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# Arm proprioception in lateral epicondylalgia; a cross-sectional study

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## Abstract

**Introduction:** Lateral epicondylalgia is one of the most common injuries due to overuse with inflammation of the elbow on the lateral epicondyle. Although the clinical features of this disorder are well defined, few therapeutic intervention has been effective.
**Objectives:** This study aimed to investigate the proprioception in the upper limb of patients with lateral epicondylalgia, using the sense of joint position and of force reproduction tests.
**Participants and Methods:** Twenty patients with unilateral lateral epicondylalgia and 20 healthy subjects participated in this study. The evaluation of position sense of shoulder, elbow and wrist, and force reproduction sense of shoulder abductor, elbow flexor and wrist extensor were conducted. The proprioceptive performance was determined, using absolute, constant and variable error values.
**Results:** Significant differences were found for the sense of the position of the elbow and wrist between the lateral epicondylalgia and control groups for the variables of absolute error ($P=0.003$ and $P=0.02$, respectively) and constant error ($P=0.001$, $P=0.03$, respectively). A significant difference was also observed for the sense of force of the elbow flexor and wrist extensor between the two groups for the variables of absolute error ($P=0.02$ and $P=0.02$, respectively) and constant error ($P=0.016$ and $P=0.001$, respectively). No statistical difference was found for variable errors neither in sense of position nor sense of force ($P>0.05$).
**Conclusion:** The data confirmed the hypothesis of proprioception deficits in subjects with lateral epicondylalgia, compared to the healthy subjects during the evaluation of the sense of force and position.

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## Introduction

Lateral epicondylalgia, also known as "lateral epicondylitis" or "Tennis Elbow", is the most common chronic cumulative trauma disorder with inflammation affecting the outer side of the elbow and is often resistant to treatment (1). This condition not only decreases the grip strength, but has the potential to cause extended sick leaves and loss of work time and income (2). This injury causes the longest leave time for manual workers, in which 17% of workers in industries who need intermittent manual labor, experience the disorder(3). Forty percent of people will experience lateral epicondylalgia in various forms in their lives (4).

Contrary to its historical title (tennis elbow), only 5% of the patients participate in tennis or racket sports. However, the rest appear to have developed the conditions due to excessive strain type trauma on the elbow's musculotendinous complex and repetitive use of the forearm muscles, such as throwing activities, housekeeping and other manual tasks at home or work which causes inflammation and pain(5). The condition is usually self-limiting; however, symptoms may last longer in some patients (6).

These patients present with chronic pain which may be due to previous stressful events that cause lasting changes in nociceptor function(7). Positron emission tomography shows peripherally increased neurokinin 1 receptor activation or upregulation in chronic lateral epicondylalgia(8). Sustained increase of cytokines and chemokines play

### Key point

Our data corroborate the hypothesis that there is a proprioceptive deficit in subjects with lateral epicondylalgia as a result of pain and inflammation, in comparison with healthy subjects. Patients with lateral epicondylalgia usually exert 5 to 10 percent more force than they need to reproduce a certain force. This must be taken into the account during the rehabilitation process.

an important role in inducing hyperalgesia and promote chronic widespread pain that affects different body sites such as shoulder, elbow, and wrist (9).

For these patients, anti-inflammatory modalities of physiotherapy, such as shock wave, laser therapy, acupuncture, eccentric strengthening exercise, bracing, and behavioral modification have been applied (10). Evaluation of various physiotherapy interventions conducted in this disorder has resulted in the opinion that existing literature does not provide conclusive evidence (9). However, studies show that most of these patients continue to have problems with movement control even after treatment, which may get aggravated and lead to the recurrence of the symptoms or need surgical intervention in the future (11). Therefore, before planning for rehabilitation or surgery, the patient should be examined thoroughly.

With the advancement in motor control and neuroscience, researchers have observed that as a result of existing pain and inflammation, these patients have central hypersensitivity, reduced reaction speed, reduced accuracy of postural functions, and increased functional errors (12). Therefore, it can be considered that the source of the problem is not only local, but also the cause should be sought in the lack of motor control, sensorimotor deficits and neuromusculoskeletal involvement, predisposing the patient to problem or aggravation of the previous condition.

