



Original article

Side-to-side range of movement variability in variants of the median and radial neurodynamic test sequences in asymptomatic people

Vaidas Stalioraitis^a, Kim Robinson^b, Toby Hall^{b,*}^a Manual Concepts, Perth, Western Australia, Australia^b School of Physiotherapy, Curtin Innovation Health Research Institute, Curtin University of Technology, Hayman Road, Bentley, Perth, Western Australia, Australia

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ABSTRACT

Side-to-side discrepancy in range of motion (ROM) during upper limb neurodynamic testing is used in part to identify abnormal peripheral nerve mechanosensitivity and is one of three factors to consider in determining a positive test. Large side-to-side variability is reported for some variants of the upper limb neurodynamic test sequences, however discrepancies for other test variants are unknown. Hence the purpose of this study was to evaluate side-to-side discrepancy in elbow flexion ROM during two variants of upper limb neurodynamic test sequence for the median and radial nerves. 51 asymptomatic subjects (26 females, mean age 29.69 years) were evaluated. A uniaxial electrogoniometer was used to measure elbow flexion ROM at onset of resistance (R1) and onset of discomfort (P1) during the median and radial neurodynamic tests on each side. Reliability was determined by testing 20 subjects twice and was found to be good (ICC greater than 0.88 and SEM less than 4.02°). There was no significant difference in mean ROM between sides. Lower-bound scores indicate that intra-individual, inter-limb differences of more than 15° for the median nerve and 11° for the radial nerve exceeds the range of normal ROM asymmetry on neurodynamic testing at R1 and P1. Correlation of ROM between limbs was significant with R^2 values of 0.62 and 0.85 for the median and radial nerves respectively. These findings provide clinicians with information regarding normal side-to-side variability in ROM during two commonly used variants of neurodynamic tests.

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1. Introduction

Upper limb neurodynamic tests are used to evaluate nerve trunk mechanosensitivity of the cervical nerve roots, brachial plexus and its terminal branches (Hall and Elvey, 2011). Range of motion (ROM) and responses (principally sensations and resistance to movement) during such tests are interpreted by comparing with normal responses and with those occurring when testing the asymptomatic side (Butler, 2000). Neurodynamic tests are important in clinical decision-making regarding diagnosis of peripheral nerve disorders (Rubinstein et al., 2007), hence these tests have the potential to direct management.

Clinically, neurodynamic tests are used to determine the presence of neural tissue pain disorders in patients with neck and/or arm pain, such as cervical radiculopathy or carpal tunnel syndrome (Wainner and Gill, 2000; Wainner et al., 2005). Such pain disorders

may arise from inflammation around peripheral nerves, which become mechanosensitized, and consequently display decreased tolerance to the mechanical stress of neurodynamic tests (Bove et al., 2003; Bove, 2009). Therefore, an indication of mechanosensitized neural tissue may be symptom provocation and ROM deficits, previously reported as important components of the evaluation process during neurodynamic tests (Hall and Elvey, 2011).

According to Elvey (Elvey, 1986), for a neurodynamic test to be positive, the patients symptoms must be reproduced, ROM diminished on the side tested compared to the unaffected side, and sensitizing manoeuvres must alter symptoms. Sensitizing manoeuvres (or structural differentiation) comprise proximal or distal remote joint movements to increase or decrease mechanical provocation on the tested neural tissue. These manoeuvres are important to differentiate between neural and non-neural involvement in upper limb pain disorders (Coppieters et al., 2002).

One of the reported factors for determining a positive neurodynamic test is side to side comparison for ROM (Nee and Butler, 2006). However, it must be recognized that ROM differences for

* Corresponding author. Tel.: +61 8938118363; fax: +61 8 93176022.
E-mail addresses: halltm@netspace.net.au, halltm62@mac.com (T. Hall).

neurodynamic tests exist between the upper limbs even in healthy individuals (Covill and Petersen, 2011; Lohkamp and Small, 2011) not accounted for by hand dominance (Lohkamp and Small, 2011). Despite small mean inter-limb difference of only 4°, large intra-individual discrepancies were reported for variants of the upper limb neurodynamic tests (Covill and Petersen, 2011). Lower-bound scores (upper limit of tolerance interval) were calculated to determine the amount of difference needed to consider asymmetry beyond measurement error. The scores for each neurodynamic test were as follows: median nerve 27°, radial nerve 20°, and ulnar nerve 21°. This is the first time such scores have been reported and indicate a large potential for error when interpreting neurodynamic tests in the absence of symptom reproduction, and when side-to-side differences in ROM are small.

