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Influence of Shoulder External Rotation Component on Median Nerve Neurodynamics in Neurogenic Cervicobrachial Pain Syndrome: A Cross-Sectional Study

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SUMMARY

Background. The upper limb neural tissue provocation test-1 (ULNTPT-1) is used for determining the neurogenic etiology of neck and arm pain. Biomechanical studies have primarily investigated *in vitro*, whereas *in vivo* examination is lacking.

Objective. The objective was to determine the effect of the shoulder external rotation (ER) component of ULNTPT-1 on the deficit in elbow extension range of motion (EEROM) and vibration threshold (VT) in participants with neurogenic cervicobrachial pain syndrome (CBPS).

Methods. Thirty-two patients were included in the study as per the inclusion criteria. ULNTPT-1 with/without shoulder external rotation was performed on symptomatic and asymptomatic side. Deficit in EEROM at the onset of muscle activation of biceps brachii (R1) and initial onset of pain (P1) along with VT in median nerve territory was recorded. One-way ANOVA was used to compare the difference and level of significance was $p < 0.05$.

Results. The effect of ULNTPT-1 with/without shoulder ER component on the deficit in EEROM at P1 & R1 was significant on symptomatic as well as on the asymptomatic side ($p < 0.001$). The difference was not significant on symptomatic ($p = 0.15$) and asymptomatic sides ($p = 0.31$) for the VT. The difference in value of responses obtained on each side with/without shoulder ER compared, showed no significant difference in all three outcomes P1, R1, and VT ($p = 0.219$; $p = 0.273$; $p = 0.145$).

Conclusions. There was greater deficit in EEROM with shoulder ER, which suggest that there is a heightened nerve mechanosensitivity with shoulder ER component of ULNTPT-1.

Study registration. Clinical Trial Registry India received a prospective registration for the trial with the number CTRI/2018/04/013383.

KEY WORDS

Cervicobrachial pain syndrome; median nerve; neurodynamics; neurogenic; upper limb neural tissue provocation test-1.

INTRODUCTION

A problem of the neck is one of the most common causes of musculoskeletal symptoms, with a lifetime frequency of 48.6%. The global burden of disease study ranks it fourth in terms of disability (1). Neck discomfort frequently radiates proximally into the head or distally toward the upper back or an upper limb. Cervicobrachial pain syndrome (CBPS) is one such condition, which is described as upper quarter discomfort with mechanosensitive neural tissue as the predominant feature (2-5). This syndrome is produced by abnormal mechanical tension in certain parts of the peripheral nervous system, resulting in atypical impulse-producing sites. When mechanical stress is applied along the length of the nerve, these locations are responsible for heightened sensitivity, which is known as mechanosensitivity (6). In the literature, a series of steps have been suggested for determining the heightened nerve mechanosensitivity (4, 5, 7).

Upper limb neural tissue provocation test-1 (ULNTPT-1) is a clinical test that is often used to diagnose CBPS-related heightened median nerve mechanosensitivity (8-11). The normal response to ULNTPT-1 in asymptomatic participants is reported as pain and paraesthesia in the distribution of a median nerve, stretch in the palmar aspect of hand/cubital fossa/shoulder area with an increase in response on adding cervical lateral flexion to the opposite side (11-14). A classic clinical indicator of heightened nerve mechanosensitivity is a decrease in Elbow Extension Range of Motion (EEROM) due to painful responses (P1) when the nerve is positioned into further position of strain (12, 15-19). To avoid further mechanical tension on the sensitive nerve and its mechanical interface, the central nervous system initiates the nociceptive-mediated flexor withdrawal response, which is usually associated with increased muscle activity (20-22). It has been postulated that the flexor withdrawal response (R1) occurs to prevent further mechanical strain on the sensitive nerve and surrounding tissue (20-22). The physical and physiological integrity of the peripheral nerves is required for normal sensory and motor functions. Vibration Threshold (VT), measures nerve physiological function, has excellent intra-rater reliability and is used in clinics to identify early signs of minor nerve dysfunction using the instruments like tuning fork and Biothesiometer (23-26). Vibration sense carried by the large Aβ fibers is one of the important aspects of the nervous system's diverse senses which is vulnerable to the blood supply reduction in case of heightened nerve mechanosensitivity (25, 26).