The role of proprioception in sensorimotor control can be explained from various perspectives. To execute a motor command correctly, the central nervous system needs an updated biomechanical assessment of most if not all parts of the body. In addition, having efficient and normal proprioception is necessary for comparing the work which is actually conducted with what was required to be done (13). As a result, efficient proprioception is essential for all daily activities. On the other hand, various factors, such as pain, inflammation, trauma, and fatigue can cause proprioceptive disorder, all of these factors are seen in varying degrees in this disorder (14).

Despite the importance of proprioception in upper extremity disorders, few studies were conducted on lateral epicondylalgia. In a study conducted by Juul-Kristensen and colleagues in patients with lateral epicondylitis, they only examined the sense of position, while considering the importance of force and the nature of the inflammatory process in muscles. In this context, it seems equally or even more important to examine the sense of force in tendinopathy cases. Moreover, in recent studies, most studies have dealt with upper limb muscle imbalance and central sensitization. Equally importantly, it is necessary to study the aspects of the proprioception in the entire upper limb of patients when designing future treatments (15).

## Objectives

This study aimed to investigate whether patients with lateral epicondylalgia have diminished senses of upper limb position and force.

## Patients and Methods

### *Study design and participants*

A cross-sectional study design was carried out to evaluate the upper limb proprioception. *Each* individual in this study *gave* a written *informed consent prior to* their participation. Participants underwent upper limb proprioception assessments on a single day. Furthermore, information on age, gender, height, weight and patient-rated tennis elbow evaluation were obtained from each patient. The patients were recruited through referrals from medical centers and physiotherapy clinics. The lateral epicondylalgia (LE) group consisted of twenty patients (9 women and 11 men), all were clinically diagnosed with lateral epicondylalgia at the time of their participation in a single musculoskeletal clinic. The control group (C) consists of healthy subjects who were university students or employees (9 women and 11 men) with no history of upper limb musculoskeletal conditions. The inclusion criteria for patients were: (a) clinical diagnosis of chronic lateral epicondylalgia (persistent or recurrent localized pain and muscle weakness not responding to conservative measures) , and (b) a pain score of ≥3 on a visual analog scale, caused by at least two of the following tests; 1) lateral epicondyle palpation; 2) wrist extension with resistance; 3) resisted extension of the middle finger; and 4) a chair test, in which the participants were asked to lift a chair weighing 3.5 kg.

The exclusion criteria were: (a) age below 18 years; (b) inflammatory or cancerous disorders; (c) concomitant disease of the upper limb; (d) cervical radiculopathy or thoracic outlet syndrome; (e) a history of fracture or dislocation at the elbow; (f) a history of elbow surgery; (g) corticosteroid injections within the last six months; and (h) inability to complete the procedure**.** In all patients, the dominant side was involved.

The control group consisted of healthy subjects with no pain, discomfort, and functional limitation in the upper limb during the previous six months and no history of significant musculoskeletal disorders.

### *Study protocol*

The upper limb proprioception was evaluated by assessing the sense of force for shoulder abductor, elbow flexor and wrist extensor, and joint position sense for (shoulder, elbow, and wrist in a series of *predetermined* tests. To prevent fatigue and disturbance in the upper limb proprioception due to forceful tests, the sense of position was assessed first.

Position sense was tested during these movements for assessing a sub-modality of proprioception, measured with a Vicon motion capture system (VICON©, Oxford Metrics ltd., Oxford, UK). A series of reflex passive markers were affixed on principal anatomical landmarks

of the upper extremity (right and left shoulder, right upper arm, right elbow, right forearm, right wrist marker B, right wrist marker A, and 3rd metacarpal) according to the Vicon Plug-In-upper extremity model and a previous study (Figure 1) (16).

To test the acuity of position sense at shoulder, elbow, and wrist, subjects were asked to move their dominant upper limb to the target angles including; 30° extension of the wrist, 60° flexions of the elbow and 120° abduction of the shoulder in random order in standing position with eyes open and hold the joint in that position for five seconds and exercise three times with a 5-second rest between trials. The subjects then went back to the starting position and replicated the same angles with their eyes close, while ensuring their trunk and other parts of the body did not move and the motion was from the testing joint (Figure 2). These motions are the most common movements of the upper limb during daily activities. The instructions for conducting the proprioception tests were fixed to ensure all participants received the same instructions. The difference between the three reproduced and the target angle was taken as the measure of position sense error.