In the study by Covill and Petersen (2011), cervical lateral flexion was not included in the test sequence. This movement is an important component of neurodynamic testing as it significantly influences responses during testing (Coppeters et al., 2001). Omitting this movement may increase variability in nerve strain both between individuals and across sides tested. In addition, the end point for each test was measured only at “firm resistance” determined by the examiner, other upper limb neurodynamic test variants and testing end-points may have a different side-to-side variability. Hence the purpose of this study was to evaluate side-to-side variation in elbow ROM during variants of the median and radial neurodynamic test sequences that included cervical lateral flexion. Two end-points were evaluated: onset of resistance (R1) determined by examiner, and the onset of the discomfort (P1) indicated by the subject.

2. Methods

2.1. Study design

A within subjects comparative measurement design was used to identify differences between sides in elbow ROM during upper limb neurodynamic tests in asymptomatic people. The primary variable of interest was elbow ROM during variants of the median and radial nerve neurodynamic tests.

2.2. Subjects

Fifty-one subjects (26 females and 25 males, mean age 29.69 years, SD 5.85) were included in the study. Volunteers were recruited from advertisements placed on physical and on-line notice-boards at Curtin University and by word of mouth. Subjects were recruited as a sample of convenience and selected on the basis of being asymptomatic and age over 18 years. A power calculation (based on using a two-tailed paired *t*-test with an α level 0.05 and power of 0.8, and a medium effect size of 0.5) indicated that a sample of 34 subjects was required for this study. The inclusion criteria required subjects to have full upper limb joint ROM, be right hand dominant, have no previous upper quadrant pathology or surgery, and no history of diabetes mellitus, rheumatologic diseases or neural disorders. Subjects prior to testing underwent upper quadrant screening examination to ensure they had full pain free ROM of the cervical spine, shoulder, elbow and wrist. In addition this study received approval from the Curtin University Human Research Ethics Committee and participants provided written informed consent before participation.

2.3. Materials and measurements

The independent variable evaluated in this study was side (left or right). The dependent variables were ROM of elbow extension measured by a uniaxial electrogoniometer (Biometrics Ltd, Nine Mile Point Ind Est, Gwent, UK), and nerve tested (median or radial).

The goniometer was fixed to the subjects arm with adhesive tape and calibrated at 0° (full elbow extension) before testing commenced. This electrogoniometer has been shown to have acceptable inter-rater and intra-rater reliability (Oliver and Rushton, 2011). In that study, intra-rater ICC values for reliability during median nerve neurodynamic testing were greater than 0.96, the standard error of measurement 2.6°, and smallest detectable difference 7.2° (Oliver and Rushton, 2011). Additionally, no significant differences were found in elbow ROM when inter-rater measurements were recorded (Goodwin et al., 1992), and acceptable levels of precision with measurement errors up to 3° (Lantz et al., 2003).

2.4. Procedure

Each subject was familiarized with the testing process. Each person was tested in a supine position with legs straight and the untested arm at the side of the body with the hand resting on the abdomen. For each neurodynamic test, the head/neck was passively placed in maximum contralateral lateral flexion and the scapula stabilized in neutral elevation/depression. No brace was used for fixation to mimic the clinical testing process, which has been previously described for each upper extremity nerve (Hall and Elvey, 2011). The electrogoniometer's axis was aligned with the subject's medial epicondyle for the median nerve, and to the lateral epicondyle for the radial nerve. The proximal arm of the goniometer was aligned with the midline of the humerus and the distal arm was aligned with the lateral midline of the ulnar or radius for measurement of the elbow during neurodynamic testing. The voltage was converted in real-time to degrees of elbow movement and manually recorded. Hyperextension was recorded as negative values, while positive values indicated the range short of full extension. Reliability of the measurements was determined by measuring the first 20 subjects twice. Between trial's, subject were given a 5-min rest-break before repeating the measurement procedures.

