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## **ABSTRACT**

### **OBJECTIVES**

Non-specific arm pain is a common clinical entity, the pathophysiological mechanisms of which are poorly understood. The purpose of this study was to investigate sensory profiles in individuals with non-specific arm pain compared with cervical radiculopathy and controls.

### **METHODS**

Forty office workers with non-specific arm pain, 17 people with cervical radiculopathy and 40 healthy controls were assessed by means of quantitative sensory testing (thermal and vibration detection thresholds; thermal and pressure pain thresholds), tests for neural tissue sensitivity and questionnaires. Between-group comparisons were conducted using Kruskal-Wallis tests. Exploratory factor analysis was used to determine characteristic features in non-specific arm pain.

### **RESULTS**

Both patient groups demonstrated cold and pressure pain sensitivity ( $p < 0.003$ ;  $p < 0.05$ ) as well as neural tissue sensitivity ( $p < 0.001$ ). The non-specific arm pain group also demonstrated heat pain sensitivity ( $p < 0.001$ ). Both groups demonstrated hypoaesthesia to vibration thresholds ( $p < 0.05$ ), whereas thermal hypoaesthesia was only evident in the cervical radiculopathy group ( $p < 0.05$ ). Exploratory factor analysis revealed pressure and thermal pain sensitivity as the key characteristics of this non-specific arm pain group.

### **DISCUSSION**

Sensory profiles in non-specific arm pain and cervical radiculopathy differ. Non-specific arm pain is characterised by widespread sensitivity to thermal and pressure pain in the absence of thermal hypoaesthesia, while cervical radiculopathy is characterised by the presence of thermal and vibratory hypoaesthesia as well as more localised cold and pressure pain sensitivity. The identification of widespread sensory hypersensitivity in non-specific arm pain has important implications for clinical decision making.

**Key words:** non-specific arm pain, quantitative sensory testing, sensory hyperalgesia, neural tissue sensitivity

## **INTRODUCTION**

Non-specific arm pain is a vague clinical entity, the prevalence of which has been estimated to be as high as 50% of all work related upper limb disorders.<sup>1,2</sup> It is defined as diffuse pain in the forearm (which can also involve the neck, upper arm, wrist and hand) in the absence of evidence of a specific disorder.<sup>3</sup> The pathophysiological mechanisms underlying non-specific arm pain remain unclear with a number of theories proposed, such as nociceptive/inflammatory pain (e.g. from muscle), neuropathic pain, central sensitization and important psychosocial contributions.<sup>4-6</sup>

Previous studies of non-specific arm pain have identified hyperalgesia in response to clinical tests of neural sensitivity.<sup>7-9</sup> The underlying mechanisms of this may relate to peripheral nerve sensitization or central sensitization.<sup>9,10</sup> In addition, the presence of sensory hypoaesthesia to light touch<sup>11</sup> and vibration have been recorded in this population.<sup>4,12,13</sup> Proposed explanations for these findings include peripheral nerve dysfunction or minor neuropathy.<sup>4,9</sup> However, the presence of widespread hypoaesthesia has also been explained by some researchers as indicative of changes in central processing, for example, in response to the presence of pain.<sup>11,13</sup>

In many chronic pain conditions, the presence of sensory hyperalgesia has been reported, with findings of hyperalgesia to thermal and mechanical stimuli detected in cohorts with neck pain,<sup>14,15</sup> whiplash,<sup>16,17</sup> patellofemoral pain<sup>18</sup> and low back pain.<sup>19</sup> These findings are important for our understanding of pathophysiological mechanisms with the finding of widespread sensory hyperalgesia likely reflective of central sensitization.<sup>20</sup> The presence of sensory hyperalgesia has not been investigated in non-specific arm pain and therefore, further research is warranted to investigate sensory profiles in a more comprehensive manner in this group.

