

Mechanically Evoked Torque and Electromyographic Responses During Passive Elbow Extension in Upper Limb Tension Test Position

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Abstract - In neural tension testing, it is critically important to establish a method to investigate the relative contribution of different neuromuscular mechanisms to resistance developed during and at the limit of the upper limb tension test 1 (ULTT1). Three males and seven females in the age range 41-72 years (mean 56, SD±10) participated in a within subject repeated measure study. The study consisted of two major testing protocols. The first was an objective passive movement protocol, which utilized a KIN-COM[®] dynamometer to measure range of motion (ROM) and evoked resistive torque during elbow extension. The second was an electromyographic (EMG) protocol, which allowed recording of EMG from 10 shoulder and arm muscles during the controlled passive elbow extension as the last component of ULTT1. A battery-operated micro-switch held by the subject, generated digital rectangular pulses to indicate occurrence of pain onset and pain tolerance limit during the experimental task. There was increased level of EMG activity prior to pain onset ($P<0.05$). There was also clear evidence that elevated perception of pain and elevated levels of resistive torque ($P<0.05$), were positively correlated with the EMG activity in the muscles responsible for antalgic posture of the upper limb ($P<0.05$). From these findings, now it is possible to propose that increased detectable resistance during elbow extension at ULTT1 position involves the protective reflex activation of the shoulder and arm muscles which is mediated by nociceptive and mechano-receptors as a result of the preferential mechanical stretching of the median nerve during the test.

Keywords: Mechanically Evoked EMG; Neural Tension testing; Upper Limb Tension Test (ULTT); Pain; Median nerve; Human motion analysis; Neuromuscular disorders

I. INTRODUCTION

Over the last two decades, clinical examination techniques have been developed to assess the mechanosensitivity of the major nerve trunks and their central neural connections. As a manually applied examination procedure, the upper limb tension test 1 (ULTT1) was originally designed for diagnostically moving and tensioning the nervous system (specially median nerve) of the upper limb. The ULTT is now ranked with other well-established 'neural tension' tests such as the straight leg raise [1].

Initially this test was used as a diagnostic aid but judicious use and variations of the test can also implicate mechanical disorders of the nervous system as a component of many common neuro-musculoskeletal disorders. The test and its derivatives may also be used as a treatment technique [1].

Coveney [2] established the high sensitivity and the predictive value of the ULTT in her study of subjects with carpal tunnel syndrome (CTS) when compared to the 'gold

standard' nerve conduction studies performed by neurologists. The ULTT involves performance of an ordered sequence of passive arm movements, which impart tensile forces to the cervical nerve roots and their peripheral nerves [1]. The sequence involves six stages: (1) stabilization of the shoulder girdle, (2) shoulder abduction to approximately 110°, (3) wrist and finger extension, (4) forearm supination, (5) shoulder lateral rotation, and (6) elbow extension. The aim of ULTT is to determine the source of a patient's pain and other sensory symptoms in the hand and arm and to evaluate any associated muscle stiffness produced during the test.

In clinical practice the outcome of the ULTT1 is interpreted with respect to three variables: 1) pain, 2) through-range muscular stiffness, and 3) the maximum range of elbow extension during the last component of the test. However, there is difficulty interpreting the findings of the ULTT. This is partly due to the difficulty in stabilizing the head, shoulder and trunk during the test and in controlling the upper limb movements. Additionally, lack of objective information concerning the activity of the upper limb muscles, range of elbow joint motion, through-range resistive torque and the pain experienced by the subject makes interpretation of the findings even more difficult. Therefore, in spite of the widespread use and recognized importance of the ULTT, controversy remains about the neurophysiological basis for sensory and motor responses produced during this test [3, 4]. It has been suggested that the increased muscle activity evoked during the ULTT may be a withdrawal response to pain that acts to indirectly protect the nerve by preventing further tensioning [4, 5], but this concept has recently been challenged [3, 6].

It is not known whether pain triggers a motor response that causes increased resistance, or whether increased muscle activity and resistance to passive movement are unrelated to pain and should be explained by a different mechanism. It is also not known which muscles are activated during the ULTT and whether the muscle activity fits a flexion withdrawal response that could act to prevent further stretch. Therefore, the purpose of this study was to investigate the correlation between the passive resistive torque and EMG activity of shoulder and arm muscles during elbow extension at periods when subjects experience onset of pain and limiting pain.

