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Side-to-side elbow range of movement variability in an ulnar neurodynamic test sequence variant in asymptomatic people

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Background: Range of motion (ROM) asymmetry between sides is one indicator of a positive neurodynamic test, but this has been less well studied for the ulnar nerve.
Objective: The purpose of this study was to investigate side-to-side variation in elbow ROM during an ulnar neurodynamic test sequence, including contralateral cervical side flexion, in 40 asymptomatic subjects.
Methods: A traditional goniometer was used to measure elbow flexion ROM at two end points, onset of resistance ($R1$) and symptom onset ($P1$). Two repeated measures of $R1$ and $P1$ were taken on each side.
Results: Reliability for $R1$ and $P1$ was found to be good (ICC ≥ 0.83, SEM ≤ 5.37) with no significant difference in mean ROM between sides. A significant relationship between sides was seen (r values ≥ 0.48) and R^2 values > 0.23; this indicates at least 23% of the variance observed in one limb was accounted for by range in the opposite limb. This relationship was slightly stronger for $R1$ than $P1$. Lower bound scores indicate that intra-individual ROM difference $> 23^\circ$ for $R1$ and 22° for $P1$ would exceed normal ROM asymmetry.
Conclusion: These findings provide clinicians with background information of ROM asymmetry during the ulnar neurodynamic test.

Keywords: Ulnar Neurodynamic test; upper limb; variability; reliability.

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Introduction

Increased neural tissue mechanosensitivity evaluated by neurodynamic tests[1,2] is frequently reported during the examination of patients with musculoskeletal disorders.[3,4] In particular, the ulnar nerve neurodynamic test is recommended in the examination of cubital tunnel syndrome,[5,6] thoracic outlet syndrome,[7] and C8 nerve root radiculopathy.[8]

To define a positive neurodynamic test, the following have been recommended. Firstly, the patient's symptoms must be reproduced and sensitizing maneuvres must increase or decrease symptoms.[2,3,8–10] Secondly, there should be a discrepancy in joint range between sides.[2] Finally, increased resistance is perceived by the examiner on the side of symptoms.[2,3,11] Side-to-side discrepancy in ROM and reproduction of symptoms are considered the most essential criteria for interpretation of neurodynamic tests,[2,12] and also useful comparable signs to evaluate treatment.[13]

Elbow ROM is frequently used as an outcome measure in studies investigating upper limb neurodynamic tests, due to the ease of side-to-side comparison.[1,14,15] Various studies show that asymmetry in elbow ROM between sides is common during neurodynamic testing in asymptomatic people.[16–18] Within-person side-to-side variability for the median nerve was reported between 15.5° and 27°.[16,18] Within-person side-to-side variability for the radial nerve was reported between 11.2° and 20°.[16,18] Similarly, between limb values of elbow ROM for the ulnar nerve was 21°.[16] The difference in values for elbow ROM reported by Covill and Petersen[16] and Stalioraitis *et al.*[18] may be due to different testing sequences. Specifically, the addition of contralateral cervical side flexion in the latter study reduced variability ROM between sides, potentially increasing the probability that ROM can be used to determine a positive neurodynamic test.[18] Structural differentiation to determine if symptom provocation is neurogenic in origin for the case of upper limb neurodynamic tests is determined by assessing the effect of adding contralateral cervical side flexion. Hence, it is important to know side-to-side variation in ROM during neurodynamic tests during different neurodynamic test variants, including cervical side flexion, as this can provide the clinician with an expectation of what could potentially be normal variance.

The purpose of this study was to investigate side-to-side variation in elbow ROM during the ulnar neurodynamic test sequence, using the sequence described by Hall and Elvey[4] in asymptomatic people. Two end points were investigated: $P1$, perceived by the subject at onset of the discomfort, and $R1$, determined by examiner, onset of resistance. The results of this study should provide clinician with background information regarding elbow ROM variability for the ulnar neurodynamic test in normal subjects, which may enable the determination of a positive test in symptomatic people.

Methods

Study design

A within-subject comparative measurement design was used to identify differences between sides during the ulnar neurodynamic test in asymptomatic people. The objective of this study was to determine the minimum side-to-side elbow ROM asymmetry required to classify an abnormal response to this specific test.