Neurodynamic tests for the median and radial nerve were examined in random order on both sides by a single physiotherapist with 5 years post-graduate clinical experience using published test protocols (Elvey and Hall, 1997). While these tests are intended to bias the median and radial nerve, they also affect the brachial plexus, cervical nerve roots and other structures. For each test sequence, the participant was given one familiarization trial before a single repetition of each test was carried out. Elbow ROM was recorded by a separate researcher. The goniometer output was not visible to the examiner to avoid bias.

A previous report has shown equal reliability when repeated measurements are used for pain tolerance (Lohkamp and Small, 2011), hence only one measurement was taken for each end-point and for each test. The end-point for each test was R1 and P1, both points have been shown to have a high degree of inter- and intra-rater reliability (Vanti et al., 2010).

2.5. Neurodynamic test sequence biased for the median nerve

The cervical spine was positioned in maximal lateral flexion to the contralateral side. The arm to be tested was positioned in 90° of glenohumeral flexion, followed by 90° horizontal extension, to achieve a position of 90° abduction and 90° external rotation. The elbow was flexed to 90° with forearm maximally supinated, and wrist/fingers maximally extended. The elbow was slowly extended and end-points measured.

2.6. Neurodynamic test sequence biased for the radial nerve

The cervical spine was positioned in maximal lateral flexion to the contralateral side. The arm to be tested was positioned in 90° of

Table 1
Reliability statistics for elbow range of motion for median and radial nerve neurodynamic tests ($n = 20$).

Measurement	ICC[2,1] (95% CI)	SEM ^a	MDC ^c
Right median R1	0.95 (0.89, 0.98)	2.48	6.87
Right median P1	0.91 (0.80, 0.96)	3.31	9.17
Right radial R1	0.94 (0.86, 0.97)	3.21	8.90
Right radial P1	0.96 (0.91, 0.98)	2.66	7.37
Left median R1	0.92 (0.81, 0.96)	3.21	8.90
Left median P1	0.88 (0.74, 0.95)	4.02	11.14
Left radial R1	0.94 (0.88, 0.98)	2.89	8.01
Left radial P1	0.89 (0.76, 0.95)	3.85	10.67

ICC = Intra-class correlation coefficient.

SEM = Standard error of the measurement.

MDC = Minimal detectable change.

glenohumeral abduction and maximum internal rotation. The elbow was flexed to 90°, with forearm maximally pronated, and wrist/fingers maximally flexed. The elbow was slowly extended and end-points measured.

3. Data analysis

Data analysis was carried out using SPSS v19. (SPSS Inc., 444 N. Michigan Avenue, Chicago, Illinois, 60611). Reliability for repeated measures on each arm for each of the two neurodynamic tests was calculated using ICC (2,1), SEM, and minimal detectable change (MDC). Mean elbow ROM and standard deviation was determined for each neurodynamic test sequence for each arm. Dependent *t*-tests were used to compare within-subject range of motion between the right and left arm for each test. Relationships in ROM between limbs was calculated using the Pearson correlation coefficient and Coefficient of determination (r^2). Since mean difference between limbs does not account for negative values, the mean absolute values (MAV) were calculated to determine differences between limbs while adjusting for negative scores (Covill and Petersen, 2011). A Lower-bound score, upper limit of a tolerance interval for a one-sided *t*-test, was used to determine the cut-off point at which the degree of difference between limbs could be considered greater than that accounted for by measurement error and variability. This calculation identified an upper threshold for which 95% of the left to right limb ROM differences can be expected in a similarly age matched population with 95% certainty (NIST/SEMATECH, 2012).

4. Results

All data were checked and found to be normally distributed. The results for intra-rater reliability are shown in Table 1. For both R1 and P1 measures, all ICC values indicate good reliability (Portney and Watkins, 2008). In addition the SEM and MDC for each

assessment point were also relatively small. Means and standard deviations for elbow ROM during the median and radial neurodynamic tests are presented in Table 2. The mean difference between sides, for both R1 and P1, was very small, and not significant as reflected by the 95% confidence intervals (Table 2).

Table 2 also shows the Pearson correlation analysis, which indicates a significant relationship between the limbs for ROM recorded during the median and radial neurodynamic tests. Furthermore, the R^2 values indicate a strong relationship for ROM between limbs, indicating that range of one side can be used to predict range of the opposite limb.

The MAV and Lower bound scores shown in Table 3 reveal relatively small variability between the right and left limbs for any assessment point. Elbow ranges recorded at R1 and P1 during the median nerve neurodynamic test were more variable than the same points assessed during the radial nerve neurodynamic test. These data indicate that we can be 95% sure that 95% of the similarly aged matched population would have between side differences in ROM of no greater than 15.5° for the median and 11.2° for the radial neurodynamic tests respectively.

