Normal response to Upper Limb Neurodynamic Test 1 and 2A

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The aim of this study was to establish normal range of motion (ROM) and sensory responses to Upper Limb Neurodynamic Test 1 (ULNT1) and ULNT2A, and to investigate gender and arm dominance influences. ULNT1 and ULNT2A without and with structural differentiation were tested on both arms of 90 healthy participants. At end range the elbow angle was measured for ULNT1 and the shoulder abduction angle for ULNT2A. Participants reported where they felt a sensory response and the nature of response. Results showed a wide range of ROM response. Structural differentiation (STD) significantly (p < 0.01) reduced ROM by 7° (ULNT1) and 10° (ULNT2A). Sensory response was felt more proximally during both tests with STD. There was a statistically significant difference of 2° in ROM during ULNT1 (p = 0.01) between dominant and non-dominant arm but not during ULNT2A (p > 0.05). Even though this difference is statistically significant, it may not be clinically significant. In the dominant arm less sensory response was felt and in the non-dominant arm the response was more of neurogenic nature. Gender did not significantly (p > 0.05) influence ROM or sensory response. These results strengthen the evidence base for clinical practice how to evaluate outcomes from ULNTs.

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1. Introduction

Neurodynamics has become increasingly popular as part of the assessment and treatment of musculoskeletal injuries (Lewis et al., 1998). Different tests were developed to assess movement and mechanosensitivity of nerves with Upper Limb Neurodynamic Tests (ULNT) using specific techniques to bias for median, ulnar and radial nerve (Butler and Gifford, 1989). ULNT1 was first described by Elvey in 1979, with ULNT2A later developed as an alternative for patients unable to place their shoulders into the required position for ULNT1 (Butler, 1991). These tests are thought to add tensile stress to the median nerve (Butler and Gifford, 1989).

Research has primarily focused on ULNT1 investigating its validity using cadavers (Lewis et al., 1998; Kleinrensink et al., 2000; Byl et al., 2002), its specificity and sensitivity to diagnose cervical radiculopathy (Wainner et al., 2003), the effect of different joint movements (Coppieters et al., 2001a, 2002a), or pain response (Van der Heide et al., 2001). ULNT2A is less frequently researched and to our knowledge only Reisch et al. (2005) investigated the reliability, range of motion (ROM), and sensory response.

Clinicians evaluate neurodynamic tests using ROM and sensory response (Butler and Gifford, 1989) by comparing sides and/or relating results to normal values (Nee and Butler, 2006). They also declare a test positive if symptoms are reproduced (Butler and Gifford, 1989). Structural differentiation (STD) helps to determine if the response is caused by musculoskeletal or neural tissues (Butler, 1989). There are different ways of performing STD for ULNTs (e.g. ipsilateral lateral flexion of cervical spine, shoulder girdle elevation, straight leg raise), however, in research most frequently contralateral lateral flexion of the cervical spine is applied (Van der Heide et al., 2001; Coppieters et al., 2001a, 2002a). Before evaluating tests in patients it is essential to have sound knowledge of the responses in healthy subjects. However, to date there is little research available providing this information.

During ULNT1 mean elbow extension angles of 169° ± 14° which reduced to 144° ± 16° with STD were reported (Coppieters et al., 2001a; 2002b). The range of extension angles was between 137° and 185° reducing to 125°–177° with STD (Coppieters et al., 2002b) and a different source reported 120°–180° (Pullos, 1986). For ULNT2A Reisch et al. (2005) reported mean shoulder abduction angles of 36.7° ± 8.5° (Trial 1) and 38.4° ± 7.0° (Trial 2).

Limited information is available regarding the area and nature of sensory response to ULNT1 and ULNT2A. Kenneally et al. (1988) reported a deep stretch/ache in the anterior elbow extending to the hand in 80% of healthy subjects. Other responses were tingling in the thumb, first and second finger (77%) and 10% reported a stretch along the anterior shoulder (Butler and Gifford, 1989). With STD the response was felt more proximal to the elbow (Coppieters et al., 2002a). Reisch et al. (2005) reported the response to ULNT2A to be mostly pulling, burning and tingling felt at the...
lateral hand (74%), lateral forearm (74%), cubital fossa (62%) and lateral upper arm (7%).