II. METHODOLOGY

Passive movement protocol

Ten subjects, three males and seven females, in the age range 41-72 years (mean 56, SD±10) with no history of neurological or upper quarter neuromusculoskeletal injury volunteered for this study. Once in the ULTT1 position, the

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elbow extension component was controlled by a KIN-COM dynamometer (125 AP, Chattecx Corporation, Tennessee USA) [7] arm moving at 3°/sec to minimise the effects of myotatic stretch reflex [8]. The dynamometer was also used to record the resistive torque and the range of elbow extension in both neutral position of the shoulder and arm joints and in the ULTT1 position (stretched position of the median nerve). For both testing positions, after standard skin preparation and attachment of surface EMG electrodes, the subjects were asked to lie supine with one pillow under their knees on a special wooden plinth which was already fixed to the dynamometer's seat/plinth assembly.

Stabilization was achieved by belts at the chest and the waist. Another strap just above the knee stabilized the lower leg during testing. Then the subject's elbow axis was aligned to the elbow axis of a mechanical range of motion control device (ROM-CD). Four adjustable straps were used to keep the subject's elbow axis aligned to the ROM-CD's elbow axis during passive elbow extension. A padded shoulder block was placed superior to the subject's acromioclavicular joint to stabilize the shoulder girdle position.

A pressure sensor was used between the padded shoulder block and the acromioclavicular joint to monitor and standardize the pressure applied to produce constant stabilization of the shoulder girdle between tests and subjects. A pressure increase of 5.32 kPa from a baseline of 2.66 kPa was applied as a suitable standard scapular depression pressure between subjects. Then, they were instructed how to use of a hand-held electronic marking switch prior to performing the elbow extension as an experimental task. Subjects were instructed to report as soon as the tightening sensation changed to 'pain' (pain onset, PO) and again report as soon as the pain onset changed to 'maximum tolerable pain' (pain limit, PL) by activation of the hand-held electronic pain switch. Subjects were requested to keep their eyes fixed on a point on the ceiling during the procedure. To help standardize the neck posture throughout the experiments, two padded wooden blocks with metal clamps were used. This preserved a neutral position of the cervical spine in the coronal plane.

The KIN-COM plinth assembly was fully adjustable in six directions. This feature along with full adjustability of the dynamometer head assembly allowed us to easily align the ROM-CD axis to the KIN-COM's mechanical axis. For elbow extension in neutral position of shoulder and arm each subject was evaluated while lying in the supine position on the wooden plinth with legs extended and the arm contralateral to that being tested resting on their sides. The arm to be tested was placed in the ROM-CD and the position of the shoulder (30 degrees of abduction), elbow (90 degrees of flexion), forearm (full supination), and wrist and fingers (neutral) were fixed and held by ROM-CD locking mechanisms prior to the test. The starting position of the subject's arm prior to testing in non stretched position was: arm resting by the side (30 degrees of abduction), elbow 90 degrees flexion, forearm supinated, and wrist and hand in neutral position. Then the start and stop angles in the KIN-KOM were set at 90 and -30

degrees, respectively. This provided a 120 degrees range from 90 degrees of elbow flexion to a maximum of 30 degrees hyperextension.

To minimize the effects of myotatic stretch reflex and to provide maximal safety for subjects an angular velocity of 3°/sec was selected for passive elbow extension on the dynamometer. Then the elbow extension (as the test movement) proceeded up to the point of pain threshold and then pain tolerance and held at this point for 3 seconds. The subjects were able to immediately stop the movement using the hand-held button at any point in this range. The starting position of the subject prior to testing in ULTT1 was: arm 110 degrees of abduction and full laterally rotated, elbow 90 degrees flexion, forearm completely supinated, and wrist and hand in full extension. With the upper cervical spine in slight flexion, a chinstrap was placed from the spinous process of C2 and fastened across the anterior aspect of the subject's chin (Figure 1) to prevent upper cervical extension.

Surface EMG protocol

The electromyographic activity was obtained with self-adhesive pre-gelled disposable surface electrodes (DUOTRODE® MYO-TRONICS, INC. USA). These silver-silver chloride electrodes have a contact diameter of 5 mm and an inter-electrode space of 2 cm. After a standard skin preparation procedure of disinfecting, shaving and abrading, pairs of electrodes were positioned over the site of placement on experimental (the muscles involved in antalgic posture of the upper limb including: upper and middle fibres of trapezius, biceps, brachialis, pectoralis major, and flexor carpi radialis) and control muscles (the antagonists of the above muscles including: lower fibres of trapezius, triceps, deltoid, infraspinatus) referenced to anatomical landmarks. A grounding lip-clip electrode was clipped onto the subjects' lip [9].

Instrumentation

To study the biomechanical and bioelectrical aspects of the mechanically evoked EMG signals, an integrated multi-channel computer-based system was developed [10] and used to simultaneously display, quantify and correlate the mechanically evoked EMG activity, ROM, pain threshold and tolerance marks created by activation of the hand-held switch. The electronic pain marks along with simultaneous ROM, torque and multi-channel evoked EMG tracings, allowed us to determine the subject's response in a quantitative and precise fashion.