Shoulder abduction and External Rotation (ER), supination of the forearm with wrist and finger extension, and extension of the elbow constitute the ULNTPT-1. Interpretation of ULNTPT-1 depends on factors like speed, rhythm, through range perception of muscle activation and sequence of movement as they influence the neurodynamics (27). The therapist can tailor the base test to the individual patients by modifying the sequencing of the components based on the severity, irritability, and nature of symptoms, thereby increasing the test's sensitivity (2, 28). In cadaveric experiments, different ULNTPT-1 movement sequences resulted in varying mechanical strain on the nervous system (29-31). The impact of shoulder ER on median nerve neurodynamic tests is debatable in the literature (32). The ER of the shoulder in the sequence of ULNTPT-1 was reported to reduce strain in cords of the neck and arm plexus, with subsequent reduction in strain on the median nerve (32-34). Nevertheless, another argument in the literature suggests that it may influence neurodynamics physiologically (35). However, all the results are based on cadaver research, and shoulder external rotation influence has not been validated *in vivo* (35, 36).

ULNTPT-1 is an essential component in testing the neurogenic nature of CBPS (10). Knowing the differences in responses when completing ULNTPT-1 with and without shoulder ER will help us decide whether the shoulder ER component should be added or removed from ULNTPT-1. The response of median nerve neurodynamics testing with and without shoulder ER in CBPS with heightened nerve mechanosensitivity is lacking in the literature. The primary objective of this study was to evaluate how the shoulder ER component of ULNTPT-1 affect P1, R1, and VT in neurogenic CBPS on each symptomatic/asymptomatic side. The secondary objective was to find out the difference in the values of P1, R1 and VT obtained on each side separately when ULNTPT-1 was performed with/without shoulder ER and further to compare the obtained values between symptomatic/asymptomatic side.

MATERIALS AND METHODS

Study design

In order to compare the response of the ULNTPT 1 performed with and without shoulder ER, an observational cross-sectional study was carried out. This study adhered with the Declaration of Helsinki and strengthened the reporting of observational studies in epidemiology (STROBE) requirements (37, 38). The Institutional Ethics Committee granted ethical approval (IEC No. 80/2018 – Date of approval: February 14, 2018).

Setting and sample size calculation

The study was carried out between July 2018 and January 2019 in the physiotherapy outpatient unit at Kasturba

Hospital in Manipal, Karnataka, India. Written consent was obtained from eligible participants after they received comprehensive information about the study's methods. Standard recommendations were followed to determine the sample size (39). To determine the necessary sample size for this study, the mean and standard deviation of EEROM variable obtained from the previous study, was used. Using the confidence interval of 95% and test power of 80%, thirty two participants were recruited.

Inclusion and exclusion criteria

Following the detailed explanation of the procedure, informed consent was obtained from the participants before proceeding with the screening. One hundred and seventy-five (n = 175) participants with a complaint of neck pain radiating to unilateral arm were screened by a researcher pursuing a post-graduate degree in physiotherapy with orthopedics as a specialization. The neurogenic character of pain was evaluated in either gender aged 18 to 65 years with a complaint of acute or subacute (≤ 12 weeks) neck and unilateral arm pain. Participants were considered to have neurogenic cervicobrachial pain syndrome if their complaints were consistent and contained all of the following physical symptoms (7): 1) active movements of the neck (either side lateral flexion, extension, and same side rotation) and shoulder abduction reproducing the participant symptoms, 2) similar movement restrictions on the passive movement of neck and arm as obtained during active movement examination, 3) increase in mechanosensitivity on the symptomatic side with reproduction of participant symptoms during the performance of ULNTPT-1 and differentiating maneuver (wrist flexion for proximal symptoms, while same side cervical lateral flexion for distal symptoms) confirms the involvement of neural tissue, 4) elicitation of symptoms on palpation of a nerve root in the neck and median nerve in the medial arm or cubital fossa or carpal tunnel on the symptomatic side, and 5) evidence of a related pathology (example: positive Spurling's test). The previously mentioned indications and symptoms have been suggested and characterized as indicators of CBPS being neurogenic (4, 7, 39). The participants fulfilling all the above mentioned criteria were included. The participants who were not able to comprehend the research protocol, had non-neurogenic pain, limited shoulder motion, diabetic peripheral neuropathy and thoracic outlet syndrome were excluded from the study.