When establishing normal values gender and/or arm dominance could influence results, however, limited research has investigated this. Pullos (1986) did not reveal gender differences when 100 healthy subjects were examined. Regarding the influence of arm dominance, Owen and Brew (2000) reported a significantly greater elbow ROM (7°; \( p < 0.05 \)) in the dominant arm during ULNT1. Pullos (1986) similarly found a difference of 8


Regarding ULNT2A, one assessor in the study by Reisch et al. (2005) measured a 9° increase in ROM in the dominant arm, although the second assessor did not find a difference between arms. This discrepancy may be due to the poor (ICC \( = 0.33 \)) inter-tester reliability (Reisch et al., 2005). This conflicting research shows the need for additional supporting evidence that the non-affected arm can be used as reference for evaluating tests.

One aim of this study was to investigate differences between gender, arm dominance, and STD in response to ULNT1 and ULNT2A in normal subjects. Prior to this, the reliability of two and three repeated measurements of both, ULNT1 and ULNT2A was established. The second aim was to investigate sensory response to ULNT1 and ULNT2A in terms of frequency and nature of response in different areas. Differences in sensory response depending on arm dominance and gender were also examined.

2. Methods

2.1. Participants

Inclusion criteria for the study were: aged 18–50 years and free from upper limb and/or neck injury within the last three months. Subjects were excluded if they reported any contra-indications and/or precautions (Butler, 1991). Arm dominance was recorded and defined as the hand they write with.

Twenty participants (10 female, 10 male) were recruited to assess reliability the elbow extension angle during ULNT1 and shoulder abduction angle for ULNT2A. Their mean age \( \pm \) standard deviation (range) was 27.9 \( \pm \) 6.2 years (20.0–40.0 years).

For the main study 90 participants (22.9 \( \pm \) 6.0 years; range: 18.0–49.0 years) from a convenient sample of 100 sport science students were included. Ten subjects were excluded due to previous repeated shoulder (sub)luxations. Forty female (age: 22.3 \( \pm \) 5.3 years; range: 18–49 years; 85% right-handed) and 50 male participants (23.4 \( \pm \) 6.5 years; range: 18.0–40.0 years; 88% right-handed) completed the study of which 77% regularly took part in different sports (e.g. football, running, hockey, lacrosse, cricket, swimming).

2.2. Procedure

Ethical approval was granted by the Departmental Ethics Committee from the University of Hull. All participants read an information sheet and signed an informed consent form prior to the study.

For both, the reliability and main study, ULNT1 and ULNT2A were carried out without and with STD on both arms. Test order was determined randomly and participants had a break (10 min) mid-testing to ensure that they did not feel persisting response in the upper limb. All tests were carried out by one investigator (ML) and measurements conducted by another (KS).

For the reliability study each test was repeated three times with 30 s rest in between. The results showed that measurements were equally reliable when repeated twice or three times (Table 1). To keep testing time and response to a minimum, tests were repeated twice for the main study.

Upper limb bony landmarks (ulnar styloid process, medial epicondyle of the humerus, and anterior aspect of the acromion process) were marked to use as reference points for the joint angle measurements. To measure joint angles a goniometer (Lafayette Instrument Co., IN, USA) was used, with the display not visible for the investigator during measurements to avoid bias. For the elbow angle the axis was placed on the medial epicondyle with the stationary arm pointing to the acromion and the moving arm to the ulnar styloid process. Shoulder abduction angle was measured by placing the axis on the acromion, with the stationary arm aligned parallel to the sternum and the moving arm aligned with the ulnar styloid process.

For all tests participants lay supine, without a pillow, arms along the body and legs straight. Tests were carried out slowly and participants were instructed to indicate the point where it was too uncomfortable to continue with the movement (point of pain tolerance), where angle measurements were taken. Once the test was released, the location and nature of sensory response was marked on a body chart. Participants were asked as an open question about the nature of sensory response but if difficulties finding a descriptor arose they were prompted with the following: stretch, pain, tingling, pins and needles, numbness, and burning. Multiple responses to both, area and nature of sensation were allowed.

