TITLE: Joint position sense, motor imagery and tactile acuity in lateral elbow tendinopathy: a cross-sectional study

ABSTRACT

Background: Impairments of sensorimotor function are evident in individuals with lateral elbow tendinopathy (LET), although understanding of the mechanisms for this is lacking.

Objectives: To determine if motor imagery, tactile acuity and wrist joint position sense (JPS) are impaired in participants with unilateral LET compared to controls, whether deficits are localised to the affected side, and whether deficits relate to severity of pain.

Design: Cross-sectional study with control group.

Methods: 14 participants with unilateral LET of 6 weeks or longer and 14 matched control participants were assessed bilaterally for motor imagery (left/right hand judgement task), tactile acuity (two-point discrimination test) and wrist JPS (reposition test for flexion and extension). Pain levels were measured using a numeric rating scale.

Results: Significant differences in JPS were observed for wrist extension only, such that participants with LET adopted less extended postures with their affected side when compared to their unaffected side (MD = 2.97°; p = 0.01) and to the matched-affected side of controls (MD = 4.89°; p < 0.01). No significant differences in tactile acuity or motor imagery were observed.

Conclusion: Altered wrist extension JPS, but not motor imagery or tactile acuity, was found in the affected side of patients with unilateral LET when compared to non-injured side and asymptomatic controls.

Keywords: tennis elbow, proprioception, imagery, body image, chronic pain
INTRODUCTION

Lateral elbow tendinopathy (LET), often referred as tennis elbow, is a common degenerative tendon pathology that affects 1 to 3% of general population.\textsuperscript{1,2} The presenting complaint is pain at the lateral aspect of the elbow, which is aggravated by resisted wrist extension, gripping or lifting. In addition, impairments to sensorimotor functions of patients with persistent LET have been widely described. Compared to asymptomatic controls, individuals presenting with LET have demonstrated lower pain thresholds when stimulated by pressure and temperature\textsuperscript{3–5}. Reaction time and speed of movement are also affected, where patients may perform a variety of manual tasks slower than controls\textsuperscript{6,7}. During submaximal gripping tasks, patients have been observed to adopt less extended positions with their wrist\textsuperscript{8}. It is noteworthy that most of these sensorimotor alterations were found in both elbows of individuals with unilateral symptoms, which suggests that the underlying mechanisms may involve maladaptation of the central nervous system. Findings of altered functioning of intracortical networks and maladaptive motor cortical maps related to the affected tendons in participants with LET\textsuperscript{9,10} provide further support to the involvement of central nervous system processes in the aetiology of this condition.

Sensorimotor function requires integration of sensory, motor and central processes\textsuperscript{11}. In the periphery, specific mechanoreceptors present in ligament, capsule and muscles detect changes in pressure, motion and velocity, producing afferent signals which are transmitted to spinal dorsal horn. These impulses may generate monosynaptic and/or polysynaptic reflexes that elicit efferent motor reaction. Afferent signals are transmitted to higher centres, such as the cerebellum and cortical sensorimotor areas, where they are interpreted and processed by complex multiregional connections among primary sensory, primary motor and dorsal premotor cortices before firing descending motor signals to the forearm muscles\textsuperscript{12}. It is assumed that altered functioning in any of these processes may lead to impaired precision of wrist movement and stability for specific tasks\textsuperscript{13}.
Appreciation of motor and sensory functioning is conducted via testing of proprioceptive senses, such as joint position sense (JPS), tactile acuity and motor imagery. Evaluation of these can provide information about someone’s perception of movement and awareness of own body. JPS refers to the ability of accurately reproducing a given joint angle and can be done actively (when patient moves the joint actively to a predetermined target position) or passively\textsuperscript{14,15}. While a body of evidence has demonstrated impaired JPS in several musculoskeletal conditions\textsuperscript{16–19}, to date, there is a single study investigating elbow JPS in people with LET.\textsuperscript{20} Although wrist position is known to affect maximal grip strength in healthy individuals and individuals with LET display altered wrist posture during spontaneous gripping,\textsuperscript{8,21} it is currently not known whether people with LET can accurately reproduce a given wrist joint angle. The ability to distinguish two distinct points applied to the skin by touch is known as tactile acuity and can be assessed by attempting to distinguish two separate stimuli applied in varying distances. Robust evidence has shown that this ability is diminished in conditions affecting the limbs, such as complex regional pain syndrome, arm and shoulder pain\textsuperscript{22–25}. Motor imagery is the conscious appreciation of the self that involves both awareness of own physical body and mental simulation of movement\textsuperscript{26}. Evaluation of motor imagery is usually performed using left/right judgement tasks in which individuals are tested for the time and accuracy taken when judging whether body images refer to either left or right side\textsuperscript{27}. Recent studies have shown that patients with peripheral pain perform worse when recognising images of their affected side compared to their unaffected side and to controls\textsuperscript{23,24,28}, however whether patients with LET are affected remains unknown.