5. Discussion

Although this study found small mean differences in ROM between sides for median and radial nerve neurodynamic tests, there was larger intra-individual variation in elbow ROM for each test. Despite this variation, ROM of one limb was related to ROM in the contralateral limb.

The mean difference between sides in elbow ROM found in this study is similar to the 2° reported by Lohkamp and Small (2011). In contrast, Van Hoof et al. (Van Hoof et al., 2012) found a slightly larger but significant mean difference of 3°. In that study ROM of the dominant side was compared to the non-dominant side. As subjects in our study were all right hand dominant we also effectively compared ROM in the dominant to non-dominant side and found no difference. One explanation may be the different measurement method. In the study by Van Hoof et al., an optoelectronic measurement device was used to measure ROM, and the scapula/neck stabilized by a brace. In the current study we used a method of measurement used clinically, with the exception of using an electrogoniometer to measure elbow ROM. In addition, subjects in Van Hoof et al. study were selected with an anatomical muscular variant, Langer's axillary arch, which may have influenced the results. Boyd (Boyd, 2012) found no effect of hand dominance, during the same neurodynamic test sequence reported by Van Hoof et al. (2012). The effect of hand dominance on ROM during upper limb neurodynamic test was also investigated by Reisch et al. (Reisch et al., 2005), who compared side-to-side variability in shoulder rather than elbow ROM, hence no direct comparisons can be made with the current study. In addition, the effect of hand dominance was not conclusive in that study.

Table 2
Mean range, mean differences between left and right sides (SD) with 95% confidence interval (CI), Pearson correlation coefficient (r), and coefficient of determination (R^2) ($n = 51$).

Measurement	Mean range (SD)		Mean difference scores (95% CI) ^a	r	R^2
	Left	Right			
Median R1	25.81 (11.37)	24.92 (11.13)	-0.88 (-2.94, 1.17)	0.79 $p < 0.001$	0.62
Median P1	25.51 (11.63)	24.06 (11.05)	-1.45 (-3.89, 0.99)	0.71 $p < 0.001$	0.50
Radial R1	14.84 (11.79)	16.86 (13.12)	1.14 (-0.24, 2.52)	0.93 $p < 0.001$	0.85
Radial P1	14.31 (11.61)	15.84 (13.39)	1.24 (5.63, 0.79)	0.91 $p < 0.001$	0.83

Table 3

Mean absolute differences (MAV) in elbow range of motion between right and left sides together with Lower-bound scores (95% confidence level) for neurodynamic testing of the median and radial nerve ($n = 51$).

Measurement	MAV (SD) ^a	Lower-bound scores ^b
Median R1	5.47 (4.88)	15.51
Median P1	5.80 (4.57)	15.18
Radial R1	4.24 (2.67)	9.72
Radial P1	4.76 (3.12)	11.17

This study found a high degree of correlation in ROM between limbs during each neurodynamic test (Table 2). Boyd (Boyd, 2012) also reported a strong correlation for elbow ROM between the dominant and non-dominant limbs with an R^2 of 0.78. These findings are in stark contrast to the study by Covill and Petersen (2011), which reported R^2 values of 0.14 indicating poor correlation between the limbs. The explanation for this difference to the current study and Boyd's study (2012) is not certain. In the study by Covill & Petersen the same neurodynamic test sequence was used as in the current study. Experienced examiners were used in each investigation, so other factors may be involved. In the current study we evaluated end points of R1 and P1. In contrast, in the study by Covill and Petersen (2011), the end-point was firm resistance or pain tolerance. In the current study, less side-to-side variation and stronger correlation was found for R1 than P1 measures. Other unidentified reasons may also explain the difference in these studies findings. Despite this, it would seem reasonable to deduce that R1 is a more suitable measurement point than P1, firm resistance or pain tolerance.