The starting position for ULNT1 was 90° abduction and 90° external rotation of the shoulder, 90° elbow flexion, forearm supination, and maximum extension of wrist and fingers. One hand of the investigator was placed on the scapula to prevent elevation, the other hand maintained finger extension. Then the elbow was slowly extended until the point of pain tolerance and the elbow angle was measured.

For ULNT2A the participant moved to the side of the plinth and the investigator depressed the shoulder with her thigh. The starting position of the arm was no shoulder abduction, shoulder external rotation, elbow extension and supination, maximum wrist and finger extension. One hand of the investigator ensured finger and wrist extension, the other elbow extension. From this position, the arm was slowly abducted until the point of pain tolerance where the angle was measured. When the tests with STD were carried out the participant’s head was placed in maximum contralateral lateral flexion without causing discomfort, followed by ULNT1 or ULNT2A.

2.3. Data analysis

Reliability of two and three measurements was calculated with an Intra-class correlation coefficient (ICC (2,1)). The standard error

| Table 1: Standard error of measurement and smallest real difference. |
|-----------------|----------------|-----------------|----------------|----------------|
|                  | ULNT1 | ULNT1 STD | ULNT2A | ULNT2A STD |
| Dominant         |       |           |       |           |
| ICC 3 repeats    | 0.93  | 0.94      | 0.97  | 0.92      |
| SEM              | 2.18  | 3.94      | 1.65  | 4.33      |
| SRD              | 6.05  | 10.93     | 4.57  | 11.99     |
| ICC 2 repeats    | 0.93  | 0.94      | 0.96  | 0.90      |
| SEM              | 2.32  | 3.91      | 1.96  | 4.77      |
| SRD              | 6.42  | 10.83     | 5.42  | 13.21     |
| Non-dominant     |       |           |       |           |
| ICC 3 repeats    | 0.92  | 0.87      | 0.95  | 0.93      |
| SEM              | 3.37  | 5.80      | 2.26  | 3.83      |
| SRD              | 9.33  | 16.09     | 6.26  | 10.62     |
| ICC 2 repeats    | 0.91  | 0.86      | 0.96  | 0.95      |
| SEM              | 3.48  | 6.02      | 2.05  | 3.24      |
| SRD              | 9.65  | 16.70     | 5.67  | 8.97      |

SEM was calculated using the formula SEM = SD × √(1-ICC) (Weir, 2005) and the smallest real difference (SRD) by using the formula 1.96 × √2 × SEM (Beckerman et al., 2001).

For the main study mean joint angles from the two measurements were calculated and used for further analysis. Normal distribution Q–Q plots showed that data was normally distributed. Descriptive statistics for elbow extension (ULNT1) and shoulder abduction (ULNT2A) angles for both arms were reported as mean, standard deviation (SD) and range. Gender, arm dominance and STD were independent variables when applying a 3-way repeated measure ANOVA for ROM during ULNT1 and ULNT2A.

After data collection all sensory responses were collated on a body chart and for analysis the body chart was divided into 14 areas where subjects reported sensory response (Fig. 1). Frequency of sensation in the different areas was counted as present or not regardless its nature. Differences in frequency of response between the tests, addition of STD, and arm dominance were investigated using a McNemar test. Gender differences were analysed applying a Chi² test.

The nature of sensation was divided into six categories: stretch, pain, tingling, pins and needles, numbness, and burning. The frequency of nature of sensory response between ULNT1 and ULNT2A with and without STD was compared as well as gender and arm dominance differences.

All statistical calculations were carried out using SPSS version 16.0 and the level of significance was set at α < 0.05.

3. Results

Descriptive statistics for elbow extension (ULNT1) and shoulder abduction angles (ULNT2A) are presented in Table 2.

3.1. 3-way repeated measure ANOVA

Results for ULNT1 and ULNT2A did not reveal any interaction effect between the three factors (arm dominance, STD and gender) or between any two of the three factors.

There was a statistically significant difference between ULNT1 and ULNT1 with STD (143.0° ± 9.9°; 136.6° ± 11.0°; p < 0.01) and for ULNT2A and ULNT2A with STD (72.0° ± 21.7°; 62.2° ± 17.9°; p < 0.01). The ANOVA revealed a statistically significant difference between both arms (dominant: 139.8° ± 10.9°; non-dominant: 137.9° ± 12.3°; p = 0.01) for ULNT1 but not ULNT2A, and no gender differences for either test.