The force reconstruction method was used for assessing the force sense in the upper limb (i.e., wrist extensors, elbow flexors, shoulder abductors), which was measured using a load cell Zemic model H3-C3/C4-100kg-3B (Zemic, the Netherlands) (Figure 3). In order to evaluate the sense of force for the shoulder abductor, elbow flexor and wrist extensor muscles, each participant was first asked to produce the maximum voluntary contraction without pain in the desired muscle at the predetermined position for five seconds. Then the examiner calculated 50% of the maximal voluntary isometric contraction as the target force and exercised with eyes open while monitoring the amount of force. The target force was reproduced after giving clear verbal instructions, the person was asked to close eyes, then push on the arm of machine and reproduce the target force and when reached the target force, the subject would inform the researcher while keeping it for five seconds. The amount of reproduced force on three trials were then recorded. Three force reproduction attempts were conducted for each of the predetermined muscles; wrist extensors, elbow flexors, shoulder abductors. The subject was allowed to rest for 5 seconds between each attempt and 1 minute between each of the muscle force reproduction tests.

The results of the reliability and validity tests on the pilot study showed that the validity and reliability of this measuring method were successfully obtained and the procedure was reliable. The mean absolute error (mean absolute difference between target and reproduction force and joint angle) for accuracy was recorded. To assess the direction of bias, the constant error was also calculated as the mean difference between the target and the reproduction measure. The variable error is the standard deviation of the individual errors, which determines the consistency of the reproductions performed, were calculated.

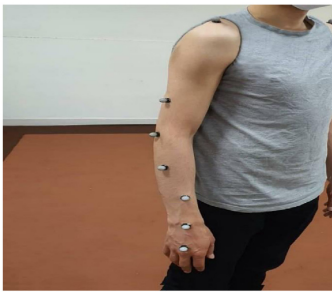

**Figure 1.** Reflective marker placement for assessing joint position sense.


**Figure 2**. Sense of position assessment: (a) right wrist, (b) right elbow, (c) right shoulder.

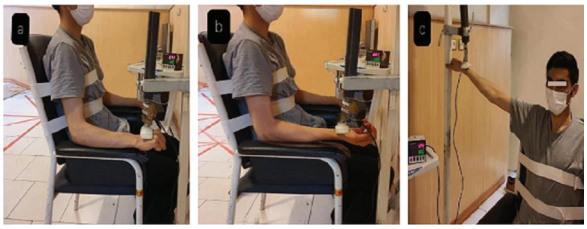


**Figure 3**. Sense of force assessment: (a) right wrist in pronated position, (b) right elbow in supinated position, (c) right shoulder in abduction.

### *Statistical analysis*

The sample size determination indicated that a minimum sample size of 14 subjects per group (i.e., lateral epicondylalgia and control groups) was required to observe at least one degree of difference in position sense between the patients and the age-matched untrained controls, with the power of 0.8 and a significance level of 0.05. Shapiro-Wilk and Levene's tests were conducted to check the normal distribution and the homogeneity of variance, respectively. Group comparisons were carried out based on the findings for the anthropometric and proprioception sense, using the unpaired t-tests. The level of significance was set at $\alpha = 0.05$ for all the tests. Statistical analyses were performed using SPSS software version 20 (IBM, Armonk, NY, USA).

## Results

The results of this study show that the mean age of the participants in the control and lateral epicondylalgia groups were 32.1 ± 7.04 years and 33.7 ± 7.64 years, respectively. In addition, the means of body mass index (BMI) were 26.49 ± 4.75 kg/m$^2$ and 25.20 ± 5.76 kg/m$^2$, respectively (Table 1).

The upper limb sense of position was compared between the two groups. Table 2 shows the mean and standard deviation of each error. Statistically significant differences were observed in the following variables representing joint position sense; absolute and constant error of elbow flexion and absolute and constant error of wrist extension. There were no significant difference in absolute and constant error of shoulder joint position sense between the two groups. There was no difference regarding variable error in any of the joints.

The upper limb sense of force was compared between the two groups. Table 3 shows the mean and standard deviation of each error. Statistically significant differences were observed in the following variables for the sense of force: absolute and constant error of elbow flexor, absolute and constant error of wrist extensor ($P < 0.05$). There was no significant differences in absolute and constant error of shoulder abductor muscles sense of force between the two groups. There was no difference in variable error in any of the muscles.