Cervical radiculopathy is a condition of neuropathy of one or more cervical nerve roots.<sup>21</sup> As some of the previous research relating to non-specific arm pain points to the presence of a nerve dysfunction or neuropathy in this group, cervical radiculopathy was selected as an appropriate comparison group to explore this further. Therefore, the purpose of this study was twofold: first, to examine the sensory profiles and identify the presence of characteristic features in non-specific arm pain and second to ascertain the absence or presence of features of neuropathy and/or neuropathic pain in non-specific arm pain compared with cervical radiculopathy. The results from this study could influence clinical decision making regarding interventions for patients with non-specific arm pain.

## **MATERIALS AND METHODS**

### **Design**

A cross-sectional observational study investigating sensory profiles in participants with non-specific arm pain, cervical radiculopathy and healthy controls was undertaken. Volunteers were screened for inclusion criteria for each particular group. Subsequently, participants underwent a physical examination and quantitative sensory testing (QST) and were asked to complete a series of questionnaires of pain and disability measures. The study design is outlined in Figure 1. All aspects of group allocation and data collection were performed by one investigator (NM). Aspects of the QST testing protocol were randomized. The study was approved by the Human Research Ethics Committee for Life Sciences in University College Dublin and the involved hospitals. All participants were unpaid volunteers and provided written informed consent before inclusion.

## **Participants**

**Non-specific arm pain:** Participants with arm pain, aged between 18-65 years, were recruited from Dublin metropolitan hospitals, medical and physiotherapy practices and via a poster/email/newspaper campaign and were screened for inclusion in this study. Screening involved taking a medical history and performing a physical examination. Patients were assigned to the non-specific arm pain group if they had pain in the arm in the absence of a specific diagnosis,<sup>22</sup> were office workers with significant upper limb pain as defined by a numerical pain rating of  $\geq 3/10$ ,<sup>23</sup> for longer than 3 months, who spent more than 40% of their working week using desktop equipment<sup>4</sup> and who had been employed using desk-top equipment for at least two years.<sup>14</sup>

**Cervical Radiculopathy:** Participants with possible cervical radiculopathy were also recruited from Dublin metropolitan hospitals (primarily neurosurgical departments) as well as medical and physiotherapy practices. They were assigned to the cervical radiculopathy group if they had radicular pain in the upper limb ( $\geq 3/10$ ),<sup>23</sup> a positive upper limb neurodynamic test (as defined by the reproduction of concordant symptoms and structural differentiation,<sup>24</sup> a positive Spurling's test, MRI confirmation of nerve compression<sup>21 25 26</sup> as well as at least one concordant clinical sign of conduction loss<sup>27</sup> (i.e. one of diminished/absent reflexes, myotomal weakness or sensory loss in a dermatomal pattern).

**Controls:** Control participants were recruited from a general email/poster campaign. They were age and gender matched with the non-specific arm pain group and were included in the control group providing they did not have a history of significant neck, scapular or shoulder pain over the previous 12 months and did not use desktop equipment for more than 40% of their working week.<sup>4</sup>

Volunteers were excluded from any of the three groups if they were seeking compensation for their injury or if they had any of the following: generalized neurological disorders, generalized musculoskeletal/inflammatory disorders, a history of low back pain and or low back related leg pain

over the previous 6 months, a history of migraine over the previous 6 months, previous trauma to the upper quadrant, diabetes, endocrine disorders, epilepsy or any significant psychiatric disorders.

## **Measurements**

A detailed description for the procedure for data collection in this study has previously been published.<sup>28</sup>

### *Sensory Assessment*

A QST protocol was designed such that small and large diameter nerve fibers and their associated central pathways were assessed.<sup>29</sup> Measures were taken of the following parameters using the method of limits: cold and warm detection thresholds; cold and heat pain thresholds and vibration thresholds. All measures were recorded on three sites on each arm. Thermal and vibration tests were performed using a NeuroSensory Analyser (TSA 2001 II Medoc, Israel). For thermal testing, a Peltier thermode (16 x 16mm) was attached directly over sites in the hand innervated by C6 (dorsum of the first metacarpal), C7 (dorsum of the second metacarpal) and C8 (dorsum of the fifth metacarpal). A Vibrometer (VSA 3000 II 2001 Medoc, Israel) was used to measure vibration thresholds with readings taken over sites of the hand innervated by C6, C7 and C8. Pressure pain thresholds were measured using a hand held pressure algometer with a probe size of 1cm<sup>2</sup> (Somedic AB, Farsta, Sweden) and an application rate of 40 kPa/s over the median, ulnar and radial nerves.<sup>28</sup> Triplicate recordings were taken at each site for all QST parameters and the mean values used for analysis. The tibialis anterior muscle was used as a distal reference point for thermal testing and pressure pain thresholds (recorded unilaterally). All aspects of QST have been found to have acceptable reliability.<sup>30-32</sup>

