Impact of shoulder internal rotation on normal sensory response during ulnar nerve-biased neurodynamic testing of asymptomatic individuals

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Objective: To determine if substitution of shoulder internal rotation for external rotation during the upper limb neurodynamic test (ULNT₃) evokes comparable ulnar nerve sensory responses in asymptomatic individuals.

Methods: Range of motion, quality, quantity, and distribution of sensory responses in 50 asymptomatic individuals during the traditional ULNT₃ were compared to identical measures during an experimental maneuver using shoulder internal rotation. Quality and quantity of sensory responses were recorded using a 10-cm visual analog scale.

Results: Means of sensory responses for traditional and experimental maneuvers, respectively, were as follows: stretching, 3.84 ± 8.85 and 5.38 ± 2.85 cm; burning, 1.82 ± 2.82 and 2.50 ± 3.10 cm; tingling, 2.13 ± 3.12 and 2.18 ± 2.97 cm; and numbness, 1.04 ± 2.17 and 1.01 ± 2.03 cm. A moderate to strong correlation (ICC = 0.51–0.86) was shown to exist between maneuvers; this relationship was significant ($p = .001$).

Discussion: Results of this study provide evidence that there was no appreciable difference in sensory responses with regard to burning and tingling when substituting shoulder internal rotation for external rotation during the ULNT₃. The results also suggest that there were only marginal differences in the sensory responses of stretching and numbness during the same substitution.

Conclusion: Patients who have limited glenohumeral external rotation due to pain, instability, and/or articular limitation may benefit from this substitution when presenting with signs of ulnar nerve pathodynamics. Further research will be needed to validate this maneuver in a symptomatic population.

Level of Evidence: Level 2b.

Keywords: Neurodynamic test, Ulnar nerve, Nerve tension, ULNT₃, Sensory response

Introduction

Neurodynamic testing is used to assess the mobility and sensitivity of neural tissue to mechanical stresses.^{1–3} Neurodynamic tests are designed to determine altered nerve mechanosensitivity.^{4–9} This heightened sensitivity in response to mechanical stimuli has been attributed to local inflammatory processes within the nerve that are specifically related to its connective tissue.^{8,10–14} The traditional upper limb neurodynamic test (ULNT₃) is a neurodynamic test biased to evaluate the mechanical and physiologic response of the ulnar nerve and its surrounding tissue to movement.^{2,3,15,16} The traditional ULNT₃ requires the clinician to sequentially move the upper extremity utilizing the following component motions: wrist/finger extension, forearm pronation, elbow flexion, shoulder external rotation, shoulder girdle depression, and shoulder abduction.^{2,3} This combination of patient positioning is utilized to evoke

tension and its manifestations along the ulnar nerve distribution.^{17–19} Neurodynamic tests assess the physical properties of neural structures and surrounding soft tissues, while also depicting normal or abnormal neural responses to a stimulus placed on the region. Abnormal neural responses to movement can implicate problems with extensibility, glide, or irritability of the nerve along its pathway.²⁰

Recent cadaver studies have suggested that the substitution of shoulder internal rotation for external rotation provides a comparable neurodynamic response along the ulnar nerve.^{21,22} Gugliotti *et al.* showed a strong correlation ($r = 0.98$, $p = 0.001$) of linear excursion and percent strain to exist between the traditional ULNT₃ and an experimental maneuver using internal rotation. Manvell *et al.* also demonstrated that the substitution of shoulder internal rotation provided greater tension (10.00 ± 3.12 N) along the ulnar nerve when compared to traditional ULNT₃ (8.71 ± 3.12 N). Results of these studies provide evidence there are similar neurodynamic responses when

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substituting shoulder internal rotation for external rotation during ULNT₃ in cadavers, however, no data exist that examine the normal sensory responses in asymptomatic individuals when shoulder internal rotation is substituted for external rotation during the ULNT₃.

The purpose of this study was to investigate if the substitution of shoulder internal rotation for external rotation during the ULNT₃ evokes comparable ulnar nerve sensory responses in asymptomatic individuals. We intended to compare the mechanical loading of the ulnar nerve using the traditional ULNT₃ and an experimental maneuver using internal rotation by quantifying the resultant sensory responses. We hypothesized that a positive correlation would exist between the two maneuvers.