## Discussion

Proprioception is defined as the perception of the position of the joints and the movement of the body in space (17). Accurate proprioception informs the person of the body's position in the space and ultimately regulates the functions of the locomotor system and ensures its health. This sensation causes neuromuscular planning to perform and control movements as well as proper motor function and ultimately provides sufficient motion stability (18). Numerous factors such as inflammation, pain and fatigue which are evident in lateral epicondylalgia can lead to a deficiency of this sensation. Cudejko et al showed that deficits in proprioception may be a key point through which systemic inflammation is associated with muscle impairment (19).

Sense of force, which is a sub-modality of proprioception and also known as sense of heaviness, effort, and tension or the force matching sense, is an important part of locomotor health and acuity. Performance of overuse tasks similar to tennis elbow was associated with increased fibro genic-related proteins in forearm muscles and decline of grip force (20). In activities of daily living, Defects in the reproduction of the force and inability to estimate the correct amount of force and position may predispose a person to increase inflammation, future injuries in adjacent areas as well as frequent recurrence of the disorder. Proprioception disturbances lead to mechanical instability and predispose the body to musculoskeletal disorders, such as tendinopathy (21).

Error, as the main variable of motion control studies, is defined as the difference between the observed value and the true value. The results of this study indicate

**Table 1**. Demographic characteristics of participants

| | Control group (n=20)<br>Mean ± SD | LE (n=20)<br>Mean ± SD |
|---|---|---|
| Age (y) | 32.1 ± 7.04 | 33.7 ± 7.64 |
| Body mass (kg) | 75.7 ± 15.79 | 71.05 ± 12.67 |
| Height (cm) | 168.75 ± 9.43 | 169.10 ± 10.05 |
| Body mass index (kg/m$^2$) | 26.49 ± 4.75 | 25.20 ± 5.76 |
| Patient rated tennis elbow evaluation questionnaire | 0 | 44.60 ± 10.94 |
| Duration of disease (months) | 0 | 15.7 ± 6.79 |

LE: Lateral epicondilalgia.

**Table 2.** SOP errors of the shoulder, elbow and wrist in lateral epicondilalgia and control groups

| | Group | AE (degree)<br>Mean ± SD | *P* value | CE (degree)<br>Mean ± SD | *P* value | VE (degree)<br>Mean ± SD | *P* value |
|---|---|---|---|---|---|---|---|
| Shoulder abduction | Control | 3.78±0.87 | 0.161 | 2.38±1.04 | 0.088 | 3.36±0.86 | 0.575 |
| | LE | 4.33±1.48 | | 3.23±1.89 | | 3.15±1.44 | |
| Elbow flexion | Control | 1.27±0.85 | 0.003* | 0.4±1.30 | 0.001** | 0.99 ±0.60 | 0.555 |
| | LE | 2.23 ± 1.03 | | 1.93±1.17 | | 1.15± 1.01 | |
| Wrist extension | Control | 2.53±1.08 | 0.02* | 2.1±1.34 | 0.03* | 2.06±1.02 | 0.922 |
| | LE | 3.33 ± 1.10 | | 3.00 ± 1.20 | | 2.09 ± 1.03 | |

SOP; sense of position, LE; Lateral epicondilalgia, AE; absolute error, CE; constant error, VE; variable error.

* Indicates a significant difference between the LE and control groups ($P<0.05$).

** Indicates a significant difference between the LE and control groups ($P<0.001$).

**Table 3.** SOF errors of the shoulder abductors, elbow flexors and wrist extensors in LE and control groups

| | Group | Absolute errors (kg) Mean ± SD | *P* value | Constant errors (kg) Mean ± SD | *P* value | Variable errors (kg) Mean ± SD | *P* value |
|---|---|---|---|---|---|---|---|
| Shoulder abduction | Control | 2.78±2.36 | 0.17 | -1.24±2.72 | 0.072 | 2.46±1.34 | 0.46 |
| | LE | 3.84±2.50 | | -2.95±3.12 | | 2.16±1.22 | |
| Elbow flexion | Control | 1.53±0.92 | 0.02* | -.56±1.36 | 0.016* | 1.29±0.76 | 0.272 |
| | LE | 2.15±0.65 | | 0.74±1.86 | | 1.53±0.59 | |
| Wrist extension | Control | 1.10±0.58 | 0.02* | -0.53±1.01 | 0.001** | 0.94±041 | 0.07 |
| | LE | 1.54±0.59 | | 0.73±1.22 | | 1.20±0.48 | |

SOF; sense of force, LE; Lateral epicondilalgia, AE; absolute error, CE; constant error, VE; variable error.