In this system, the EMG responses picked up by the electrode pairs were first amplified 3000 times by a low-noise EMG amplifier with high common mode rejection ratio (120 dB) [11]. The signals were then filtered with a band-pass filter with corner frequencies of 10 – 500 Hz. A band-reject filter centered on 50 Hz removed the power line hum. The filtered EMG signals were further band-limited using a second-order Butterworth filter and then digitized using a sampling rate of 1000 Hz.

During the experiment the electrode leads were secured to minimize movement artifact. All measurements were made

by the same investigator. Standardized instruction was given to the subjects prior to each test. Then each subject was tested for mechanosensitivity of the median nerve in both neutral position of the arm and the tensioned position of median nerve in the ULTT.

Statistical analysis

Differences in elbow extension (EE-ROM) or elbow flexion resistive torque (EF-RT) at movement onset (MO), PO and PL and 3-seconds mean value of EMG signals in each muscle before and after MO, PO and PL during elbow extension (at neutral and ULTT1 position in each group) were analyzed with two-way repeated measures ANOVA. The design employed was a 2*2 within-subjects ANOVA. The first within-subject factor was testing position, which had two levels: testing in neutral and ULTT1 position. The second factor was timing of data reduction with six levels: before/after MO, PO and PL.

In these series of analyses before interpretation of the F-ratio of the within-subjects effects, the assumption of sphericity was assessed by Mauchly's test of sphericity [12] as part of the analysis. If this test remained insignificant it meant that the required assumptions were met and the assumption of sphericity has not been violated, but if it was significant, the obtained F-ratio was to be re-evaluated by using new degrees of freedom. Alpha was set at 0.05 for each analysis. Ad-hoc comparisons were made using Tukey's honestly significant difference (Tukey's HSD) method. [12]

III. RESULTS

Figures 2a and 2b show the EE-ROM, EF-RT and EMG activity of shoulder and arm muscles during passive elbow extension at MO, PO and PL. It is observed that at MO there is similar resistive torque in neutral and ULTT1 positions. At PO there is more resistive torque in ULTT1 position ($p < 0.001$), and this difference is greater at the PL position ($p < 0.001$). The results for evoked EMG responses before and after MO, PO and PL during passive elbow extension in the ULTT position are summarized in Figures 3 and 4.



Fig.1. Elbow extension at ULTT1 position.

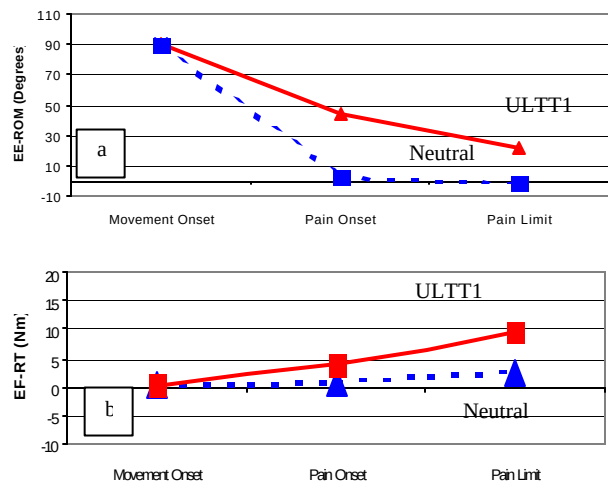


Fig. 2. The range of passive elbow extension (a), and elbow flexors resistive torque (b) at MO, PO and PL.

These figures illustrate that in some muscles the EMG values tended to increase over the range of elbow extension. This upward trend occurred to a different extent in different muscles. In all muscles, compared to baseline EMG, the mean values of EMG activity before PL showed a significant increase ($p < 0.001$). This increase in the upper and mid-trapezius, pectoralis major, biceps, and brachialis was greater than in the other muscles. Figure 3 also shows an increase in EMG activity of these muscles before onset of pain. The evoked EMG activity in flexor carpi radialis, deltoid, infra-spinatus and the lower fibres of trapezius remained relatively constant over the range of elbow extension at different pain levels.