3.2. Sensory response

Every subject reported a sensory response and the nature of response fitted the six given descriptors. The frequency of responses in the different areas for both arms is shown in Table 3. The main findings were that during ULNT2A a sensory response was felt more frequently compared to ULNT1, the response was felt more proximally with STD and more responses were felt in the non-dominant arm. Gender did not significantly influence the sensory response for most tests.

Fig. 2 shows the nature of sensory response in the dominant and Fig. 3 that of the non-dominant arm. The results are reported as a percentage from all given descriptors. The most frequently reported response was stretch (58–63%), followed by pain (20–27%) and tingling (8–11%). All other descriptors accounted for less than 10%. In the dominant arm (Fig. 2) more frequently pain, tingling and pins and needles were reported during ULNT2A than in the non-dominant arm (Fig. 3).

Fig. 1. Body chart divided in 14 areas where sensory response was felt.
Adding STD to ULNT1 or ULNT2A reduced the frequency of stretch response and an increase in pain. In the non-dominant arm, during ULNT1 more frequently stretch, numbness and burning was reported compared to ULNT2A where pain was more frequently named. Adding STD to ULNT1 and ULNT2A in the non-dominant arm resulted in an increase in pain sensation, and in ULNT1 less frequently sensations of burning, numbness and pins and needles were noticed. During ULNT2A with STD less tingling, but more pins and needles and burning sensations were reported.

4. Discussion

The results from this study showed a wide range of normal values for both ULNT1 and ULNT2A and without and with STD. Arm dominance influenced ROM for ULNT1 only, whereas gender had no influence for either test. As expected, STD significantly reduced ROM for ULNT1 and ULNT2A.

In the present study the mean elbow ROM for ULNT1 was 26° less than that reported by Coppieters et al. (2001a,b, 2002b) and 7° less for ULNT1 with STD. The discrepancy in results may be linked to methodological or subject differences. Coppieters et al. (2001a,b, 2002b) placed the wrist in 70° extension, used and electromiometer for angle measurements and included a lower number (n = 35) of male participants with a more narrow age range compared to the present study. The range of elbow extension for ULNT1 in the present study was 118°—171°, similar to that of 120°—180° reported by Pullos (1986) and slightly lower than the 137°—185° stated by Coppieters et al. (2002b). For ULNT2A the present study reported a mean value of 72° ± 21° abduction ranging from 31° to 118°. The mean and SD is nearly twice as high as that of 36.7° ± 8.5° previously reported by Reisch et al. (2005). The test protocols were similar between the studies, however, Reisch et al. (2005) used different landmarks to measure the abduction angle which might explain some of the difference. Also, Reisch et al. (2005) might have applied a different level of shoulder depression than the present study which might have contributed to the different results. The wide range of normal values found in this study together with previous literature strengthen the reasoning behind the clinical practice of not solely evaluating tests by comparing findings to normative values but also compare sides and take symptom response into consideration.

It was expected that the mean ROM for both tests would be reduced with STD as this elongates the nervous system more, therefore reducing the nerve movement (Byl et al., 2002). Previous studies reported a reduction of the mean angle for ULNT1 of 17° (Coppieters et al., 2002a) and 25° (Coppieters et al., 2001b, 2002b), far higher than the 7° observed in the present study. Coppieters et al. (2001b, 2002a) standardised the degree of shoulder depression whereas in the present study the participants were instructed to move as far as it was comfortable. This methodological difference

### Table 2

Descriptive statistics for Range of Motion results during ULNT1 and ULNT2A.