Outcome measures and rationale

Upper limb neural tissue provocation test-1 (ULNTPT-1)

In patients with neurogenic neck pain radiating to arm, ULNTPT-1 can be used reliably in the clinics with a difference of > 7 degrees can be considered as a meaningful change in the prognosis of the condition (15). In the symptomatic population with nerve related neck and arm pain, there exists moderate inter-tester reliability for assessing the mechanosensitivity of nerve on neural tissue palpation and tension testing (19).

Initial onset of pain (P1) and onset of muscle activity (R1)

Nerve throughout its course is surrounded by different connective tissue considered as nerve bed. Injury to the nerve increase the sensitivity of the nerve in response muscle gets overactive to offload the nerve to prevent undue stress on the nerve allowing symptom to get resolve (40). To examine the onset of muscle activity the initial disturbance in the flat line suggesting muscle activation, wireless surface EMG (Delsys Trigno wireless EMG system, AD Instruments, USA 2016) was used. Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM) recommendations was used to position the electrode over the biceps brachii (20, 22, 43, 53). The elbow range at the point of onset of muscle activity (R1) can be measured using Electromyography (EMG), but low inter-tester reliability for perceiving the through range resistance in testing has been described in the literature (16). In the asymptomatic population, it was demonstrated good intra-rater reliability for R1 but fair inter-tester reliability (41). In a normal person with variation in neural extensibility have demonstrated an increase in muscle activity in a less extensible group (20). The response of the nerve to ULNTPT-1 in the asymptomatic population has shown an increase in the contraction of trapezius much earlier in the range in relation to initial onset of pain (P1) (42). Pain receptors and movement receptors send the afferent impulses resulting in an increase in resistance prior to the onset of pain (P1) with increased in the torque at the onset of pain response (22).

Measurement of Elbow Extension Range of Motion (EEROM)

Measurement of EEROM is a common procedure to estimate the mechanosensitivity of ULNTPT-1. The universal goniometer was used to measure EEROM. The intra-rater reliability intraclass correlation coefficient ranged from 0.45 to 0.99, the inter-rater reliability ranged from intraclass correlation coefficient 0.53-0.97, in the measurement of elbow range of motion using universal goniometer (43).

Vibration threshold (VT)

Measurements of vibration sensitivity are used both for detection and monitoring dysfunctions (44, 45). The test targets the Ab fibres - which mediate the sensation of vibration and are sensitive to ischemia. For example, vibration perception has been shown to be the first sensation to be

lost in patients with diabetic neuropathies (46). In manual therapy, measurements of vibration thresholds (VTs) identified the existence of minor neuropathies (as exemplified by raised VTs in the Median and Ulnar nerves) associated with computer usage (47). These findings suggest that manual therapists could utilize vibration perception outcome measures for monitoring and managing such conditions (47). The vibration threshold has been measured using the standardized procedure (23). The intra-rater reliability for the median nerve, when tested over 2nd metacarpal head over the palmar surface of the hand, was reported as 0.922 (48).