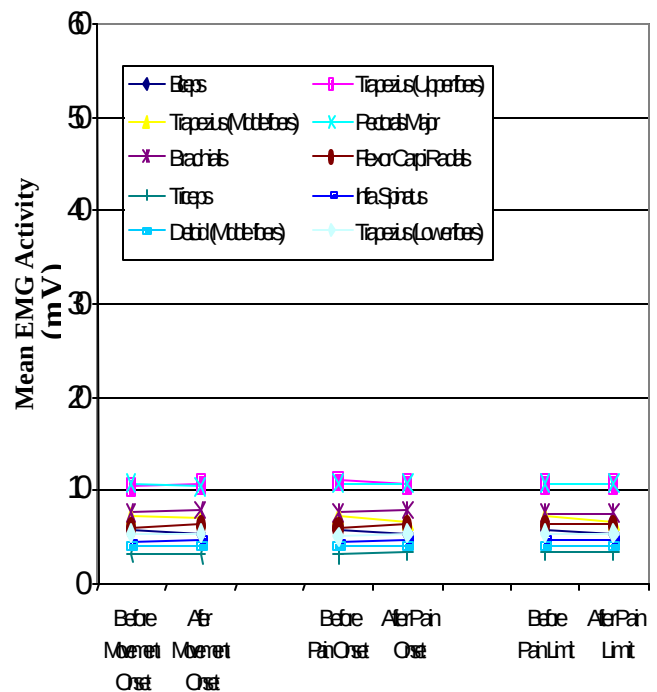


Fig. 3. Mean EMG responses in experimental and control muscles during passive elbow extension in neutral position.

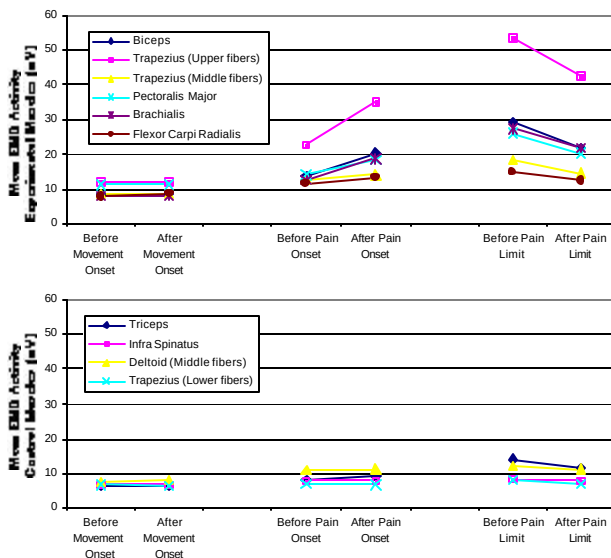


Fig. 4. Three-second mean EMG in experimental (a) and control muscles (b) before and after MO, PO and PL.

IV. DISCUSSION

The present study offers clear evidence that elevated perception of pain and elevated levels of motor responses (such as elbow flexor resistive torque) are positively correlated with EMG activity of shoulder and arm muscles. These findings support the assumption that the cause of the increased through-range or end-range resistive torque and muscle activity during ULTT may be a withdrawal response to pain that acts to indirectly protect the nerve by preventing further tensioning. The results show that the EMG activity increased prominently in those muscles, which are responsible for the antalgic posture of shoulder and arm. These results are in substantial agreement with those of Hall et al [5] and Elvey [4].

Our data indicate that the relative increase of EMG activity from movement onset to 3 seconds before pain onset, during elbow extension at the ULTT position, is not solely the result of pain. This finding is of considerable importance since it suggests that a number of mechanisms may have contributed to the EMG responses of muscles during elbow extension at ULTT1 position. The currently hypothesized mechanisms linking the muscle activity with neural tissue tension are: mechanical sensitivity of ganglion cell bodies [13], existence of mechanoreceptors in thoracolumbar spinal cord [6] and mechanoreceptors in the peripheral nervous system [14].

These hypotheses infer that the somatic nervous system has normal mechanisms, which may protect the peripheral nerves against tensile stresses. According to these authors it is a surprising fact that while muscles, bones and joints are equipped with a massive number of proprioceptors, large peripheral nerves such as the median nerve which is also exposed to stretch and pressure is not equipped with a kind of mechanoreceptor mechanism.

Our finding does not support the above-mentioned hypotheses and so we can conclude that muscle-pain

interaction via the nociceptive mediated flexor withdrawal reflex may not be the only mechanism responsible for EMG activity of shoulder and arm muscles during passive elbow extension at ULTT1 position. On the other hand, our findings are in agreement with those of Balster and Jull [3] who concluded that mechanosensitivity of peripheral nerves in asymptomatic subjects is not solely mediated by pain. Our findings in normal subjects suggest that mechanosensitivity of peripheral nerves to stretch may be a physiological protective mechanism rather than a pathological phenomenon following peripheral nerve injury.

V. CONCLUSION

It is possible to propose from these findings that increased detectable resistance and EMG activity during elbow extension at ULTT1 position involves the protective reflex activation of the shoulder and arm muscles. This may be mediated by flexor withdrawal reflex and mechanoreceptors in peripheral nervous system as a result of the preferential mechanical stretching of the median nerve during the ULTT.

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