### *Neural tissue sensitization*

Neural tissue sensitization was measured using the upper limb neurodynamic test 1 and nerve palpation of the median, ulnar and radial nerves. The neurodynamic test 1 is a passive brachial plexus provocation test, performed in supine lying which involves the following: gentle scapular depression, shoulder abduction, forearm supination combined with wrist and finger extension, shoulder external rotation and elbow extension.<sup>24</sup> The test was considered positive with the reproduction of arm symptoms (at least in part) as well as structural differentiation tests, indicating a neural tissue source for the reproduced symptoms.<sup>24</sup> The other variables recorded from the neurodynamic test 1 were range of motion of elbow extension, using a goniometer secured to the arm, and numerical pain rating at the onset of pain during the test. Nerve palpation involved gentle digital palpation of the median nerve, medial to the tendon of biceps at the elbow, the radial nerve in the radial groove of the humerus and the ulnar nerve medial to the olecranon.<sup>10</sup> This was rated as either painful or not.

### *Neuropathic pain*

All participants in the non-specific arm pain and cervical radiculopathy groups completed the LANSS, with a score of  $\geq 12$  (out of 24) indicating the possible presence of neuropathic pain.<sup>33</sup>

#### *Kinesiophobia*

All participants in the two clinical groups completed the TSK,<sup>34</sup> with a score of  $\geq 37$  (out of 68) considered to indicate the presence of significant fear-avoidant pain beliefs.<sup>35</sup>

#### *Disability*

All participants in the two clinical groups completed the DASH questionnaire (0-100 with 0 indicating no disability).<sup>36</sup>

#### *Pain*

All participants in the two clinical groups provided an average numerical pain rating for the previous 24 hours and completed a short form McGill pain questionnaire which assesses sensory and affective dimensions of pain.<sup>37</sup>

### **Statistical Analysis**

PASW Version 18 (SPSS equivalent) statistical package for Windows was used for analyses.

Descriptive statistics were calculated for all measurements. As most data were not normally distributed between-group comparisons were analysed using Kruskal-Wallis tests with post-hoc analyses conducted using Mann-Whitney U tests. Bivariate correlation analyses were conducted between QST, clinical measures and results from questionnaires.

Using significant between-group findings, exploratory factor analysis (principal component analysis model) was conducted in order to identify characteristic components of the non-specific arm pain group. Comparisons of the resultant components between the three groups were conducted using one-way ANCOVAs with Tukey's post hoc analyses and with age as a co-variate.

## **RESULTS**

### **Demographic details**

Details of participants are outlined in Table 1. The mean age of the non-specific arm pain and control groups was 36 years while the cervical radiculopathy group were older at 53 years ( $F = 21.41, p < 0.001$ ). There were a higher number of females in all groups.

### **Side to side differences**

Significant side-to-side differences were identified for cold pain at the C8 site in the non-specific arm pain group and between the symptomatic and asymptomatic side in the cervical radiculopathy group

for neurodynamic test measures of range of elbow extension and numerical pain rating ( $p < 0.05$ ). Therefore, these measures were analysed separately in subsequent analyses. No side-to-side differences were found for any other measure in any of the groups ( $p > 0.05$ ) and therefore, the mean of right and left sides was used for analyses. Thirty-two participants in the non-specific arm pain group presented with unilateral arm pain. Significant differences were identified between the symptomatic and asymptomatic limb for vibration at the C7 site ( $p = 0.02$ ) and pressure pain at the median nerve site only ( $p = 0.03$ ). Comparisons between asymptomatic limb, symptomatic limb and controls for all QST measures were also conducted.