Participants

Forty asymptomatic subjects (19 females and 21 males, mean age 30.14 years) were included in this study. Participants were excluded if they had a current or previous history of trauma to the cervical spine, thoracic spine, shoulder, elbow, wrist, or hand. They were also excluded if they had any limitation of ROM in the upper quadrant. All participants underwent pre-test screening to ensure that they had pain-free and normal range of upper limb joint movement. This study received approval from Curtin University Human Research Ethics Committee. All participants were provided with information and gave informed consent. Using the two-tailed paired t-test, with an alpha level 0.05, power of 0.8, and a medium effect size of 0.5, 34 subjects were calculated to be needed for this study.

Equipment and measurements

The independent variable was side (left or right). The dependent variable was range of elbow flexion. Extraneous variables include body mass index, age, gender, and hand-dominant side. A traditional

goniometer was used to record elbow ROM. Acceptable validity for measurement of elbow ROM using a traditional goniometer when compared with radiograph measurement has been reported.[19] In that study, the intra-class correlation coefficient (ICC) ranged from 0.94 to 0.97 for the goniometric measurements and from 0.98 to 0.99 for the radiographic measurements.[19] The two methods correlated and the maximum error of the goniometric measurement was 7.0° for flexion, 95% of the time.[19]

Procedure

Participants were tested according to a standard clinical testing protocol, without fixation devices. The untested limb was placed in a relaxed position with the hand resting on the abdomen. The cervical spine was placed in contralateral side flexion to the side tested, without rotation. The shoulder girdle on the tested side was held in neutral elevation and/depression position manually by the examining therapist to mimic the clinical situation.

The ulnar neurodynamic test sequence was tested on each side in random order. The participants underwent one familiarization trial. Two measurements of range of elbow movement were recorded after the familiarization trial using the traditional goniometer by a separate independent researcher while the main researcher maintained the arm position during the measurement process. The goniometer was not visible to the main researcher to avoid bias. The goniometer axis was aligned with the medial epicondyle, with the proximal arm aligned with the midline of humerus and the distal arm aligned with the line formed by the medial epicondyle and radial styloid process.

Good intra-tester reliability of goniometric measurement has been shown when the mean of two or three measurements is taken,[20–22] hence only two measurements were taken for each end point and each test. The end points were $R1$ and $P1$, as these have been shown to have excellent inter- and intra-rater reliability.[21,23,24] Participants were instructed to say "now" upon the onset of any sensation change during the neurodynamic test and the movement paused for measurement purposes. The examiner said "R" when the onset of resistance was felt and again the movement was paused for measurement.

Neurodynamic test sequence for the Ulnar nerve

The tested arm was positioned in 90° shoulder abduction, 90° shoulder external rotation with the shoulder girdle maintained in neutral. The cervical spine was placed in maximal lateral flexion to the contralateral side.[4] The elbow was fully extended, with the forearm in maximum pronation, and wrist/fingers maximally extended. Elbow flexion was initiated, and at $P1$ and $R1$, elbow movement was paused while ROM recorded. The neurodynamic test continued until both end points had been achieved. The subjects were given one familiarization trial on each side followed by two trials where measurements were recorded in between a 10-second rest interval.

Data Analysis

Data analysis was carried out using SPSS v19. (SPSS Inc., 444 N. Michigan Avenue, Chicago, Illinois, 60611). All data were normally distributed. Intra-tester reliability for repeated measures on each arm was calculated using ICC (2,1), standard error of the measurement (SEM), and minimal detectable change (MDC). Mean elbow ROM and standard deviation was determined for the Ulnar neurodynamic test sequence for both arms. Dependent t-tests were used to compare within-subject range of motion (ROM) between the right and left arms for each test. Relationship in ROM between limbs was calculated using the Pearson correlation coefficient and coefficient of determination (r^2). The mean absolute values (MAVs) were calculated to determine differences between limbs while ensuring that all values remain positive. A lower bound score 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 was carried out according to the method reported in another study by multiplying the standard deviation of the MAV by the z-score (1.65) of a one-tailed t-test ($\alpha = 0.05$) and adding the MAV (lower bound score = (SD) (1.65) + MAV).[16]

Results

All data were checked and found to be normally distributed. The results for intra-therapist reliability

Table 1. Reliability statistics for elbow ROM for ulnar neurodynamic test ($n = 40$).