The current study calculated MAV's for intra-individual ROM difference between sides. Radial nerve MAVs were similar at each end-point to those for the median nerve (Table 3). These findings are consistent with those reported by Boyd (2012). In that study, within subject inter-limb difference was highly consistent with the current study. In contrast, in the study by Covill and Petersen (2011) MAV's for the median nerve were 10° and 7° for the radial nerve. MAV's do not portray the range of difference in side-to-side variation in ROM that may occur during a neurodynamic test. In contrast, Lower bound scores represent the potential difference in ROM between sides more accurately. Lower bound scores reported by Covill and Petersen (2011) were 20° for the radial nerve and 27° for the median nerve, much higher than in the current study. Again, it could be suggested that the difference between these findings may be explained by the neurodynamic test variant used. Maximally stressing the nervous system with the addition of cervical spine lateral flexion may have the effect of reducing the variability between sides. Other unidentified factors may also explain the difference in the two study findings. The only other study to report lower bound scores for neurodynamic tests investigated straight leg raise and found similar variability between sides as in the current study (Boyd and Villa, 2012).

Despite the finding in the present study of smaller Lower bound scores than previous reports, the fact remains that ROM symmetry between sides cannot be assumed during neurodynamic testing. This highlights the importance of other factors to be considered during test interpretation including symptom reproduction, which must be influenced by structural differentiation.

Results for reliability testing of repeated measures (Table 1) were good to excellent according to published guidelines (Portney and Watkins, 2008). These findings are consistent with other reports, albeit for different neurodynamic test variants and different end-points. For example, ICC values were stated as greater than 0.92 for the ROM at pain tolerance for median and radial nerve neurodynamic tests (Lohkamp and Small, 2011) and 0.98 in another

study where ROM at P1 and pain tolerance were assessed (Oliver and Rushton, 2011). In contrast, in the study by Covill and Petersen (2011) ICC's ranged from 0.62, indicating only moderate to good reliability. The ICC provides an indication of the amount of agreement between measurements, whereas the SEM expresses measurement error (Eliasziw et al., 1994; Portney and Watkins, 2008). SEM in the current study was at most 4.2°, very similar to a previous study with a similar measurement method (Oliver and Rushton, 2011). In contrast, in the study by Covill and Petersen (2011) the SEM was larger up to 6.7°. It would appear that side-to-side variability of elbow ROM is greater, and reliability and measurement error worse, in the study reported by Covill and Petersen (2011) compared to the current and other studies investigating similar neurodynamic tests (Oliver and Rushton, 2011; Van Hoof et al., 2012; Boyd, 2012). One explanation may be that in the study by Covill and Petersen (2011) the end point to neurodynamic testing was "firm resistance", whereas in the present and other studies the end points were pain (P1 or pain tolerance) or R1. These end-points, together with the neurodynamic test variants used in this study that included cervical lateral flexion, may be more reliable and should be used in future studies.

Mean ROM values for elbow extension during the two neurodynamic test variants used in the present study were approximately 25° for the median nerve and 15° for the radial nerve (Table 2). Previous studies have reported values for the median nerve neurodynamic test that are highly diverse in terms of ROM findings. Reported values range from 53.0° elbow extension for pain tolerance (Oliver and Rushton, 2011), to 22.2° for P1 (Van Hoof, Vangestel, 2012), to 38.4° for firm resistance (Boyd, 2012). The difference in ROM may be explained by the difference in testing protocol, examiners, end-point, and measuring methods as well as subtle variation in joint position and fixation force. Hence no direct comparison can be made with the current study findings. This diversity highlights the difficulty when comparing ROM results from studies of neurodynamic tests. There are many variables that make test standardization almost impossible.

It is important to recognize that while the neurodynamic tests used in this study replicated standard clinical procedures, measurement were taken using an electrogoniometer, which has greater accuracy than visual estimation or standard goniometry. Despite this, when using a standard goniometer, the lower bound scores reported in this study are greater than the smallest detectable change for elbow measurements using a standard goniometer (Geertzen et al., 1998). A further limitation of this study is the relatively young age of the sample tested. The results may not be applicable to an older population.

6. Conclusion

The results of this study provide clinicians with background information regarding normal ROM variability for commonly used neurodynamic test sequences of the upper limb. The Lower bound scores were 15° for the median nerve and 11° for the radial nerve. Variability greater than these values can be judged to be greater than normal side-to-side variability. The presence of side-to-side differences in ROM in asymptomatic people indicates caution when interpreting neurodynamic tests. Instead greater focus should be on symptom provocation associated with structural differentiation.

Ethical study

Ethical approval for this study was granted by Curtin University Human Research Ethics Committee.

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