Methods

Study design

This was a correlational study investigating the relationship of ulnar nerve sensory responses between the traditional ULNT₃ and an experimental maneuver in asymptomatic individuals. This study was performed at the New York Institute of Technology's (NYIT) Physical Therapy Research Laboratory in October 2014. This study was approved by the Biomedical and Health Sciences Institutional Review Board of NYIT.

Reliability study

The intra-rater reliability of specific joint angle measurements (shoulder abduction, external rotation, internal rotation, and elbow flexion) during the traditional ULNT₃ and the experimental maneuver was determined using 10 healthy individuals (5 men, 5 women) with a mean age of 26.5 ± 3.5 years who only participated in this phase of the study. The neurodynamic maneuvers were each performed twice on their left upper extremity, with 30 s between repetitions. The stationary and moving arms were placed according to Clarkson.²³ For each repetition, the measurements were taken just prior to the limit of tolerance, defined as the point which the participant was too uncomfortable to continue with the test. Range of motion (ROM) of shoulder abduction, shoulder internal and external rotation, and elbow flexion were recorded at this point. Measurements were taken using a digital goniometer (Baseline; Fabrication Enterprises Inc, White Plains, NY, USA). The reliability (0.47–0.62) and validity (100%) of the digital goniometer have been previously established.²⁴ The same operator was used to measure ROM in both the reliability and main portions of this study. No methods of operator blinding were used during either portions of the study.

Main study

Participants

Individuals between 18 and 65 years of age were recruited to participate in the study. Prospective participants were excluded if any of the following were present: ROM

Figure 1 Flow chart of study.

limitations in the cervical spine or upper limbs, neurological signs, a positive Spurling's A test²⁵, or associated cervical spine or upper limb injury and/or surgery. Additional exclusion criteria included the following: pregnancy, inability to lie supine for an extended period of time, current use of pain or sedative medications, and/or any other health-related conditions interfering with the individual's ability to safely participate in the study.

Fifty-three volunteers were recruited from the NYIT community through the use of IRB-approved flyers. All participants signed an IRB-approved informed-consent demonstrating voluntary participation and understanding of the study prior to study participation. Of these 53 volunteers, three were excluded after not meeting the study's inclusion criteria. Fifty participants (22 men, 28 women), with a mean age of 25.9 ± 8.1 years, were then included in the main study (Fig. 1).

Procedures

On entry to the main study each participant was randomly assigned to one of two groups. Group A received the traditional ULNT₃ on their left upper extremity, followed by the experimental maneuver 60 s later; while group B received the same maneuvers on their left upper extremity but in reverse sequence. The researcher who performed these two maneuvers is an experienced physical therapist, orthopedic certified specialist, and a certified orthopedic manual therapist with advanced training in neurodynamics.

In order to standardize each participant's responses, the principle investigator provided instruction for the outcome measurement tool used (Appendix A). Four individual 10-cm visual analog scales depicting sensory responses of stretching, burning, tingling, and numbness were reviewed with each participant to ensure its proper use. A body chart

depicting the left upper extremity was also reviewed and used to document the distribution of sensory responses. Following each maneuver, participants were asked to rate the intensity and quality of symptoms using the appropriate visual analog scales. Each participant was also asked to mark the location of their perceived sensory responses on the body chart. The variables measured in this study were the select passive upper extremity ROM and the quality, quantity, and distribution of sensory responses; all just prior to the participant's limit of tolerance and available range.

The traditional ULNT₃ was performed following the sequence of movement described by Butler^{2,3}: wrist and finger extension, followed by forearm pronation, elbow flexion, shoulder external rotation, shoulder girdle depression, and shoulder abduction. The experimental maneuver was performed following the alternative sequence of movement described by Gugliotti *et al.*²¹: shoulder girdle depression, followed by wrist and finger extension, forearm pronation, slight shoulder abduction, elbow flexion to 90°, shoulder internal rotation, full elbow flexion, and continued shoulder abduction (Appendix B). The starting position was standardized for both maneuvers. Each participant remained supine without a pillow under their head, upper extremities extended and alongside their trunk, and lower extremities extended.