### **Sensory assessment**

All QST results are presented in Tables 2 and 3.

#### *Thermal detection thresholds*

Significant between group differences were found for cold detection and warm detection at all upper limb sites ( $p \leq 0.02$ ) and for cold detection at the tibialis anterior muscle site ( $p = 0.04$ ). Post-hoc analysis revealed that cold detection was elevated (participants detected the stimulus later) in the cervical radiculopathy group compared with both the control and non-specific arm pain groups at all sites including tibialis anterior muscle ( $p < 0.02$ ). Warm detection was elevated in the cervical radiculopathy group compared with the control group at all upper limb sites and compared with the non-specific arm pain group at the C6 site only ( $p = 0.01$ ). Warm detection was significantly elevated in the non-specific arm pain group compared to the control group at the C8 site only ( $p = 0.009$ ).

#### *Thermal pain thresholds*

Significant between group differences were found for cold pain and heat pain at all upper limb sites ( $p \leq 0.011$ ) and for heat pain at the Tibialis Anterior muscle site ( $p = 0.001$ ). Participants in the cervical radiculopathy and non-specific arm pain groups were more sensitive to cold pain than controls ( $p \leq 0.003$ ) at all upper limb sites with no significant differences between the cervical radiculopathy and non-specific arm pain groups ( $p > 0.05$ ). In addition, cold pain sensitivity was evident at the Tibialis Anterior muscle site in the non-specific arm pain group compared with the control group ( $p = 0.02$ ). Participants in the non-specific arm pain group were more sensitive to heat pain than controls ( $p \leq 0.001$ ) and the cervical radiculopathy group ( $p \leq 0.05$ ) at all sites. There were no significant differences between the cervical radiculopathy group and control group ( $p > 0.36$ ).

#### *Vibration thresholds*

Significant group differences were identified between the 3 groups for vibration at the C7 site only ( $p = 0.01$ ), although there was a trend towards significance at the C6 and C8 sites ( $p \leq 0.07$ ). Post-hoc analyses revealed that the cervical radiculopathy group detected vibration significantly later than the control group at the C7 ( $p = 0.002$ ) and C8 ( $p = 0.01$ ) sites with C6 close to significance ( $p = 0.06$ ).

Vibration thresholds were also detected later in the non-specific arm pain group compared to controls at C6 and C7 sites ( $p \leq 0.04$ ), whereas the non-specific arm pain group did not differ significantly from the cervical radiculopathy group ( $p > 0.14$ ).

#### *Pressure pain thresholds*

Significant group differences were found for pressure pain thresholds at all sites including Tibialis Anterior muscle ( $p \leq 0.04$ ). The non-specific arm pain group were more sensitive to pressure pain compared to controls for all three upper limb nerves and Tibialis Anterior muscle ( $p < 0.02$ ), while the cervical radiculopathy group were more sensitive than controls at the median and radial nerve sites ( $p \leq 0.03$ ) with the ulnar nerve site close to significance ( $p = 0.06$ ). There were no differences between the non-specific arm pain and cervical radiculopathy groups for any site ( $p > 0.183$ ).

#### **Sensory assessment in non-specific arm pain participants with unilateral arm pain**

The results for comparisons between non-specific arm pain participants with unilateral arm pain (asymptomatic and symptomatic limbs) with controls are presented in Table 3. Both limbs demonstrated significant cold, heat and pressure pain sensitivity when compared to controls. Vibration was detected later in the symptomatic limb of this group compared with controls ( $p \leq 0.03$ ). There was no difference between the asymptomatic limb and controls ( $p \geq 0.07$ ) although the C6 site was close to significance ( $p = 0.07$ ) for vibration thresholds. Detection of warm sensation was also significantly later in the symptomatic limb compared to controls but only at the C8 site ( $p = 0.02$ ).