<table>
<thead>
<tr>
<th>Test</th>
<th>Dominant arm</th>
<th>Non-dominant arm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>Female</td>
</tr>
<tr>
<td>ULNT1</td>
<td>143.0 ± 10.0</td>
<td>144.0 ± 10.2</td>
</tr>
<tr>
<td>(117.5—170.5)</td>
<td>(127.0—170.5)</td>
<td>(117.5—164.5)</td>
</tr>
<tr>
<td>ULNT1 with STD</td>
<td>136.6 ± 10.9</td>
<td>138.4 ± 12.2</td>
</tr>
<tr>
<td>(117.0—169.0)</td>
<td>(117.0—169.0)</td>
<td>(118.0—155.0)</td>
</tr>
<tr>
<td>ULNT2A</td>
<td>72.0 ± 21.7</td>
<td>70.0 ± 24.2</td>
</tr>
<tr>
<td>(30.5—119.0)</td>
<td>(30.5—119.0)</td>
<td>(42.0—113.5)</td>
</tr>
<tr>
<td>ULNT2A with STD</td>
<td>62.2 ± 17.9</td>
<td>61.0 ± 20.4</td>
</tr>
<tr>
<td>(30.5—115.0)</td>
<td>(30.5—115.0)</td>
<td>(34.5—107.5)</td>
</tr>
</tbody>
</table>

### Table 3

Frequency of sensory response in the different areas for the dominant and non-dominant arm.

<table>
<thead>
<tr>
<th>Area</th>
<th>Dominant</th>
<th>Non-dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ULNT1</td>
<td>ULNT1 STD</td>
</tr>
<tr>
<td>1</td>
<td>14°</td>
<td>13°</td>
</tr>
<tr>
<td>2</td>
<td>7°</td>
<td>5°</td>
</tr>
<tr>
<td>3</td>
<td>21°^a</td>
<td>20°</td>
</tr>
<tr>
<td>4</td>
<td>18°</td>
<td>16°</td>
</tr>
<tr>
<td>5</td>
<td>23°^b</td>
<td>31°</td>
</tr>
<tr>
<td>6</td>
<td>47°^b,c</td>
<td>53°</td>
</tr>
<tr>
<td>7</td>
<td>23°^b</td>
<td>33°^b</td>
</tr>
<tr>
<td>8</td>
<td>4°^b</td>
<td>14°</td>
</tr>
<tr>
<td>9</td>
<td>0°</td>
<td>4°</td>
</tr>
<tr>
<td>10</td>
<td>3°</td>
<td>6°</td>
</tr>
<tr>
<td>11</td>
<td>1°</td>
<td>0°</td>
</tr>
<tr>
<td>12</td>
<td>3°^a</td>
<td>4°</td>
</tr>
<tr>
<td>13</td>
<td>3°</td>
<td>3°</td>
</tr>
<tr>
<td>14</td>
<td>0°</td>
<td>0°</td>
</tr>
<tr>
<td>Total</td>
<td>167°</td>
<td>202</td>
</tr>
</tbody>
</table>

^a Statistically significant difference (p < 0.05) between ULNT1 and ULNT2A.
^b Statistically significant difference (p < 0.05) between ULNT1 and ULNT1 with STD.
^c Statistically significant difference (p < 0.05) between ULNT2A and ULNT1 with STD.
^d Statistically significant difference (p < 0.05) between ULNT1 and ULNT2A with STD.
^e Statistically significant difference (p < 0.05) between dominant and non-dominant arm for ULNT1.
^f Statistically significant difference (p < 0.05) between dominant and non-dominant arm for ULNT2A.
^g Statistically significant difference (p < 0.05) between dominant and non-dominant arm for ULNT1 with STD.
^h Statistically significant difference (p < 0.05) between dominant and non-dominant arm for ULNT2A with STD.
found a difference of 8° range with STD during ULNT2A. The present results showed a reduction was caused by STD or measurement error. The dominant arm therefore it could be questioned whether this change is not due to measurement error.

No previous study has reported changes in shoulder abduction range with STD during ULNT2A. The present results showed a reduction of 8° for the non-dominant and 10° for the dominant arm. The SRD for ULNT2A with STD was 9° and 13° for the non-dominant and dominant arm, respectively, therefore, the changes with STD may not be caused by the addition of STD but by measurement error. Maybe using a different movement (e.g. shoulder elevation) as STD would produce different results and might be more appropriate to use in clinical practice. More research should be carried out to establish more supporting evidence for clinical application of STD.