Measurement	ICC [2,1] (95% CI)	SEM°	MDC°
Right Ulnar $R1$	0.83 (0.67, 0.91)	5.4	14.9
Right Ulnar $P1$	0.84 (0.69, 0.91)	4.7	13.0
Left Ulnar $R1$	0.90 (0.81, 0.95)	3.7	10.1
Left Ulnar $P1$	0.90 (0.81, 0.95)	4.2	11.6

are shown in Table 1. For both $R1$ and $P1$, the range recorded during Ulnar neurodynamic test, ICC (2,1) values was greater than 0.83 indicating good reliability.[16] In addition, the SEM and MDC for each assessment point were also relatively small.

Means and standard deviations for elbow ROM during the ulnar neurodynamic test are presented in Table 2. The mean difference between the left and right sides, for both $R1$ and $P1$, was very small, with at most 1.5° between sides. At any assessment point, there was no significant difference between the left and right sides as reflected by the 95% confidence intervals (Table 2).

A Pearson correlation analysis revealed a significant relationship between the limbs, with r values greater than 0.48. Furthermore, the R^2 values were greater than 0.23, indicating that at least 23% of the variance observed in one limb was accounted for by range in the opposite limb. This relationship was slightly stronger for $R1$ than $P1$. These data point to a relationship for elbow ROM between limbs, indicating that elbow ROM of one side can be used to some degree to predict elbow ROM of the opposite limb.

The MAV and lower bound scores shown in Table 3 revealed some degree of variability between the right and left limbs for any assessment point. Elbow ranges recorded at $R1$ had slightly more variability between limbs than $P1$ during the ulnar neurodynamic test.

Discussion

This study investigated side-to-side variation in elbow ROM at $P1$ and $R1$ for the ulnar neurodynamic test sequence as described by Hall and Elvey.[4] Small mean differences were detected between sides for $R1$ (1.6°) and $P1$ (1.1°). However, despite these small mean differences, this did not equate to a strong correlation between sides as seen in Table 2. This might be explained by the relatively large MAVs for ROM differences between limbs, which indicate large intra-individual differences in ROM between limbs as shown in Table 3.

The MAVs for discrepancy between sides were similar in order of magnitude for both $R1$ and $P1$. The lower bound scores were calculated from the MAV, and indicate that elbow ROM difference between limbs for the ulnar neurodynamic test must be greater than 23° for $R1$ and 22° for $P1$ for the ROM findings to be considered relevant beyond normal variation and measurement error. These findings were similar to those reported by Covill and Petersen,[16] who had also investigated the Ulnar neurodynamic test. In that study, the MAV was 6.1° and lower bound score was 20.9°. Small differences in MAVs for ROM between Covill and Petersen[16] and the current study were likely to be attributed to differences in end-point measurement, type of goniometer used, and variation in neurodynamic test sequence. Also, $P2$ and $R2$ were the end points measured by Covill and Petersen,[16] while in the present study, $P1$ and $R1$ were recorded instead. To the best of our knowledge, no other study has reported lower bound scores for the ulnar neurodynamic test.

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) ($n = 40$).

Measurement	Mean range (SD)		Mean difference scores (95% CI)°	r	R^2
	Left	Right			
Ulnar $R1$	110.8 (1.6)	112.4 (13.0)	1.6 (−2.5, 5.6)	0.53 $p < 0.001$	0.28
Ulnar $P1$	110.8 (13.2)	111.9 (11.8)	1.1 (−2.8, 5.0)	0.48 $p < 0.001$	0.23

Table 3. Mean absolute differences (MAV) in elbow ROM between right and left sides together with lower bound scores for neurodynamic testing ($n = 40$).

Measurement	MAV (SD)°	Lower bound scores°
Ulnar *R*1	9.7 (8.1)	23.1
Ulnar *P*1	9.0 (8.2)	22.5

