraclass correlation coefficients (ICC_{3,1}).

RESULTS

THE ANALYSIS OF VARIANCE REVEALED no significant differences among the symptomatic tennis players, the nonsymptomatic tennis players, and the control group for age ($P = .329$), weight ($P = .702$), height ($P = .059$), and body mass index ($P = .722$). There were also no significant differences for the number of years playing tennis, self-reported skill level, or frequency of play between the tennis players with and without lateral elbow pain (**TABLE 1**).

The participants in the STP group reported a mean duration of symptoms of 26.4 weeks (range, 4-104 weeks) and median of 16 weeks. The mean duration of symptoms was largely influenced by 2 participants with a longer duration of symptoms. Pain intensity, measured with an 11-point numeric pain rating scale on which 0 was no pain and 10 was maximum pain, ranged from 2 to 7.

The reliability of strength measurements and strength ratio data, as determined with ICCs, ranged from 0.92 to

0.98 and from 0.66 to 0.87, respectively. Strength data for the 3 groups of participants are presented in **TABLE 2**. Strength ratio data are presented in **TABLE 3**.

Strength

The strength values for the LT ($P < .001$) and wrist extension ($P = .004$) were significantly different among groups. Post hoc analyses indicated that LT strength was significantly greater in the NSTP group when compared with the STP and control groups. Wrist extension strength was significantly greater in the NSTP and control groups when compared to the STP group. No significant difference was found among the 3 groups for the strength of the shoulder internal and external rotators, shoulder abductors, UT, elbow flexors and extensors, and wrist flexors.

Strength Ratios

A significant difference was found among the groups for shoulder IR/ER ($P = .01$), UT/LT ($P = .03$), and wrist flexion/extension ($P = .02$) strength ratios (**TABLE 3**). Post hoc analysis indicated that the shoulder IR/ER strength ratio was higher in the STP group compared to the NSTP and control groups. The UT/LT strength ratio was greater in the STP group compared to the NSTP group, but was not significantly different from the control group. The wrist flexion/extension strength ratio was significantly greater in the STP group compared to the control group (mean difference, 0.14; 95% confidence interval [CI]: 0.01, 0.27), but not when compared to the NSTP group (0.13; 95% CI: -0.01, 0.26). No significant difference was found among the 3 groups for shoulder abduction/ER and elbow flexion/extension strength ratios.

DISCUSSION

THE CURRENT STUDY DEMONSTRATED that the women in the STP group had weakness of their wrist extensors, compared to the NSTP group and a control group of non-tennis players, and of their LT compared to the NSTP

Variable	STP (n = 21)	NSTP (n = 21)	Controls (n = 21)
Age, y	44.9 ± 5.2 (35-55)	46.8 ± 9.9 (20-63)	43.0 ± 8.4 (23-55)
Mass, kg	63.6 ± 9.2 (43.1-83.9)	65.5 ± 7.8 (54.4-86.2)	66.0 ± 12.2 (51.7-99.8)
Height, cm	163.7 ± 6.3 (156.8-176.5)	165.5 ± 6.6 (157.5-180.3)	168.6 ± 6.8 (157.5-180.3)
BMI, kg/m ²	23.7 ± 3.0 (16.3-29.6)	23.9 ± 2.9 (19.0-30.7)	23.2 ± 3.6 (19.5-32.5)
Days per week of tennis play, d	2.5 ± 0.7 (2-4)	2.4 ± 0.7 (2-4)	N/A
Hours per day of tennis play, h	1.9 ± 0.5 (1-3)	2.0 ± 0.3 (1-3)	N/A
Years of play, y	9.0 ± 7.5 (2-30)	13.5 ± 12.7 (2-43)	N/A
Intermediate player, %	71.4	76.2	N/A

Abbreviations: BMI, body mass index; N/A, not applicable; NSTP, nonsymptomatic tennis players; STP, symptomatic tennis players.
**Values are mean ± SD (range) unless otherwise indicated. No statistically significant differences were found among groups ($P > .05$).*

group. The data also revealed significant differences in muscle strength ratios for the scapular musculature, shoulder rotators, and wrist musculature of the female tennis players who had symptoms of lateral epicondylalgia compared to the 2 other groups. Although this study reported a potential association between these findings and lateral elbow pain in this population, it cannot establish a causal relationship, as these differences may be the result as much as the cause of the injury. Either way, the findings may have implications for rehabilitation of this population.