To determine if a test is positive or not bilateral comparison is recommended in clinical practice (Nee and Butler, 2006). Current findings indicate a significant difference in ROM between both arms for ULNT1 which clinicians should take into consideration when evaluating results. However, only a 2° difference was observed which may not be clinically significant and considering the SRD of 6° (dominant arm) and 9° (non-dominant arm) these results might be due to measurement error. Owen and Brew (2000) and Pullos (1986) found a difference of 8° which was claimed to be statistically significant by Owen and Brew (2000) and non-significant by Pullos (1986). These conflicting results show the need for further research in this area to be able to give clear recommendations to clinicians.

Gender did not influence the results from the present study for both, ULNT1 and ULNT2A which is in accordance with Pullos (1986). This finding indicates that normative values obtained from mixed gender samples are valid to be used for females and males equally.

A clear pattern of frequency and nature of sensory response could not be established for all tests due to high variation. Overall, the areas of sensory response corresponded with those reported by Kenneally et al. (1988) and Butler and Gifford (1989) who stated the highest frequency of response to be felt in the area of anterior elbow extending to the hand. The present study also found responses in the area of posterior arm and shoulder. These areas are more extensive than the sensory distribution of the median nerve which might suggest that sensory response during ULNT1 originates from the nerve roots rather than the peripheral nerve.

Similar areas of response were observed between ULNT1 and ULNT2A, however, sensory response was reported more frequently during ULNT2A. The nature of response was more neurogenic (i.e. pins and needles, burning, tingling) during ULNT2A compared to ULNT1. This may indicate that during ULNT2A changes in the mechanosensitivity of the nerve root may produce sensory response and that during ULNT1 other structures, such as muscles, can be responsible for this. It was also shown that the activity of trapezius, biceps and pectoralis major muscles increased when extending the elbow during ULNT1, indicating a protective mechanism of the nerves from tensile forces which could cause a sensory response of stretch (Jaberzadeh et al., 2005).

Adding STD to ULNTs increases the tension in the median nerve (Ryl et al., 2002), resulting in reduced ROM (Coppier et al., 2001a,b) and might change the sensory response. Results showed that with STD the frequency of response significantly increased in the areas proximal and decreased distal to the elbow which is in accordance with findings from Coppier et al. (2002a). This observation might be caused by either increased tensile force of the nerve, causing decreased circulation (Ogata and Naito, 1986) or by a change in trapezius activity due to lengthening of the muscle (Van der Heide et al., 2001).

The present study found a difference in sensory response between the dominant and non-dominant arm which needs to be taken into consideration by clinicians when evaluating the tests. During ULNT1 with and without STD and ULNT2A with STD sensory responses were reported more frequently in the non-dominant. This may be due to less frequent and maybe reduced movement of the non-dominant arm during daily living, thus, making the nerves more sensitive to stretch. This might also explain the more frequent neurogenic sensation in the non-dominant arm.

The most frequently reported nature of response during all tests was a stretch followed by pain. Participants frequently reported “painful stretch” which was analysed as pain and stretch separately and may explain the high prevalence of these responses. These results are in accordance with findings by Kenneally et al. (1988) who stated that up to 99% of participants felt a stretch during ULNT1. They also reported a response up to 77% to be tingling in compared with around 10% in the present study. The addition of STD did not consistently change the nature of sensory response in the present study which might be linked to the chosen method of STD. The lack of neurogenic responses in the present study might be because healthy subjects were included and therefore the point of pain tolerance was not determined by neural tissues but by other tissues causing a stretch or painful response. Moses and Carman (1996) demonstrated that nerves attach to vertebral bodies, intervertebral discs and the posterior longitudinal ligament which may also be the cause of the pain. To date it is not clear which anatomical structures cause the end range and sensory response during ULNT1 and ULNT2A in healthy subjects which should be investigated further.
5. Conclusion

The results of the present study provide more evidence for large individual differences as response (ROM and sensory) to ULNT1 and ULNT2A which highlights the need for bilateral comparison. However, there are differences in ROM, frequency and nature of sensory response between the dominant and non-dominant arm which can be normal and need to be acknowledged by the clinician when evaluating results from neurodynamic tests.

Sensory response in healthy subjects does not only occur in the area of median nerve distribution but also in other areas of the arm. The nature of response in healthy subjects was mainly a stretch and pain, therefore not predominantly neurogenic and hence the source of sensory response in healthy subjects might not be solely nervous tissue.

References