Although investigation of pain in LET is plentiful, there is a lack of studies that evaluate other sensorimotor functions, such as JPS, tactile acuity and motor imagery. A better comprehension of these senses and the involved mechanisms may promote a broader understanding of how symptoms relate to movement processing and motion itself. Therefore, this study aimed at determining whether wrist JPS, tactile acuity and motor imagery were affected in patients with chronic LET. Secondly, we aimed at investigating whether these variables would be related to clinical outcomes.
MATERIALS AND METHODS

Study design

An observational cross-sectional study was conducted to compare a group of individuals experiencing chronic unilateral lateral elbow tendinopathy with matched asymptomatic control participants. This study followed the recommendations of the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) statement and was in accordance with the Declaration of Helsinki. Ethical approval was received by the University’s ethical committee (protocol number 1.871.697).

Setting

Residents of Porto Alegre, Brazil were recruited through social media advertising and from private physiotherapy and orthopaedic clinics between April of 2017 and April of 2018. Recruitment of asymptomatic matched-controls was performed through both social media posts and personal invitation. Participants fulfilling preliminary eligibility criteria were contacted by either phone or e-mail and invited to attend a private clinic in the centre area of Porto Alegre, Brazil for physical screening. If included, participants received detailed information about the study procedures and provided written consent. All procedures were then performed in the same private clinic by a single researcher.

Participants

Participants were included in the LET group if they were aged between 18 and 60 years, reported pain at the lateral epicondyle of one of the elbows lasting for longer than six weeks provoked by two or more of the following: gripping, resisted extension of the wrist or third finger, and palpation of the lateral epicondyle. Asymptomatic control participants without history of neck or arm pain in the last 6 months were recruited in a 1:1 ratio, matched for sex and age. All participants were excluded if they reported other cervicobrachial pain preventing from work or
recreational activities, corticosteroid injections in the preceding 6 months, history of arthritic, inflammatory or malignant diseases, sensory disturbances (e.g. allodynia, paraesthesia or anaesthesia in the upper limb), history of trauma or previous elbow surgery.

Sample size was estimated based on previously reported findings of large deficits in left-right hand judgement accuracy measured in patients with carpal tunnel syndrome using E-prime software. Using a web-based sample size calculator, with power and significance level set as 0.8 and 0.05, respectively, a minimum of 24 individuals (12 for each group), would be necessary to detect significant differences.

Outcomes

Participants in both groups were tested, in the following order, for pain intensity, motor imagery, JPS and tactile acuity. Hand dominance was determined through questioning which hand they used for most of daily manual tasks, such as writing and brushing teeth.

Pain intensity

Current pain intensity, worst pain in the previous 24 hours and worst pain the previous week were measured using 11-pointed Numerical Rating Scales (NRS) ranging from zero (no pain) to 10 (worst pain imaginable). Also, participants were instructed to report any pain felt during data collection procedures.

Motor imagery

Motor imagery was assessed through a left/right judgement task in which participants had to recognise whether hand images corresponded to their left or right side using the Recognise™ application (Neuro Orthopaedic Institute, Adelaide, Australia). For this test, participants remained comfortably seated in front of a desk, with both elbows flexed at 90° and both index fingers positioned over the bottom of an electronic tablet’s screen. Forty images of hands (20 of each side), in multiple postures, angles and skin colours, were randomly shown at the centre of the device’s screen. Standard instructions were given for participants to judge, as quick and
accurate as possible, whether each of the images were right or left hands by clicking on a ‘left’ (with their left finger) or on a ‘right’ (with their right finger) button shown at the bottom of the screen. Participants were instructed to focus on the displayed images and avoid mimicking or comparing the postures with their own hands. If decisions on hand laterality exceeded 7 seconds, new images would be displayed. Prior to data collection, a series of 10 images were performed for familiarization. Previous research has found good to excellent reliability for the tablet device version of Recognise™31. Mean values of accuracy (percentage of correct answers) and reaction time (seconds) were used for further analysis.