Set-up, familiarization and procedure

After getting the consent, the demographics including age, gender, weight, height, hand dominance, symptomatic side and duration of symptoms of each participant were recorded. Participants were asked to lie down on a firm plinth (without pillow). Considering the sensory supply of the median nerve on the palmar aspect of the hand, vibration thresholds were recorded on the palmar aspect of the head of the second metacarpal (48). Before starting the procedure, participants were familiarized with vibration sense at the head of the second metacarpal bone on the hand's palmar surface. The participants were explained to say "started" with the initial perception of vibration and to say "stopped" when they stop perceiving it (23, 49). The laptop and EMG device was placed at the head end of the participants (to prevent any feedback to the participant) which can be seen by the examiner to look for the point at which the flat line (muscle is in relaxed state) show initial disturbance (indicating muscle activation) through the range of elbow extension movement as a protective response. The EMG electrode was placed over the belly of biceps brachii. To ensure constant shoulder depression pressure during the procedure, a biofeedback device inflated to 40 mmHg was placed on the superior aspect of the shoulder girdle. The asymptomatic side was assessed first. On the asymptomatic side, participants were given five minutes of rest between sequences (with or without shoulder ER). The sequence performed was shoulder depression (40 mmHg), shoulder abduction to 90°, forearm supination, wrist, and finger extension, with or without shoulder ER to 90° (as per randomization; flipping a coin; head, with shoulder ER and tail, without shoulder ER), followed by elbow extension. Investigator number 1 performed the sequence while investigator number 2 recorded the outcomes. During the performance of the sequence, the point at which EMG flat line showed the disturbance indicating onset of muscle activity (R1) and the point at which participants complained of onset of pain (P1), deficit in EEROM was recorded using a universal goniometer by investigator 2. While performing ULNTPT-1 with shoulder ER fulcrum of the goniometer was placed at humerus medial epicondyle, stationary arm parallel to the long axis of the shaft of humerus, while stationary arm pointing to the ulnar styloid. When ULNTPT-1 was performed without the shoulder external rotation component from the sequence, the lateral epicondyle was used as a fulcrum with a stationary arm parallel to the shaft of the humerus and a moving arm pointing towards the radial styloid (50). Participants were blinded from reading while recording. Five degrees short of the P1 range, the vibration of gradually increasing intensity was applied using Biothesiometer (VibrothermDx) to establish the vibration threshold. Vibration perception threshold (VPT) was recorded at which the participants first became aware of the sensation of vibration. The intensity was then increased by 50% and gradually reduced to establish the vibration discrimination threshold (VDT). When the participants were no longer able to perceive the fading vibration stimuli, VDT was recorded. Measurement of perception and discrimination thresholds were repeated thrice. No clues in any form (verbal or non-verbal) were provided to prevent inaccurate recordings. VT was calculated as a factor of the mean of the perception and discrimination thresholds. Participants were blinded from reading while recording. After completing the procedure on the asymptomatic side, a 5-minute rest period was given before repeating the process on the symptomatic side.

Statistical method

The data was analyzed using version 16 of the Statistical Package for the Social Sciences (IBM SPSS Modeler 16.0) software. Descriptive analysis was used to examine demographic data. Lewen's test for homogeneity of variance was used to assess for data homogeneity. One-way ANOVA for outcomes (P1, R1, and VT) both on symptomatic and asymptomatic sides for testing with and without shoulder external rotation. One-way ANOVA for outcomes (P1, R1, and VT) with the standard sequence between symptomatic and asymptomatic side. One-way ANOVA to compare the difference in the values of P1, R1 and VT obtained on each side separately when ULNTPT-1 was performed with/without shoulder ER.

RESULTS

Participants

Of the 175 participants screened, 34 were recruited. Due to technical error, data of 2 participants were not included in the analysis of the final results. The participants flow chart can be seen in the **figure 1**.

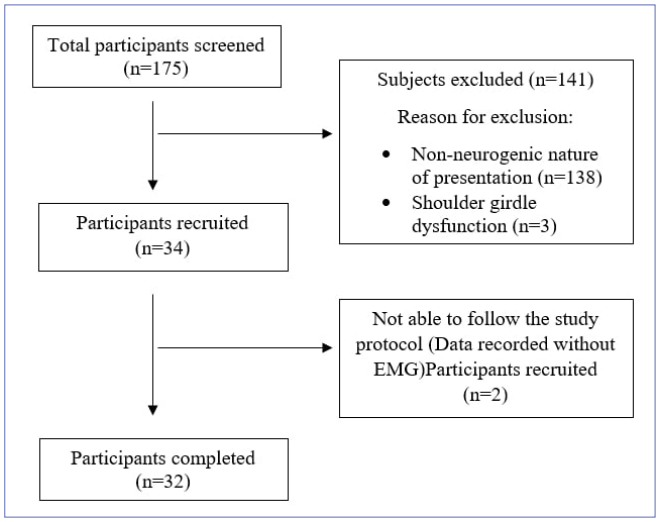

Figure 1. Participants flowchart.

The mean age of the participants (n = 32) was 38.91 ± 10.25 years. The demographic details of the participants provided in **table I**.

Lewen's test for homogeneity of variance showed that data was homogenous. Results of the comparison of responses on the symptomatic side with/without shoulder ER (**table II**) showed that R1 and P1 responses occurred earlier in the range when ULNTPT-1 was performed with standard sequence on the symptomatic side. Mean difference of more than 10 degrees were found for R1 and P1 responses between two sequences of ULNTPT-1. The VT response, however, did not differ between the sequences.