* Indicates a significant difference between the LE and control groups ($P<0.05$).

** Indicates a significant difference between the LE and control groups ($P<0.001$).

that patients with lateral epicondylalgia suffer from impairment in various dimensions of the upper extremity proprioception. As presented in the results section, the limb with the affected elbow generally demonstrated higher values of absolute and constant errors (worse values) in elbow joint, compared with the healthy subjects. The results of absolute error demonstrated that the injured limb cannot accurately reproducing the force in the elbow and the constant error results demonstrated that the injured limb overestimated the target force. These patients suffer from control impairment and typically exert 5-10% greater force than they need to reproduce the target force and overshoot the target.

Proprioceptive dysfunction is not limited to the area involved in the elbow, but also a decrease in the senses of force and position was observed in other parts of the upper limb. In these patients, the absolute and constant errors of the senses of position and force in the shoulder and wrist were greater than those in the healthy subjects and the difference in the wrist was significant. The variable errors in the senses of position and force in either shoulder, elbow or wrist did not show a significant difference between people with lateral epicondylalgia and the healthy participants. This means that regardless of the presence or absence of the injury, individuals show the same consistency on the force and angle reproduction tests. Variable error values are not commonly conducted in the literature, which negates the comparison of the results.

Accuracy is how close to the actual value a given measurement is and precision is how well several independent measurements agree with one another (22). In general, patients with lateral epicondylalgia who were studied had low accuracy and near normal variability, suggesting that they suffered from systematic error and their locomotor system appeared biased. This systematic error, as we observed in the variable error results, is reproducible and arises from faulty calibration of the locomotor system. Although the sense of force is an important aspect of the limbs' proprioception, very few studies have examined it in patients with tendinopathy. Maenhout et al evaluated the sense of force in thirty-six patients with rotator cuff tendinopathy and found patients significantly overshoot the target (mean, 6.04% of target) (23). In another study, Torres et al studied the sense of resistance, using a weight discrimination protocol and joint position sense in 21 basketball and volleyball players with patellar tendinopathy. They found whereas joint position sense remained unaffected in patients still, they had a diminished perception of force signals (24). The results of this study are consistent with the results of other studies mentioned above.

## Conclusion

The present study investigated proprioception, measuring force sensation and sense of position in lateral epicondylalgia. It was shown that these patients have more sense of position errors in elbow and wrist, also in sense of force, they show worse values of errors in elbow and wrist and they overshoot the target during force reproduction tests and have systemic errors. This should be taken into account in the physiotherapy assessment and treatment of patients with lateral epicondylalgia; however, the consistency of force exertion remains unaltered. Further research, such as longitudinal research, is needed to investigate sequences of events and to study cause and effect. In addition, it is recommended that future studies address the accuracy of proprioception tests and the result of local inflammation in patients with tendinopathies. In addition, we recommend that tendinitis at other parts of the body and in different classes of patients, including athletes, be investigated versus proprioception, the extent of pain, and prevalent clinical symptoms.

## Limitations of the study

This study had two limitations that should be addressed in future studies. First, the study focused on lateral epicondylalgia in the general population. Therefore, we designed the position and force reproduction tests, so as not to cause or increase the patient's pain. In addition, our goal was to study the proprioception with the subjects being in comfortable positions and conditions.

### Authors' contribution

PA, MKH, KKK and AAB participated in the design and

implementation of the study. PA, MKH and KKK prepare the manuscript draft. AAB participates in the description of research methods and statistical data analysis and in the review of the manuscript of the article. Final manuscript read and approved by all authors.

## Conflicts of interest

The authors declared no competing interests.

## Ethical issues

This research followed the doctrines of the Declaration of Helsinki and was extracted from the thesis conducted by Parisa Arzani for the degree of Ph.D., Student Research Committee, Department of Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran (Thesis #23807). The study was approved by Research Ethics Committees of Vice-Chancellor in Research Affairs - Shahid Beheshti University of Medical Sciences (IR.SBMU.RETECH.REC.1399.1134). Therefore, the study process was exactly explained to the participants and informed consent was signed by all of them. Additionally, ethical issues including plagiarism, double publication and redundancy have been completely observed by the authors.

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