*Wrist joint position sense*

Wrist JPS was measured by asking participants to move their wrist actively to reproduce two predetermined target positions (20° of flexion and 20° of extension). A custom-made apparatus (Figure 1) consisting of 45.50x45.50cm wood board with a 60cm-long, 180-pointed semicircular paperboard protractor perpendicularly fixed and indicating 0 (at its centre) to 90° to both sides was used. Participants were seated, blindfolded, with their tested forearm resting in neutral pronation-supination and stabilised over a cushioned wood support, so that the wrist and hand could move without obstacles. Participants were asked to sustain their tested hand in a relaxed fist position, with a laser pointer attached in parallel to the dorsal surface of their thumb. To measure the wrist range of motion, the laser light pointed towards the semicircular protractor indicating the degrees of wrist flexion-extension movement.

The participant’s wrist was passively moved by the researcher to the target angle (20° of flexion) and rested in this angle for 5 seconds before being passively moved to about 20° of extension. From this angle they had to actively reposition the wrist as close as to the target angle. The final angle adopted was used for further analysis. For wrist extension position sense, the procedure was repeated using a target angle of 20° extension. The test was repeated 3 times for both movements (flexion and extension) and for each arm, each time recording the final reposition angle in degrees.
In addition to the final reposition angle, the variable error of each participant was used for analysis. The variable error reflects the consistency of the errors among the 3 trials performed by participants and was calculated as the group mean of the standard deviation taken from the difference between target and final angle.

![Stylised picture of the custom-made apparatus used for measurements of wrist flexion and extension JPS.](image)

**Tactile acuity**

Tactile acuity was measured through the two-point discrimination test using a 150-mm digital calliper (MTX™, Sao Paulo, Brazil). The minimal distance necessary to identify two nearby touch stimuli applied on the skin as two separate objects and not one was recorded. Two-point discrimination thresholds were measured with participants lying in supine, with their eyes closed and upper limbs extended in internal rotation. The tactile stimuli were applied over the lateral epicondyle area. Participants had to inform, for each stimulus, whether they felt one or two distinguishable sharp point touching their skin. Three to five ascending and descending measures were performed for each arm and the geometric average of the ascending and
descending thresholds was used for data analysis. Two-point discrimination test has shown moderate to good reliability when measured in multiple body regions\(^3\).

**Data management and analysis**

For JPS, the final reposition angle was analysed as it reflects both the size and direction of error. In addition to the final reposition angle, the within-subject variation, or the variability in the repositioning errors (differences between target and final angle neglecting the direction of error) within the 3 consecutive trials was also analysed. The variable error was calculated as the group mean of the standard deviation taken from the difference between target and final angle.

Shapiro-Wilk tests were used for the assumption of data normality. Normally distributed data are presented in mean ± standard deviation while non-normally distributed data are presented in median (1\(^{st}\) quartile – 3\(^{rd}\) quartile). Upper limbs of participants in both groups were categorised as either ‘affected’ or ‘unaffected’ sides. For participants in LET group, these terms referred to the sides with and without symptoms, respectively. However, for participants in the control group, sides were matched to the LET group based on hand dominance.

For normally distributed data, two-way repeated measures analysis of variance (ANOVA) tests with side (affected and unaffected) and group (LET patients and asymptomatic controls) factors were performed to assess effects of side, group and interaction side*group. When a side*group interaction was found, independent samples t-tests were used to verify differences between groups and paired samples t-tests to verify differences between sides for each group. Partial eta-squared values generated from ANOVA tests were used as measure of effect sizes (ES). Mann-Whitney U tests to verify differences between groups and Wilcoxon Signed Rank tests were used to evaluate differences between sides when data were not normally distributed. Pearson correlation tests were used to identify relationships between outcomes and pain scores in participants with LET.

Data analysis was performed using the IBM Statistical Package for the Social Sciences (SPSS) version 20.0 and significance was set as p < 0.05.
RESULTS

Participants

Fourteen individuals (8 males and 6 females), with mean age of 46.14 ± 10.85 years and experiencing LET for a median 39 (11.5 - 110.5) weeks, met the inclusion criteria and consented to participate. All participants in LET group had symptoms at their right elbow and ten (71.43%) reported dominance for their right side. Mean NRS scores were 3.29 ± 1.98, 4.93 ± 1.98 and 5.64 ± 1.86 for current pain, worst pain in the last 24 hours and worst pain in the week, respectively. The control group consisted of 14 asymptomatic participants (8 males and 6 females), with mean age of 46.21 ± 10.88 years. There were no differences between groups for sex and age.

Insert Table 1 here

Table 1: Means ± standard deviations and medians (25th percentile- 75th percentile) of motor imagery and tactile acuity assessed in the affected and unaffected sides of patients with LET as well as matched-affected and matched-unaffected sides of controls. LRTJ: left/right judgement task, JPS: joint position sense, TPD: two-point discrimination.