Scapular Musculature

The STP group had a significantly higher UT/LT strength ratio than the NSTP group. This higher ratio indicates a relatively greater strength of the UT when compared to the LT. This difference in strength appears to be consistent with results of previous motion analysis and dynamic studies on subjects with shoulder pathology and, specifically, impingement syndrome.^{7,9,22,24,27} To our knowledge, this is the first time significant weakness of the LT has been studied or identified in individuals with symptoms of lateral epicondylalgia.

Biomechanically, the dynamic stabilizers of the scapula provide a stable platform for the arm throughout its arc of

motion to allow a powerful tennis stroke. These dynamic stabilizers contribute to positioning of the scapula for optimal force production at the shoulder, and the lack of a stable anchor for the rotator cuff muscles seems to adversely affect their function, especially when the arm is elevated.¹⁶ Scapular movement alterations have been associated with shoulder pathology²⁵ and may affect the function of the distal musculature of the upper extremity during the tennis stroke, leading to overuse injury involving the wrist extensors. A rehabilitation protocol that addresses the scapular musculature, with exercises to correct this apparent muscular imbalance, may be needed in this population.^{8,29,34}

Shoulder Rotation

The investigators of the present study suspected that weakness of the shoulder external rotators would result in compensatory overuse of the wrist extensors, potentially leading to lateral epicondylalgia. However, the data did not support this premise. When calculated as a ratio of IR/ER strength, the STP group demonstrated an IR/ER ratio significantly higher than that of the other 2 groups. The ratio of IR/ER strength has been shown to normally vary among people and different athletic groups.⁶ It is possible that the relative strength difference between

TABLE 2

MUSCLE STRENGTH OUTCOMES AND DIFFERENCES BETWEEN GROUPS

Muscles Measured	STP (n = 21)*	NSTP (n = 21)*	Control (n = 21)*	Difference, STP and NSTP [†]	Difference, STP and Control [†]	Difference, NSTP and Control [†]
Shoulder IR	88.0 ± 18.7 (53.5-118.6)	87.0 ± 18.8 (55.7-118.8)	83.3 ± 19.5 (46.0-116.5)	1.0 (-13.5, 15.4)	4.6 (-9.8, 19.1)	3.7 (-10.8, 18.1)
Shoulder ER	67.0 ± 11.8 (42.1-83.5)	75.3 ± 12.4 (56.2-99.2)	74.0 ± 15.1 (42.1-104.2)	-8.3 (-18.3, 1.7)	-7.0 (-17.0, 3.0)	1.3 (-8.7, 11.3)
Shoulder AB	78.9 ± 21.5 (43.4-121.3)	87.6 ± 21.3 (46.6-119.7)	81.5 ± 20.0 (50.6-122.7)	-8.8 (-24.7, 7.1)	-2.7 (-18.6, 13.2)	6.1 (-9.8, 22.0)
Upper trapezius	165.9 ± 23.8 (129.6-223.6)	177.0 ± 25.3 (142.1-226.9)	159.5 ± 23.2 (120.2-219.7)	-11.1 (-29.4, 7.3)	6.4 (-11.9, 24.7)	17.5 (-0.8, 35.8)
Wrist F	64.2 ± 7.9 (45.2-78.3)	71.4 ± 11.3 (42.3-89.1)	74.6 ± 20.8 (43.4-137.4)	-7.2 (-18.2, 3.8)	-10.4 (-21.4, 0.5)	-3.2 (-14.2, 7.7)
Wrist E	52.9 ± 10.8 (36.7-78.1)	65.6 ± 15.1 (39.9-97.9)	68.1 ± 19.0 (38.2-102.6)	-12.7 (-24.4, -1.1) [‡]	-15.2 (-26.9, -3.6) [‡]	-2.5 (-14.1, 9.2)
Lower trapezius	27.8 ± 6.4 (12.7-42.8)	36.8 ± 7.5 (22.1-49.4)	29.7 ± 3.9 (22.8-38.7)	-9.0 (-13.5, -4.4) [‡]	-1.9 (-6.5, 2.7)	7.1 (2.4, 11.7) [‡]
Elbow F	138.4 ± 20.9 (103.2-173.0)	148.6 ± 29.2 (101.0-195.3)	134.3 ± 28.6 (80.5-176.1)	-10.2 (-30.3, 10.0)	4.1 (-16.1, 24.2)	14.2 (-5.9, 34.4)
Elbow E	95.4 ± 13.2 (70.9-118.2)	93.3 ± 21.4 (65.1-136.9)	88.8 ± 19.8 (53.8-129.7)	2.1 (-11.9, 16.2)	6.6 (-7.4, 20.7)	4.5 (-9.5, 18.6)

Abbreviations: AB, abductors; E, extensors; ER, external rotators; F, flexors; IR, internal rotators; NSTP, nonsymptomatic tennis players; STP, symptomatic tennis players.