For both maneuvers, the participants were instructed to report their sensory responses when they first felt sensation and then again at their limit of tolerance when it was too uncomfortable to continue with the movement. ROM measurements of shoulder abduction, shoulder internal and external rotation, and elbow flexion were recorded at this point. Measurements were taken with the same digital goniometer and goniometer arm placements used in the reliability portion of this study.

Statistical analysis

Reliability of shoulder abduction, shoulder internal and external rotation, and elbow flexion ROM was calculated

using the intra-class correlation coefficient (ICC) model 2.1. The relationship of sensory responses (stretching, burning, tingling, and numbness) between the two maneuvers was calculated using the ICC model 2.1 with a 95% confidence interval (CI). The strength of correlation was determined using Dancey and Reidy's categorization (1-perfect, 0.7–0.9 strong, 0.4–0.6 moderate, 0.1–0.3 weak, 0–zero).²⁶ Significance was set at an alpha level of 0.05. All eligible participants completed the study. Data were analyzed using SPSS (Version 22.0, IBM, Armonk, NY, USA).

Results

Reliability study

Intra-rater reliability was determined to be strong to moderate for the operator responsible for ROM measurements. The ICC values for ROM between traditional and experimental ULNT₃ maneuvers are as follows: shoulder abduction, ICC = 0.96 (95% CI: 0.85, 0.99; $p = 0.001$); shoulder internal rotation, ICC = 0.76 (95% CI: 0.29, 0.93; $p = 0.001$); shoulder external rotation, ICC = 0.67 (95% CI: 0.08, 0.90; $p = 0.001$); and elbow flexion, ICC = 0.98 (95% CI: 0.93, 0.99; $p = 0.001$).

Main Study

ROM measurements

The mean ROM measurements taken at the limit of tolerance for both maneuvers are provided in Table 1.

Onset of sensory responses

For the traditional maneuver, 70% of the participants reported the onset of symptoms with shoulder abduction, while during the experimental maneuver, 50% of participants reported the onset of symptoms with shoulder internal rotation (Table 2).

Quality and distribution of sensory responses

The quality and frequency of the standardized sensory responses for each participant are listed in Table 3. Sensory

Table 1 Upper extremity ROM during traditional upper limb neurodynamic test (ULNT₃) and experimental maneuver

	Traditional mean $\pm$ SD	Experimental mean $\pm$ SD
Elbow flexion (°)	131.6 $\pm$ 5.7	107.6 $\pm$ 12.2
Shoulder external rotation (°)	87.0 $\pm$ 4.8	
Shoulder internal rotation (°)		76.5 $\pm$ 10.3
Shoulder abduction (°)	116.8 $\pm$ 16.4	75.1 $\pm$ 13.3

Table 2 Frequency of the motion at which onset of symptoms was reported to occur during ULNT₃

Motion	Traditional		Motion	Experimental	
	N (50)	Frequency (%)		N (50)	Frequency (%)
Wrist and finger extension	0	0	Shoulder girdle depression	0	0
Forearm pronation	0	0	Wrist and finger extension	8	16
Elbow flexion	1	2	Forearm pronation	6	12
Shoulder external rotation	1	2	Slight shoulder abduction	4	8
Shoulder girdle depression	5	10	Elbow flexion to 90°	3	6
Shoulder abduction	35	70	Shoulder internal rotation	25	50
No symptoms	8	16	Full Elbow Flexion	1	2
			Shoulder abduction	2	4
			No symptoms	1	2

Table 3 Frequency of sensations reported during traditional and experimental versions of ULNT₃

Descriptors	Traditional (N = 50)	%	Experimental (N = 50)	%
Stretching	41	82	44	88
Burning	22	44	25	50
Tingling	19	38	24	48
Numbness	13	26	17	34

Figure 2 Body charts divided into nine areas in which sensory response was felt during the traditional (a) and experimental (b) versions of ULNT₃.

responses were predominantly located in the medial forearm/hand region for both maneuvers; however, participants also reported symptoms in the remaining portions of the left upper extremity (Fig. 2).