Insert Table 2 here

Table 2: Means ± standard deviations and medians (25th percentile- 75th percentile) of JPS outcomes assessed in the affected and unaffected sides of patients with LET as well as matched-affected and matched-unaffected sides of controls. LRTJ: left/right judgement task, JPS: joint position sense, TPD: two-point discrimination.

Motor imagery

Data of accuracy and reaction time for left/right hand judgement task are shown in Table 1. No significant main effects of side (F[1] = 0.61, p = 0.44, ES = 0.01), group (F[1] = 2.065, p = 0.16, ES = 0.04) or interaction side*group (F[1] = 0.29, p = 0.60, ES = 0.01) were found for accuracy or
reaction time for side (F[1] = 0.02, p = 0.89, ES = 0.01), group (F[1] = 0.01, p = 0.94, ES = 0.01) and interaction side*group (F[1] = 0.245, p = 0.62, ES = 0.01).

Wrist joint position sense

Final reposition angles and variable errors for JPS testing of flexion and extension are shown in Table 2. Participants did not report any pain during JPS measurement. A two-way ANOVA revealed a significant side*group interaction for wrist extension final repositioning angle (F[1] = 4.21, p = 0.045, ES = 0.75). Using paired t-tests, significant differences were observed between the affected and unaffected sides of participants with LET (t[13] = -3.04, MD = 2.97°, p = 0.01) but not for participants in control group. Significant differences in extension repositioning angle were also found comparing the affected side of participants in LET group with the matched-affected side of participants in control group (t[26] = 3.17, MD = 4.89°, p = 0.004), but not when the unaffected side of each group were compared (Figure 2). Results indicated a less extended final wrist position for the affected side of participants with LET compared to the unaffected limb or matched limb in the control group. Analysis of variable errors for wrist extension using non-parametric tests found significant differences between groups only in the affected side (U = 48,000, p = 0.02, ES = 0.44). Results indicated lower variable errors for the affected side of participants with LET compared to the matched limb in the control group.

No significant main effects of side (F[1] = 0.43, p = 0.51, ES = 0.01), group (F[1] = 2.756, p = 0.10, ES = 0.05) or side*group interaction were found for wrist flexion final repositioning angles (F[1] = 311, p = 0.58, ES = 0.01). Analysis of variable errors for wrist flexion showed no difference between groups (U = 92,000, p = 0.80, ES = 0.05), but a significant difference between sides in participants with LET (T = 16,000, p = 0.02, ES = 0.61). Results indicated higher variable errors for the affected than unaffected side in participants with LET.
Figure 2: Graphic of JPS for wrist extension and flexion of affected and unaffected sides of patients with LET as well as matched-affected and matched-unaffected sides of controls. * indicates $p = 0.01$ and ** indicates $p = 0.004$. AFF: affected side, UNAFF: unaffected side, M-AFF: matched-affected side, M-UNAFF: matched-unaffected side.

**Tactile acuity**

Data of two-point discrimination thresholds are shown in Table 1. No significant differences between groups ($U = 82,000$, $p = 0.48$, $ES = 0.14$) and sides ($T = 59,000$, $p = 0.68$, $ES = 0.11$) were found for tactile acuity using non-parametric tests.

**Relationship with clinical or demographic variables**

JPS, motor imagery and tactile acuity were not correlated with values of pain intensity. A Pearson correlation test found a significant positive correlation between pooled values (from
both groups and both sides) of two-point discrimination thresholds and age ($r = 0.44$, $p = 0.001$), i.e. older participants had higher thresholds for two-point discrimination.

**DISCUSSION**

To our knowledge, this is the first study to investigate wrist JPS, motor imagery and tactile acuity in individuals experiencing LET. Our key findings were: (a) that lesser extended wrist postures were adopted by the painful limb in an angle reproduction test compared to unaffected side and control participants; and (b) that neither motor imagery nor tactile acuity seemed impaired in people with LET. In addition, none of the main outcomes were correlated to clinical or demographic characteristics, except for age and two-point discrimination threshold, where older participants performed worse in the tactile acuity testing.

In the present study, participants with chronic unilateral LET adopted different final repositioning angles when tested with their injured limb in a wrist extension JPS task, while measures of JPS for wrist flexion did not differ from unaffected side and controls. When instructed to actively reposition their affected wrist in a 20° target angle of extension, they adopted approximately 5° less extended wrist posture. This finding may relate to previous work where people with LET were observed to adopt less wrist extension than controls when performing pain-free gripping tasks. As participants with LET demonstrated significant lower values of variable error for wrist extension in the affected side in comparison to controls, it is possible that participants with LET made consistent errors in undershooting the target wrist extension position. Previous research into the patterns of muscle activation during submaximal gripping tests has identified that patients with LET display less movement variability when using their affected side. As repositioning angles were not correlated with pain intensity and participants did not report pain during the repositioning task, it appears that elbow pain was unlikely to be causing the reduced wrist extension. We speculate that dysfunctional proprioception may develop as a result of long-term overuse, especially through chronic
exposure to repetitive and sustained manual tasks, which may lead to maladaptation and morphophysiological changes of muscle spindles. In consequence, maladaptive firing pattern of these structures may potentially induce altered reflexes and ascending signalling, thus impairing wrist motor control. However, since we did not investigate the tendon structural aspects of our sample, this speculation must be cautiously interpreted.