*Values are mean ± SD (range) N.

[†]Values are mean (95% confidence interval).

[‡]Significant difference between groups (P < .05).

TABLE 3

MUSCLE STRENGTH RATIOS AND DIFFERENCES BETWEEN GROUPS

Muscle Strength Ratios	STP (n = 21)*	NSTP (n = 21)*	Control (n = 21)*	Difference, STP and NSTP [†]	Difference, STP and Control [†]	Difference, NSTP and Control [†]
IR/ER	1.34 ± 0.31 (0.82-2.04)	1.15 ± 0.15 (0.94-1.50)	1.13 ± 0.18 (0.84-1.60)	0.19 (0.02, 0.35) [‡]	0.21 (0.04, 0.38) [‡]	0.02 (-0.15, 0.19)
UT/LT	6.27 ± 1.60 (3.78-10.16)	4.95 ± 0.97 (3.82-7.57)	5.40 ± 0.64 (4.38-6.68)	1.32 (0.41, 2.23) [‡]	0.87 (-0.02, 1.77)	-0.44 (-1.34, 0.45)
AB/ER	1.18 ± 0.28 (0.66-1.87)	1.17 ± 0.28 (0.72-1.65)	1.12 ± 0.26 (0.73-1.81)	0.01 (-0.20, 0.22)	0.06 (-0.15, 0.27)	0.05 (-0.16, 0.26)
Elbow F/E	1.46 ± 0.27 (0.90-1.92)	1.60 ± 0.21 (1.32-2.07)	1.53 ± 0.18 (1.18-1.85)	-0.14 (-0.31, 0.03)	-0.07 (-0.24, 0.10)	0.07 (-0.10, 0.24)
Wrist F/E	1.24 ± 0.20 (0.76-1.60)	1.11 ± 0.17 (0.79-1.36)	1.11 ± 0.14 (0.91-1.34)	0.13 (-0.01, 0.26)	0.14 (0.01, 0.27) [‡]	0.01 (-0.12, 0.14)

Abbreviations: AB, abductors; E, extensors; ER, external rotators; F, flexors; IR, internal rotators; LT, lower trapezius; NSTP, nonsymptomatic tennis players; STP, symptomatic tennis players; UT, upper trapezius.

*Values are mean ± SD (range).

[†]Values are mean (95% confidence interval).

[‡]Significant difference between groups, (P < .05).

the shoulder rotators may impact the ability of tennis players to dynamically control the tennis stroke and result in subtle compensatory strategies distally.

Elbow

The strength of elbow flexors was greater than the elbow extensors in all 3 groups studied and was consistent with normative values.⁴ No significant differences in elbow flexion or extension strength or elbow flexion/extension strength ratio were evident among the 3 groups of women in this study. This is a noteworthy finding, given the strength differences in muscle groups proximal to the elbow.

Wrist

In our study, the average strength of the wrist flexors was slightly greater than that of the wrist extensors in all 3 groups. In contrast, Bohannon⁵ found slightly less wrist flexor strength as compared to wrist extensor strength in healthy women. The STP group had a significantly greater wrist flexion/extension strength ratio (mean difference, 0.14; 95% CI: 0.01, 0.27) than that of the control group but not the NSTP group (mean difference, 0.13; 95% CI: -0.01, 0.26). The relative weakness of the wrist extensors may result in a relatively flexed wrist posture during various tennis strokes, thus mak-

ing the wrist extensors vulnerable to injury.³ Strength balance between the wrist flexors and extensors may be protective against repetitive trauma of the common extensor insertion in tennis players.

Pain

Most symptomatic players (61.9%) had a symptom duration of 6 to 20 weeks and could be considered to be in a subacute stage. Only 2 participants (9.5%) presented within the first 5 weeks of symptom onset. Most symptomatic subjects (85.8%) reported pain intensity that ranged from 2/10 to 4/10 on a numeric pain rating scale and were still actively

playing tennis at the time of the study. Kelley et al¹⁷ proposed that when using subjects who are not acutely symptomatic, more information could be gathered in regard to the pathomechanics that likely produced the stresses leading to injury. The 6 (28.6%) symptomatic tennis players with a more chronic (6 months or more) presentation of symptoms could have been characterized by long-term sequelae of pathology at the elbow. This study would have been strengthened by a more homogeneous sample of individuals with lateral elbow pain symptoms of between 6 and 20 weeks in duration, thus isolating a more specific subgroup of players with subacute symptoms. Because wrist strength was assessed with the elbow in a flexed position and other strength measures were taken proximal to the wrist joint, we do not believe that pain negatively impacted the strength measurements in the symptomatic group.