#### **Neural tissue sensitization**

Of the 40 participants with non-specific arm pain, 31 had a positive neurodynamic test i.e. reproduction of symptoms in the symptomatic limb. Significant differences were identified for both range of elbow extension ( $p < 0.001$ ) and numerical pain rating ( $p < 0.001$ ) on neurodynamic testing between all three groups (Figures 2, 3). Post-hoc analyses revealed that the non-specific arm pain group as well as both symptomatic and asymptomatic limbs of the cervical radiculopathy group were significantly different to the control group (non-specific arm pain median of both limbs =  $47^\circ$  (IQR = 28) from full elbow extension  $p < 0.001$ ; cervical radiculopathy symptomatic limb =  $61^\circ$ ; (IQR = 20)  $p < 0.001$ ; cervical radiculopathy asymptomatic limb =  $46^\circ$  (IQR = 35)  $p < 0.01$ ; control group median of both limbs =  $23^\circ$  (IQR = 15). The symptomatic limb of the cervical radiculopathy group demonstrated significantly reduced range of elbow extension ( $p = 0.008$ ) and higher pain ratings ( $p = 0.009$ ) on the neurodynamic test compared with the non-specific arm pain group. No differences were found between the non-specific arm pain group and the asymptomatic limb of the cervical radiculopathy group for either measure of the neurodynamic test ( $p > 0.70$ ).

Significant group differences were found for nerve palpation at all three sites, with both limbs of the cervical radiculopathy group and the non-specific arm pain group significantly different to the control group ( $p < 0.001$ ). There were no differences between the non-specific arm pain and cervical radiculopathy groups ( $p > 0.13$ ).

### **Pain, disability and kinesiophobia**

Results for measures of pain, disability and kinesiophobia are presented in Table 4. There were significant differences between the cervical radiculopathy group and the non-specific arm pain group for all measures ( $p \leq 0.01$ ) except pain intensity ( $p = 0.37$ ). The cervical radiculopathy group recorded higher scores of kinesiophobia ( $p = 0.02$ ) and disability ( $p = 0.02$ ) as well as higher scores on the LANSS questionnaire ( $p \leq 0.01$ ). Five (29%) of the cervical radiculopathy group recorded a score of  $\geq 12$  (out of 24) on the LANSS questionnaire, suggesting possible neuropathic pain compared with 4 (10%) of the non-specific arm pain group. No significant correlations were found between results from QST and any measure of the following measures: neural tissue sensitization, self-reported measures of neuropathic pain, kinesiophobia, and disability or pain ( $p > 0.05$ ).

### **Exploratory Factor Analysis**

Exploratory factor analysis was conducted on the data from the non-specific arm pain group and revealed four components based on eigenvalues  $> 1$ . The weights of the extracted components (based on a significance level of  $p \leq 0.05$ ), identified four components which explained 79% of the variance. The first component was a measure of pressure pain sensitivity explaining 39% of the variance, the second component a measure of thermal pain sensitivity (heat and cold) explaining 20% of the variance, the third component a measure of vibration hypoesthesia explaining 11% of the variance and the fourth component a measure of neural tissue sensitivity (neurodynamic test range of elbow extension and pain as well as nerve palpation) explaining 9% of the variance. Between group comparisons, corrected for the effect of age, revealed significant differences for each component ( $p \leq 0.003$ ) (Table 4). Post-hoc analyses revealed that pressure and thermal pain sensitivity distinguished the non-specific arm pain group, while vibration hypoesthesia was significantly different between the cervical radiculopathy group and the control group ( $p = 0.03$ ) with no difference between the non-specific arm pain group and healthy control group ( $p = 0.53$ ) or cervical radiculopathy group ( $p = 0.09$ ).

## **DISCUSSION**

The main findings of this study indicate that non-specific arm pain is characterised by widespread pressure and thermal hyperalgesia, which accounts for 59% of the variance in this group. Thermal hyperalgesia was also found to be more characteristic of non-specific arm pain than cervical radiculopathy. While vibration hypoesthesia was evident in both groups compared to controls,



results from factor analysis found it to be more characteristic of the cervical radiculopathy group, even when the difference in age was accounted for. Hypoaesthesia to thermal stimuli was only evident in the cervical radiculopathy group and both groups demonstrated evidence of neural tissue sensitization.