Results of the comparison of responses on the asymptomatic side with/without ER (**table III**) showed that R1 and P1 responses occurred earlier in the range when ULNTPT-1 was performed with standard sequence on the asymptomatic side. Mean difference of more than 10 degrees were found for R1 and P1 responses between two sequences of ULNTPT-1. The VT response, however, did not differ between the sequences.

When the difference in the value of responses of each outcome measure obtained with/without shoulder ER on the symptomatic and asymptomatic sides was compared (example: symptomatic side P1/R1/VT with shoulder ER minus symptomatic side P1/R1/VT without shoulder ER and asymptomatic side P1/R1/VT with shoulder ER minus asymptomatic side response P1/R1/VT without shoulder ER), none of the outcome were significantly different indicating that the shoulder ER component has impacted both sides equally (**table IV**).

Table I. Demographic characteristics of the participants.

Parameters	Mean ± Standard deviation
Male/Female, n (%)	13 (40.6%)/19 (59.4%)
Age (year)	38.91 ± 10.25
Weight (kg)	67.73 ± 9.07
Height (cm)	162.20 ± 9.28
Hand dominance right/left n (%)	32 (100%) / 0
Symptomatic side right/left n (%)	16 (50%)/16 (50%)
Duration of symptoms (weeks)	5.62 ± 3.43

Table II. Symptomatic side - comparison of the initial onset of pain (P1) in degrees of deficit in Elbow Extension Range of Motion (EEROM), onset of muscle activity (R1) in degrees of deficit in EEROM and Vibration Thresholds (VT).

Symptomatic side	Mean (SD)	Mean difference ± SE	95%CI of the difference	F	P-value
P1 With shoulder ER	51.50 (13.10)	12.65 ± 3.20	6.25, 19.05	15.61	0.001*
Without shoulder ER	38.84 (12.51)				
R1 With shoulder ER	61.71 (12.45)	12.43 ± 2.89	6.65, 18.21	18.49	0.001*
Without shoulder ER	49.28 (10.61)				
VT With shoulder ER	4.49 (0.93)	0.32 ± 0.22	- 0.12, 0.76	2.10	0.15
Without shoulder ER	4.17 (0.85)				

Measurements five-degrees short of P1 in volts obtained on the symptomatic side when ULNTPT-1 was performed with and without shoulder ER (n = 32). *Significant difference ($p \leq 0.05$).

Table III. Asymptomatic side - comparison of the initial onset of pain (P1) in degrees of deficit in Elbow Extension Range of Motion (EEROM), onset of muscle activity (R1) in degrees of deficit in EEROM and Vibration Thresholds (VT).

Asymptomatic side	Mean (SD)	Mean difference ± SE	95%CI of the difference	F	P-value
P1 With shoulder ER	27.34 (10.08)	9.68 ± 2.54	4.60, 14.76	14.53	0.001*
Without shoulder ER	17.65 (10.24)				
R1 With shoulder ER	37.12 (9.59)	10.06 ± 2.36	5.33, 14.78	18.10	0.001*
Without shoulder ER	27.06 (9.32)				
VT With shoulder ER	3.58 (0.72)	0.18 ± 0.17	-0.17, 0.53	1.05	0.31
Without shoulder ER	3.40 (0.69)				

Measurements five-degrees short of P1 in volts obtained on the asymptomatic side when ULNTPT-1 was performed with and without shoulder ER (n = 32). *Significant difference ($p \leq 0.05$).

Table IV. Effect of shoulder ER when the difference of responses is compared between the asymptomatic and symptomatic side (n = 32).

Between sides comparison of difference value of each response	Mean difference ± SE	95%CI of difference	F	P-value
P1 Difference	2.96 ± 2.38	-1.80, 7.74	1.54	0.219
R1 difference	2.37 ± 2.14	-1.91, 6.66	1.22	0.273
VT difference	0.20 ± 0.14	-0.07, 0.48	2.18	0.145

No significant difference ($p \leq 0.05$); P1 and R1 in degrees and VT in volts.

DISCUSSION

The primary objective was to determine the effect of the shoulder ER component of ULNTPT-1 on P1, R1 and VT in participants with neurogenic CBPS. We observed that the shoulder ER component of ULNTPT-1 for the symptomatic and asymptomatic sides resulted in a statistically significant effect on P1 and R1 as shown by more deficit in EEROM suggesting it caused more nerve mechanosensitivity. However, the shoulder ER component had no significant effect on VT.