Limitations of the Current Study

The purposive sampling technique used in the present study might have had some inherent internal validity problems, such that an inadvertent volunteer bias could have affected the results. Efforts were made to include a sample size sufficient to represent typical variations in the population of recreational tennis players. The examiner who performed all the measurements of muscle force was not blinded to group assignment, which could have led to examiner bias; however, that a single examiner was used for all testing likely improved the reliability of the measurements.

During the performance of HHD testing, the force measured is directly related to the point of application of the dynamometer. Upper extremity length was not measured in this investigation; however, because there were no significant height differences among the 3 groups, it is assumed that their upper extremity dimensions were similar. Strength ratio data are not affected by a lack of knowledge of upper extremity anthropometry. All strength measures were performed in fixed con-

secutive order rather than in random order. This lack of randomization could have affected the strength ratio values but not the comparisons among groups. Measurements of strength ratios were less reliable than measurements of absolute strength values; therefore, one should use strength ratio data cautiously when making treatment-related decisions.^{21,23}

CONCLUSION

THE RELATIVE WEAKNESS OF THE LT and wrist extensors may be an important factor to identify and address in tennis players with lateral elbow pain. The identified muscle strength imbalances of the shoulder rotators and wrist musculature may result in subtle disruptions in normal movement patterns, making the wrist extensors more vulnerable to injury. ●

KEY POINTS

FINDINGS: Recreational female tennis players with symptoms of lateral epicondylalgia demonstrated significant weakness of the LT and wrist extensors compared to asymptomatic players and individuals in a control group. The symptomatic players also exhibited greater strength ratios for shoulder IR/ER, UT/LT, and wrist flexion/extension.

IMPLICATIONS: Shoulder and wrist muscle strength deficits should be considered in the management of female recreational tennis players with lateral elbow pain.

CAUTION: This was a cross-sectional study of a small group of female recreational tennis players; therefore, the data do not indicate a causal relationship between the factors identified in this sample and lateral epicondylalgia.

REFERENCES

1. 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>

2. Bisset L, Paungmali A, Vicenzino B, Beller E. A systematic review and meta-analysis of clinical trials on physical interventions for lateral epicondylalgia. *Br J Sports Med.* 2005;39:411-422. <http://dx.doi.org/10.1136/bjsm.2004.016170>
3. Bisset LM, Russell T, Bradley S, Ha B, Vicenzino BT. Bilateral sensorimotor abnormalities in unilateral lateral epicondylalgia. *Arch Phys Med Rehabil.* 2006;87:490-495. <http://dx.doi.org/10.1016/j.apmr.2005.11.029>
4. Bohannon RW. Reference values for extremity muscle strength obtained by hand-held dynamometry from adults aged 20 to 79 years. *Arch Phys Med Rehabil.* 1997;78:26-32.
5. Bohannon RW. Upper extremity strength and strength relationships among young women. *J Orthop Sports Phys Ther.* 1986;8:128-133.
6. Codine P, Bernard PL, Pocholle M, Benaim C, Brun V. Influence of sports discipline on shoulder rotator cuff balance. *Med Sci Sports Exerc.* 1997;29:1400-1405.
7. Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scand J Med Sci Sports.* 2007;17:25-33. <http://dx.doi.org/10.1111/j.1600-0838.2006.00570.x>
8. 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/10.1177/0363546507303560>
9. Cools AM, Witvrouw EE, Mahieu NN, Danneels LA. Isokinetic scapular muscle performance in overhead athletes with and without impingement symptoms. *J Athl Train.* 2005;40:104-110.
10. Coombes BK, Bisset L, Vicenzino B. Elbow flexor and extensor muscle weakness in lateral epicondylalgia. *Br J Sports Med.* 2012;46:449-453. <http://dx.doi.org/10.1136/bjsm.2011.083949>
11. De Smet L, Fabry G. Grip force reduction in patients with tennis elbow: influence of elbow position. *J Hand Ther.* 1997;10:229-231.
12. Dorf ER, Chhabra AB, Golish SR, McGinty JL, Pannunzio ME. Effect of elbow position on grip strength in the evaluation of lateral epicondylitis. *J Hand Surg Am.* 2007;32:882-886. <http://dx.doi.org/10.1016/j.jhsa.2007.04.010>
13. Ellenbecker TS. Rehabilitation of shoulder and elbow injuries in tennis players. *Clin Sports Med.* 1995;14:87-110.
14. Harrington JM, Carter JT, Birrell L, Gompertz D. Surveillance case definitions for work related upper limb pain syndromes. *Occup Environ Med.* 1998;55:264-271.
15. Hume PA, Reid D, Edwards T. Epicondylar injury in sport: epidemiology, type, mechanisms, assessment, management and prevention. *Sports Med.* 2006;36:151-170.
16. Jobe FW, Kvitne RS, Giangarra CE. Shoulder pain in the overhead or throwing athlete. The relationship of anterior instability and rotator cuff impingement. *Orthop Rev.* 1989;18:963-975.
17. Kelley JD, Lombardo SJ, Pink M, Perry J,