MAVs of 10.1° and 6.7° for the median and radial neurodynamic tests were also reported by Covill and Petersen,[16] which are higher than that reported by Stalioraitis *et al.*[18] where ROM values were 5.5° for *R*1 and 5.8° for *P*1 for the median nerve and 4.2° for *R*1 and 4.8° for *P*1 for the radial nerve. As such, it might be expected that the MAV for the ulnar nerve reported by Covill and Petersen[16] would be greater than those in the current study, but the reverse was seen. One explanation for these differences between the three studies might be in the type of measurement device which in the current study was a traditional goniometer. In contrast, an electrogoniometer has often been used in the previous research.[16,18] Additionally, the type of neurodynamic sequence might also affect the difference in MAV. A different test sequence that did not include the contralateral cervical side flexion was used by Covill and Petersen.[16] Cervical side flexion is an important component of neurodynamic testing used in structural differentiation which increases strain on the nervous system without differing the mechanical load on the musculoskeletal system.[23] The effect of including contralateral cervical side flexion in the median neurodynamic test sequence was to reduce mean elbow ROM to 132.8° in asymptomatic subjects whereas the same sequence without contralateral cervical side flexion had achieved elbow ROM of 149°.[23]

Mean ROM difference between sides for *R*1 and *P*1 was noted to be similar to Stalioraitis *et al.*[18] with the exception of *R*1 for the median nerve which had a mean difference of only 0.9°. This similarity may be attributed to the consistency in neurodynamic test sequence used in both studies.

The mean elbow ROM values were smaller in this study than those reported by Covill and Petersen[12] for the ulnar neurodynamic test. This could be explained by the various differences in methodology used by the two studies, most notably, the different end-point measures. As observed by Vanti *et al.*,[21] for the median neurodynamic test, mean elbow ROM was 155° for *P*1 and 164° for *P*2. As such, the use of *P*2 as an end-point measure might explain the greater mean elbow ROM reported by Covill and Petersen.[16] There are differences of opinion as to the use of end-point measure with *P*1 being more clinically relevant as it is included in the definition of a positive neurodynamic test to reproduce the patient's symptoms[3,8] without bringing on greater pain.

The correlation (R^2) in elbow ROM between sides was higher being 0.23 for *R*1 and *P*1 in this study compared to 0.13 reported by Covill and Petersen.[16] Although values varied slightly, the clinical interpretation of these small R^2 values was that it may not be possible to use elbow ROM comparison between sides as one of the criteria to support a positive ulnar neurodynamic test. In other words, the range in one limb accounts for only a small proportion of the predicted range in the opposite limb during this neurodynamic test. This would indicate that other criteria should be used to identify a positive neurodynamic test, with ROM difference between limbs being of minor importance.

Intra-tester reliability was found to be good for the left and right sides of ulnar neurodynamic test (Table 1). These findings are consistent with other studies reporting reliability of other neurodynamic tests when measuring elbow ROM with an electrogoniometer.[18,21,24] Neither the left nor right side showed any indication of substantially better intra-tester reliability. Hence, a possible conclusion would be the degree of intra-tester reliability which is not related to the side measured and it would suggest that future neurodynamic test studies should include intra-tester reliability within every study.

The use of traditional goniometer has been recommended to depict a realistic clinical situation.[16] Despite this, a traditional goniometer is clumsy to use, as the therapist must control many components during the ulnar neurodynamic test. Trying to correctly place the goniometer during the neurodynamic testing process greatly adds to this complexity and makes it difficult to accurately measure ROM. Future studies should look for simpler methods of measuring ROM that can be easily applied and read by the clinician.

Conclusion

The results of this study provide clinicians with baseline knowledge of normal ROM variation

between sides during the ulnar neurodynamic test using a commonly used measurement device. The lower bound score of 23° for measurement at $R1$ and 22° for $P1$ would suggest that side-to-side variation of more than 23° would exceed normal variability and would likely not be due to measurement errors and is therefore clinically relevant. Large variation in ROM between sides indicates that ROM is less helpful in determining a positive neurodynamic test than other test criteria. One explanation for large side-to-side variation in ROM is the cumbersome nature of using a traditional goniometer during neurodynamic testing.

Conflict of Interest

The authors declare that there is no conflict of interest relevant to the study.

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Author Contributions

Study design was initiated by Dr. Toby Hall. Data Collection was collected by Ms. Michelle Tong with the assistance of Mr. Vincent Liu. Michelle and Vincent had written the majority of this paper under the supervision of Dr. Toby Hall. Data Analysis was done by Dr. Toby Hall. Subsequent revisions of the drafts made for publication were done by Michelle under the supervision of Dr. Toby Hall. Each author has reviewed and approved the submission of this updated draft of the manuscript and takes full responsibility for the manuscript.

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