Two primary differences were identified in this study between the clinical groups. First, the non-specific arm pain group demonstrated more widespread hyperalgesia than cervical radiculopathy, with cervical radiculopathy participants only found to have pressure and cold sensitivity in the upper limb sites and not at the distal site of Tibialis Anterior muscle. This is despite the fact that both groups had a mean duration of symptoms of between 4 and 5 years and reported similar levels of pain intensity. This result suggests that the pathophysiology underlying non-specific arm pain is more likely associated with central sensitization and/or widespread peripheral sensitization than in cervical radiculopathy.

The second main difference between the groups relates to the presence of both thermal and vibration hypoaesthesia in cervical radiculopathy, whereas subjects with non-specific arm pain demonstrated vibration hypoaesthesia only. Furthermore, the results from the factor analysis indicate that the vibration hypoaesthesia component accounted for only 11% of the variance in the non-specific arm pain and that it characterised cervical radiculopathy significantly more than non-specific arm pain, even when corrected for age. Previous studies have reported the presence of hypoaesthesia to vibration, which has been interpreted as indicating a minor large fibre neuropathy<sup>4 38</sup> although others suggest it is consistent with altered central processing.<sup>13</sup> The interpretation of the results for vibration data in this study is open to ambiguity. On one hand, the presence of widespread hyperalgesia would lend weight to the argument that vibration hypoaesthesia is secondary to altered central processing, a scenario explained by Apkarian et al.<sup>39</sup> as a reverse pain gate mechanism. However, the fact that the symptomatic limb in those with unilateral non-specific arm pain demonstrated significantly more vibration hypoaesthesia compared with the asymptomatic limb lends credence to the argument for the presence of a minor large fibre neuropathy. Finally, it is important to consider whether mean/median values of vibration thresholds as low as 0.5 to 0.8 $\mu$ m as recorded in this study and others<sup>4 13 17</sup> are suggestive of a diagnosis of a neuropathy when compared with values recorded in carpal tunnel syndrome and diabetic neuropathy (0.9 to 1.1 $\mu$ m).<sup>40 41</sup>

Neural tissue sensitization was demonstrated in both of the clinical groups tested, a finding consistent with many previous reports in non-specific arm pain<sup>7-9 42</sup> but which in this study did not distinguish the two clinical groups from one another. A positive neurodynamic test was recorded in 31 of the 40 participants with non-specific arm pain, which demands that the symptoms are reproduced at least in part and that structural differentiation points to the neural tissue as the source of symptoms. Despite

this, it was most interesting to note that while differences were recorded in terms of pain and range of motion between the symptomatic and asymptomatic limbs in the cervical radiculopathy group, this was not the case in the non-specific arm pain group. This would suggest that relying on side-to-side differences in range of motion to interpret the test as positive would likely be misleading in the non-specific arm pain group. This finding also supports the hypothesis that non-specific arm pain may be principally characterised by widespread hyperalgesia which includes neural tissue and that the reduction in range of motion associated with a positive responses reflects a protective flexor withdrawal response mediated by the central nervous system.<sup>43</sup> Other hypotheses include sensitization of the nervi nervorum and inflammation of the neural tissue i.e. neuritis, both of which may lead to the finding of neural sensitization to movement or pressure.<sup>44</sup>

In some previous studies, the assertion that the pathophysiology underlying non-specific arm pain relates to a neuropathy and/or neuropathic pain has been made.<sup>44 45</sup> In this respect, it is interesting to note that only four participants presented with possible neuropathic pain as screened using the LANSS questionnaire. Furthermore, considering recently proposed criteria for the classification of neuropathic pain,<sup>46</sup> few of the non-specific arm pain group would have been considered for this classification as a history of a nerve lesion was impossible to identify. The presence of vibration hypoaesthesia is ambiguous as previously outlined, while the presence of neural tissue sensitization could be interpreted as either evidence of a more generalised sensitization or a specific neural tissue disorder. These results combined would imply that the results should be interpreted cautiously and while there may well be a degree of neurogenic pain, the presence of a neuropathy and/or neuropathic pain is unlikely to be the main pathology in the majority of this cohort.