Giangarra CE. Electromyographic and cinematographic analysis of elbow function in tennis players with lateral epicondylitis. *Am J Sports Med.* 1994;22:359-363.

18. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26:325-337.
19. Kolber MJ, Beekhuizen K, Cheng MS, Fiebert IM. The reliability of hand-held dynamometry in measuring isometric strength of the shoulder internal and external rotator musculature using a stabilization device. *Physiother Theory Pract.* 2007;23:119-124. <http://dx.doi.org/10.1080/09593980701213032>
20. Kolber MJ, Beekhuizen KS, Cheng MS, Hellman MA. Shoulder joint and muscle characteristics in the recreational weight training population. *J Strength Cond Res.* 2009;23:148-157. <http://dx.doi.org/10.1519/JSC.0b013e31818eafb4>
21. Kramer JF, Ng LR. Static and dynamic strength of the shoulder rotators in healthy, 45- to 75-year-old men and women. *J Orthop Sports Phys Ther.* 1996;24:11-18.
22. Laudner KG, Myers JB, Pasquale MR, Bradley JP, Lephart SM. Scapular dysfunction in throwers with pathologic internal impingement. *J Orthop Sports Phys Ther.* 2006;36:485-494. <http://dx.doi.org/10.2519/jospt.2006.2146>
23. Liu Y, Schutz RW. Statistical validity of using ratio variables in human kinetics research. *Res Q Exerc Sport.* 2003;74:226-235.
24. Ludewig PM, Cook TM. Alterations in shoulder

kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther.* 2000;80:276-291.

25. Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther.* 2009;39:90-104. <http://dx.doi.org/10.2519/jospt.2009.2808>
26. Maffulli N, Wong J, Almekinders LC. Types and epidemiology of tendinopathy. *Clin Sports Med.* 2003;22:675-692.
27. McClure PW, Michener LA, Karduna AR. Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Phys Ther.* 2006;86:1075-1090.
28. O'Driscoll SW, Spinner RJ, McKee MD, et al. Tardy posterolateral rotatory instability of the elbow due to cubitus varus. *J Bone Joint Surg Am.* 2001;83-A:1358-1369.
29. Oyama S, Myers JB, Wassinger CA, Lephart SM. Three-dimensional scapular and clavicular kinematics and scapular muscle activity during retraction exercises. *J Orthop Sports Phys Ther.* 2010;40:169-179. <http://dx.doi.org/10.2519/jospt.2010.3018>
30. Petersen SM, Wyatt SN. Lower trapezius muscle strength in individuals with unilateral neck pain. *J Orthop Sports Phys Ther.* 2011;41:260-265. <http://dx.doi.org/10.2519/jospt.2011.3503>
31. Pienimäki T, Siira P, Vanharanta H. Muscle function of the hand, wrist and forearm in chronic

lateral epicondylitis. *Eur J Phys Med Rehabil.* 1997;7:171-178.

32. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice.* 2nd ed. Upper Saddle River, NJ: Prentice Hall Health; 2000.
33. Regan W, Lapner PC. Prospective evaluation of two diagnostic apprehension signs for posterolateral instability of the elbow. *J Shoulder Elbow Surg.* 2006;15:344-346. <http://dx.doi.org/10.1016/j.jse.2005.03.009>
34. Reinold MM, Escamilla RF, Wilk KE. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther.* 2009;39:105-117. <http://dx.doi.org/10.2519/jospt.2009.2835>
35. Sandmark H, Nisell R. Validity of five common manual neck pain provoking tests. *Scand J Rehabil Med.* 1995;27:131-136.
36. Stanley J. Radial tunnel syndrome: a surgeon's perspective. *J Hand Ther.* 2006;19:180-184. <http://dx.doi.org/10.1197/j.jht.2006.02.005>
37. Walker-Bone KE, Palmer KT, Reading I, Cooper C. Criteria for assessing pain and nonarticular soft-tissue rheumatic disorders of the neck and upper limb. *Semin Arthritis Rheum.* 2003;33:168-184.



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