Correlation of sensory responses between traditional ULNT₃ and experimental maneuver

The mean intensities of the stretching sensations for the traditional and experimental maneuvers were 3.84 ± 8.85 and 5.38 ± 2.85 cm, respectively. The stretching sensation reported during the experimental maneuver was found to be moderately correlated ($ICC = 0.61$) with the results from the traditional ULNT₃ (95% CI: 0.40, 0.75; $p = 0.001$).

The mean intensities of the burning sensations for the traditional and experimental maneuvers were 1.82 ± 2.82 and 2.50 ± 3.10 cm, respectively. The burning sensation measured during the experimental maneuver was found to be strongly correlated ($ICC = 0.74$) with the results from the traditional ULNT₃ (95% CI: 0.58, 0.84; $p = 0.001$).

The mean intensities of the tingling sensations for the traditional and experimental maneuvers were 2.13 ± 3.12 and 2.18 ± 2.97 cm, respectively. The tingling sensation measured during the experimental maneuver was found to be strongly correlated ($ICC = 0.86$) with the results from the traditional ULNT₃ (95% CI: 0.77, 0.92; $p = 0.001$).

The mean intensities of the numbness sensations for the traditional and experimental maneuvers were 1.04 ± 2.17 and 1.01 ± 2.03 cm, respectively. The numbness sensation

measured during the experimental maneuver was found to be moderately correlated ($ICC = 0.51$) with the results from the traditional ULNT₃ (95% CI: 0.26, 0.68; $p = 0.001$).

Discussion

To the best of our knowledge, this is the first study to examine the normal sensory responses of the ulnar nerve when shoulder internal rotation is substituted for external rotation during the ULNT₃. As hypothesized, the sensory responses were comparable in intensity between maneuvers and revealed a moderate to strong correlation. A strong correlation was shown to exist between maneuvers for the sensory response of tingling ($ICC = 0.86$) and burning ($ICC = 0.74$) with a resultant significance ($p = 0.001$). In addition, a moderate correlation was shown to exist for the sensory response of stretching ($ICC = 0.61$) and numbness ($ICC = 0.51$) with a resultant significance ($p = 0.001$). No *in vivo* studies to date have examined the efficacy of substituting shoulder internal rotation for external rotation during the ULNT₃, however, cadaveric studies have provided supportive results with respect to neurodynamic responses of linear excursion, strain, and tension.^{21,22}

The quality and distribution of sensory responses during the ULNT₃ for both maneuvers were consistent with previous studies.^{2,16,27–30} The sensations of stretching, burning, tingling, and/or numbness were localized along the ulnar nerve distribution in over 51% of the participants in both groups. This percentage is lower when compared to

Martinez *et al.*¹⁷, however, their study incorporated the use of cervical contralateral side-bending to assist in structural differentiation. It was our intention to remain consistent with the previous cadaver study and forego the use of cervical contralateral side-bending.²¹ The initial onset of symptoms with the traditional ULNT₃ occurred later in range during the component motion of abduction. This was reported by 70% of the study participants. The initial onset of symptoms with the experimental maneuver occurred earlier in range during the component motion of shoulder internal rotation. This was reported by 50% of the study participants. We speculate that the early application of shoulder girdle depression contributed to this earlier onset. Shoulder girdle depression is known to place the cervical nerve roots on tension and subsequently suggests that sequencing of upper extremity movements play a role in neurodynamic testing.^{31–33}

In addition to the point of symptom onset, the position where a limit of tolerance was reported was also of particular interest in this study. All ROM measurements taken at the position of limit tolerance during the main study were consistently less during the experimental maneuver. In other words, less movement was required to elicit a comparably intense sensory response in our participants when using the experimental maneuver vs. the traditional ULNT₃. The clinical application of this finding may prove beneficial to those populations who have limited glenohumeral external rotation due to pain, instability, and/or articular limitation when presenting with signs of ulnar nerve pathodynamics. Patients with arthritis, thoracic outlet syndrome, and/or anterior glenohumeral instability often demonstrate limitations of shoulder external rotation and abduction.^{34–40} For these patients, an alternative ULNT₃ maneuver utilizing early shoulder girdle depression and shoulder internal rotation may provide a more comfortable, therapeutic effect.