The mechanosensitivity of the median nerve was higher when ULNTPT-1 was performed with a standard sequence (10, 27, 31). This may suggest that shoulder ER induces more nerve strain which could account for the reduction in range of motion at the elbow during ULNTPT-1. Controversy exists in the literature from several authors' works on the cadavers concerning the role of shoulder ER component in ULNTPT-1 testing. It was suggested that the shoulder ER component could be excluded (32-34). We disagree with the argument that exists with respect to the shoulder ER component, as our findings show that when ULNTPT-1 was performed with the standard sequence, an earlier increase in mechanosensitivity occurred. The reason for different results could be that during the performance of ULNTPT-1 *in vivo*, various mechanical events like strain, sliding and pressure, as well as physiological events like reduced blood flow and inflammation, may have influenced the mechanosensitivity of the nerve. In this current study, we attribute the mechanosensitivity to be resulting from physiological events in addition to mechanical events (2, 9). Hence our findings disagree with the argument to discard the shoulder ER component from the standard sequence of ULNTPT-1.

The nerve, throughout its course, is surrounded by different connective tissue, considered as nerve bed. With increased strain in the nerve, protective muscle activity occurs, which prevents the sensitized nerve from further elongation (20-22, 40). Evidence suggests low to fair inter-tester reliability with good intra-rater reliability for perceiving them through range resistance R1 (16, 51). Neural tissues are protected from stretch not solely by pain, but also by muscle activity, noted with an increase in EMG activity in muscles before pain onset (15, 20-22, 42, 52). Our study findings align with existing literature, as there was an increase in EMG activity of biceps brachii R1 earlier to the onset of pain. Biceps brachii was chosen for recording as it is one of the muscles involved in antalgic posture protecting the strain on the median nerve. It gets activated to prevent further elongation with elbow extension at the final component. Early dysfunction of a nerve can be identified reliably with a valid method of determining VT (23, 25, 26). We found no significant effect of the shoulder ER component of ULNTPT-1 on VT. Even though we put forward that both physiological and mechanical events in and around the nerve may influence the mechanosensitivity. We did not find any significant

effect because of the methodology we adopted, as VT was measured 5 degrees short of P1. As the VT testing procedure is time-consuming, maintaining the position at the onset of mechanosensitivity was not opted in the current study as sustained strains & physiological events could lead to an increase in mechanosensitivity. As the participants in this study were symptomatic, we offloaded the nerve and recorded the VT, because of which we would not have found the disputed result in terms of vibration.

The secondary objective was to determine the effect of the shoulder ER component of ULNTPT-1 between symptomatic and asymptomatic sides. Although the mechanosensitivity was significantly early on the symptomatic side than on the asymptomatic side, we found that the difference in the magnitude of response of P1, R1 and VT to the shoulder ER component was similar when compared between the symptomatic and asymptomatic sides - suggesting that the shoulder ER component had impacted both the sides equally.

Clinical implications

In our study, we found that without the shoulder ER component, the mechanosensitivity of the nerve occurs relatively later in range for both sides. Thus, in participants with limited shoulder ER where the standard procedure of ULNTPT-1 testing could not be performed, we can use the response to compare what we get without shoulder ER. However, the same testing procedure should be used throughout follow up visits to assess for change in degrees of range of motion at which P1 and R1 occurred. Use the same procedure to compare between sides even if need to modify the test in that way.

Limitations

The speed with which elbow extension was performed is not quantified. However, care was taken to perform elbow extension with a constant slow speed and rhythm. The R1 was considered at the point where deflection can be seen on the EMG. However, deflection strength was not considered/quantified while recording. Also, during the recording of the responses no structural differentiation was performed.

Future recommendations

In future studies, different shoulder girdle muscles can be chosen for recording EMG activity during the testing, along with the quantification of the elbow flexor resistive torque. The R1 can be measured at the specific strength of deflection, and also the structural differentiation can be performed while during the recording of the responses.

CONCLUSIONS

There was greater deficit in EEROM with shoulder ER, which may suggest that there is a heightened nerve mechanosensitivity with shoulder ER component of ULNTPT-1. The practitioner can use the results acquired without a shoulder ER in cases where the patient's shoulder has limited range of motion.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

PK, RG, AP: study design. PK: writing - original draft. PK, RG: material preparation. PK: data collection. PK, RG, AP statistical analysis. All authors: writing - review and editing, final approval.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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