The presence of widespread hyperalgesia, while a novel finding in non-specific arm pain, has been observed in a multitude of other chronic musculoskeletal cohorts such as whiplash,<sup>47</sup> office workers with neck pain,<sup>14</sup> low back pain,<sup>19</sup> and lateral epicondylagia.<sup>48</sup> Interestingly, the presence of cold hyperalgesia, particularly when present with other indicators of sensitivity, has been identified as predictive of poor outcomes in whiplash<sup>47 49</sup> and characterises people with lateral epicondylagia who have higher pain and disability levels. Therefore, perhaps the presence of thermal hyperalgesia, as well as the other evidence of sensitization could explain some of the chronicity that has previously been reported in non-specific arm pain.<sup>50</sup> While such widespread findings of hyperalgesia points to sensitization of the central nervous system, it is important to note that mechanisms of sensitization involve a complex interplay of peripheral and central events. There is evidence that sensitization of primary sensory neurons to thermal or mechanical stimuli occurs secondary to inflammation,<sup>51</sup> which would lower the threshold of primary sensory neurons to these stimuli, allowing lower temperatures and lighter pressure to be registered as painful. This is relevant in work related upper limb disorders, considering findings from animal studies, whereby animals performing repetitive low or negligible

load tasks demonstrated widespread expression of inflammatory mediators.<sup>52,53</sup> Another mechanism of peripheral sensitization is hyperalgesic priming, which is a form of nociceptor plasticity that causes nociceptors to become hyper-responsive to input that normally does not evoke pain.<sup>54</sup> The initial event is thought to be a response to an acute inflammatory event or an environmental stressor and subsequently these nociceptors demonstrate hyperalgesic responses to further repeated (mild) stimuli.<sup>54</sup> As exposure to environmental stressors may be one of the causes of hyperalgesic priming, psychosocial factors are important to consider in conditions like non-specific arm pain as previously demonstrated.<sup>5</sup> The non-specific arm pain group in this study, on the whole, demonstrated low levels of disability and kinesiophobia and none of the pain or disability measures correlated with any sensory measures. This finding is in line with previous research by Johnston and colleagues;<sup>55</sup> however, measures such as stress, anxiety and workstyle, which weren't assessed in this study, may be important features to examine.

There are a number of limitations associated with this study. Participants in the cervical radiculopathy group were older than the other groups, which may have affected detection thresholds. However, interestingly, an effect of age was only identified for the component neural sensitization during between group comparisons of the components identified in factor analysis. There may also have been some validity in testing other measures of neural sensitivity, such as the straight leg raise, to facilitate differentiation between local neural sensitivity of the upper limb and more generalised sensitization.

In conclusion, the findings from this study are important in providing a better understanding of the possible pathophysiological mechanisms in non-specific arm pain. These results should guide clinicians to assess for the possible presence of general sensitization e.g. to cold, heat and pressure as well as neural sensitization in these patients, alongside screening for neuropathic pain. The basis for the classification of neuropathic pain in the majority of non-specific arm pain participants should be carefully considered. Finally, in terms of intervention, this research would support the basis for interventions which target widespread sensitization and neural tissue sensitization, while those which potentially aggravate an already sensitised state should be avoided. However, further research is warranted into the effectiveness of various interventions in this group.

## Competing Interests

No conflict of interests exists.

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**Figure Legends**

Figure 1 Study design

Figure 2 Neurodynamic testing: range of elbow extension

Figure 3 Neurodynamic testing: numerical pain rating

**Table Legends**

Table 1 Demographic details

Table 2 QST comparisons between groups non-specific arm pain, cervical radiculopathy and controls

Table 3 QST comparisons between unilateral non-specific arm pain (asymptomatic and symptomatic limbs) (n = 32) and controls (n = 40)

Table 4 Self reported pain and disability questionnaires: Median (IQR) and results from Mann-Whitney U tests

Table 5 Results from ANCOVAs for comparisons of components identified during factor analysis between groups non-specific arm pain, cervical radiculopathy and Controls