Measurements of shoulder abduction, internal rotation, external rotation, and elbow flexion angles were considered reliable when applying the traditional ULNT₃ and experimental maneuvers. Shoulder abduction had an ICC of 0.96 (95% CI: 0.85, 0.99), and elbow flexion an ICC of 0.98 (95% CI: 0.93, 0.99); thus, indicating good reliability. Similar studies have shown good intra-rater reliability of goniometric measurements of shoulder abduction ROM, with an ICC greater than or equal to 0.94.⁴¹ Shoulder external and internal rotation measurements had lower ICC values of 0.67 (95% CI: 0.08, 0.99) and 0.76 (95% CI: 0.29, 0.93), respectively, indicating moderate reliability. These lower values were attributed to the fact that only one arm of the goniometer was in direct contact with the participant when these measurements were being taken. Although bubble levels in digital goniometry have been shown to help maintain free arm verticality, their use during measurements of shoulder internal and external rotation has provided similar reliability outcomes.²⁴ Skin and other soft tissues can also obscure the precise anatomic

landmarks resulting in malalignment of the goniometer arms and measurement inaccuracy for these positions. This has been shown to be a common error in studies using goniometry.⁴² For this reason, investigators should be mindful when measuring shoulder internal and external rotation ROM in supine. Consideration may also be given to using alternative positions or measuring devices when appropriate.

Limitations

Potential limitations of this study include the variance in age of our participants. Our participants ranged in age from 20 to 59 years of age with a mean age of 25.9 ± 8.1 years. This convenience sample was largely university-based and, therefore may not be representative of the normal population. The plane and surface on which the ROM of shoulder internal rotation and external rotation were measured is also a concern for the study. The position to measure both shoulder internal and external rotation was a limiting factor to achieve high intra-rater reliability secondary to the fact that only one arm of the goniometer was in direct contact with the participant at the time the measurements were recorded. The intra-rater reliability of shoulder external rotation measurement has been found to be the least reliable movement in the glenohumeral joint.⁴³ In addition, the goniometric measures of selected joint angles recorded at the completion of both maneuvers could vary based on the pain tolerance of the participants at the particular moment, which can be influenced by the individual's characteristics and external stimuli prior to arriving at the research site.¹⁷ The willingness of participants to tolerate more intensity of the sensations before deciding they reached their unbearable threshold may have also influenced the results. Previous studies have described the ULNT₃ based on a variety of movement sequences. The selection of the specific sequences used in this study was based on Butler and Gugliotti's description of the tests.^{2,3,21} Recent literature provides evidence that the order in which the movements of the neurodynamic test are introduced can influence the responses obtained with the test.³³ Consequently, a different sequence of component motions could have resulted in different findings than those obtained in this study.

Conclusions

The results of this study provide evidence that there is no appreciable difference in sensory response with regard to burning and tingling when substituting shoulder internal rotation for external rotation during the ULNT₃. The results also suggest there is only a marginal difference in sensory response with respect to stretching and numbness during the same substitution. Patients who have limited glenohumeral external rotation due to pain, instability, and/or articular limitation may benefit from this substitution when presenting with signs of ulnar nerve pathodynamics. Further research involving symptomatic patients

is warranted to assess the validity of the experimental maneuver for clinical application.

Disclaimer Statements

Contributors: All authors have equally contributed to the design, data collection/analysis, and writing of this manuscript.

Conflicts of interest: The authors report no conflict of interest.

Ethics approval: Each researcher was provided a certificate from the National Institutes of Health (NIH) demonstrating successful completion of the NIH Web-based training course 'Protecting Human Research Participants.'

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Appendix A

UE Neurodynamic VAS

Subject: _____

Date: _____

Figure A1 Visual analog scales and body chart used by participants to grade intensity and location of sensory response during the traditional and experimental versions of ULNT.

Appendix B

Figure B1. Shoulder girdle depression

Figure B2. Wrist/finger extension with pronation

Figure B3. Slight abduction

Figure B4. Elbow Flexion to 90°

Figure B5. Shoulder internal rotation

Figure B6. Full elbow flexion

Figure B7. Shoulder abduction