Dysfunction of JPS has been reported for other musculoskeletal conditions, such as anterior cruciate ligament reconstruction, shoulder impingement, patellofemoral pain syndrome, chronic low back pain and idiopathic neck pain\textsuperscript{16-19,35}. To date, JPS has only been evaluated at the elbow joint in 15 participants with unilateral or bilateral LET\textsuperscript{20}. These authors found no differences between LET-diagnosed and non-diagnosed elbows in those with unilateral LET (n=11), but reported a trend toward differences in JPS as measured by absolute errors between the affected elbow of patients with unilateral LET in comparison to right elbow of healthy controls (n=21). However, these authors also reported greater variable errors, which differs from our reported lower variable errors. Several differences in testing and analysis may explain the heterogeneous results. First, it is plausible that impairments in JPS may be more pronounced when assessing wrist repositioning than elbow repositioning. This may reflect the greater effect of wrist position on the wrist extensor musculotendinous origin. Second, altered JPS may be better visualised when considering the final repositioning angle than absolute errors, which neglect the direction of error (e.g. undershoot or overshoot). Third, the type of reproduction test differed between studies, as in our study, participants were instructed to actively reproduce a target angle that was set passively, whereas in the study by Juul-Kristensen and colleagues (2008) both the target angle and its reproduction were performed actively.

Across multiple musculoskeletal disorders, controversial findings of motor imagery are reported in the literature. Recent metanalysis has shown that, although axial painful conditions may not display disrupted motor imagery, individuals with painful conditions affecting their limbs perform consistently worse in left/right judgement tasks when compared to their pain-free sides.
and controls. The present study is not in accordance with this body of evidence, given that the affected side of patients with persistent unilateral LET did not differ to their unaffected side and to controls in terms of motor imagery. The findings in our sample of unchanged tactile acuity and motor imagery may indicate that supraspinal networks related to body representation may not be affected in patients with LET.

Also in contrast to previous research findings of impaired tactile acuity in other painful disorders including frozen shoulder, knee osteoarthritis, complex regional pain syndrome and low back pain, our results did not demonstrate significant differences between both sides and groups. Although non-significant, relatively large differences (median differences of 10.5mm in unaffected sides) were observed between groups, with patients demonstrating better precision (i.e. lower thresholds) than controls. In patients with frozen shoulder, their symptomatic side showed elevated thresholds in relation to the unaffected side, which led to thoughts of neurophysiological changes developed only at the site of symptoms. The finding that both tactile acuity and motor imagery were preserved in our sample, combined with evidence of altered JPS only at the affected limb, allows us to suspect that changes in sensorimotor functioning in LET may not relate to central processing and instead be limited to peripheral structures, such as muscle spindles and articular mechanoreceptors.

It is crucial to highlight some limitations in our study. First, as there were no studies of motor imagery on LET, sample size estimation was based on large deficits in patients with carpal tunnel syndrome. Hence, our relatively small sample might have limited our study to detect only moderate to large size effects. Second, wrist JPS data was not collected at multiple angles or using gold-standard instrumentation, such as isokinetic dynamometer. Instead, a custom-made apparatus was built in a similar fashion as that reported by Carey and team which showed good to excellent reliability. In spite of its possible deficiencies during data collection, for example only 2 wrist positions were assessed, this instrument is low-cost and potentially useful for proprioceptive rehabilitation in a clinical basis. Last, the Recognise™ application used to
measure motor imagery did not provide reaction time data in milliseconds as did the previous software version, compromising the precision of the time required for each image judgement. Our original research project considered the use of the previous version (with time in milliseconds), but its online use was replaced by the application by the time when sample recruitment began.

**CONCLUSION**

Altered wrist JPS was found in the affected side of patients with chronic LET when compared to non-injured side and asymptomatic controls. These changes were not correlated to clinical variables. Other sensorimotor functions, such as motor imagery and tactile acuity, seemed to be preserved. Further investigation is encouraged to determine whether altered JPS in patients with LET can be modified by exercise training.

**REFERENCES**


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