Impact of shoulder internal rotation on ulnar nerve excursion and strain in embalmed cadavers. A pilot study

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Design: Laboratory study, repeated-measures design.

Objective: To determine if the substitution of shoulder internal rotation for external rotation during the upper limb neurodynamic test (ULNT₃) evokes a comparable ulnar nerve excursion and strain in embalmed cadavers. Shoulder external rotation is a primary movement component of the ULNT₃. It has been suggested that shoulder internal rotation may provide a similar load to the nervous system. There are no data to either support or negate this claim.

Methods: Excursion and strain were measured in the ulnar nerve of six embalmed cadavers during the traditional ULNT₃ and an experimental maneuver using shoulder internal rotation.

Results: The total means $\pm$ SD of excursion for the traditional and experimental maneuvers were 2.11 ± 0.89 and 2.09 ± 0.92 mm, respectively. The total means $\pm$ SD of strain for the traditional and experimental maneuvers were 5.274 ± 2.223 and $5.241 \pm 2.308\%$, respectively. A very strong correlation ($r=0.98$) was shown to exist between maneuvers and this relationship was determined to be significant ($P=0.001$).

Discussion: The results of this study provide evidence that there is no appreciable difference in excursion or strain when substituting shoulder internal rotation for external rotation during the ULNT₃. Patients who exhibit limitation of shoulder external rotation mobility may benefit from this substitution when presenting with signs of ulnar nerve pathodynamics. Further research involving patients will be needed to assess the validity of the experimental maneuver for clinical application.

Keywords: Neurodynamics test, Ulnar nerve, Nerve tension

Introduction

Neurodynamics is the application of the mechanics and physiology of the nervous system and their integration in the context of musculoskeletal function.^{1,2} Normal mechanical responses to loading, such as gliding and tension, are necessary for the maintenance of physiologic processes including healthy blood perfusion, axonal conduction, and target tissue innervation. Limitations of nerve glide and tension can lead to impaired nerve mobility, decreased nerve conduction velocity, nerve damage, and loss of function. Neurodynamic maneuvers are utilized by orthopedic manual therapists to identify and treat these adverse responses.²⁻⁵ The upper limb neurodynamic test (ULNT₃) is a neurodynamic test used to evaluate the mechanical and physiologic response of the ulnar nerve and its surrounding tissue to movement.²⁻⁵ This test involves a sequence of passive extremity motions that

have been developed to bias gliding and strain along the ulnar nerve. The ULNT₃ requires the clinician to passively move the upper extremity utilizing the following sensitizing component motions: wrist/finger extension, forearm pronation, elbow flexion, shoulder external rotation, shoulder girdle depression, and shoulder abduction.^{4,5} Previous cadaveric studies have confirmed ulnar nerve bias during these aforementioned passive extremity movements.^{6,7}

In 2000, based on anatomical considerations, Butler proposed the substitution of forearm pronation for supination during the ULNT₃.⁴ He suggested that the distance from the pisiform bone to the medial elbow is greater during forearm pronation resulting in an increase of strain along the ulnar nerve. In 2008, Butler⁵ presented an additional variation of the traditional maneuver but this was shown solely as a self-mobilization exercise. The 'crawl to the pits' exercise employs all movements of the traditional ULNT₃ but substitutes shoulder external rotation with shoulder internal rotation (Fig. 1). It is actively

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Figure 1 Crawl to the pits exercise for ulnar nerve self-mobilization.

performed while standing and is prescribed to reinforce treatment carryover for maintaining healthy neurodynamics. Even though it is depicted in text, no rationale has been provided for its validation. The lead author (MG) has adapted this modification in clinical practice as a passive, manual, neurodynamic technique. It is performed in supine for patients exhibiting pathodynamics of the ulnar nerve and who are unable to tolerate the traditional ULNT₃ position due to painful limitations in glenohumeral external rotation. Despite anecdotal reports of positive patient outcomes related to improved ulnar neurodynamics, this alternative maneuver lacks research evidence to support its influence on the ulnar nerve.

The purpose of this study was to examine the use of shoulder internal rotation as a sensitizing movement, rather than shoulder external rotation, during the traditional ULNT₃. We intended to compare the mechanical loading of the ulnar nerve using the traditional ULNT₃ and an experimental passive mobility sequence by quantifying the resultant linear excursion and nerve strain. We hypothesized that a positive correlation would exist between the two maneuvers.

Methods

Cadavers

Six cadavers (three male and three female), embalmed within the previous 3–10 months, were used for this

study. The mean age at time of death was 80.3 ± 9.13 (range: 65–88 years). The left upper extremity of the cadavers was tested as they exhibited no evidence of trauma, surgery, or deformity. Passive range of motion was performed on all cadavers prior to the study in order to minimize the limiting effects of embalming on upper extremity movement throughout the testing maneuver. The cadavers were provided by the New York Institute of Technology College of Osteopathic Medicine's Anatomy Department. The Institutional Review Board of New York Institute of Technology approved this study. 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'.

ULNT₃ test maneuver versus experimental test maneuver

Each cadaver was placed in a supine position on a stainless steel cadaver dissection table in preparation for the two testing positions. Shoulder depression was maintained using a wooden block placed medial and superior to the glenohumeral joint and fastened to the treatment table using a C-clamp. Throughout all trials, the traditional ULNT₃ was performed first and was immediately followed by the experimental maneuver. The traditional ULNT₃ was performed with a non-continuous, passive, distal-to-proximal sequence of wrist/finger extension with forearm pronation, elbow flexion, shoulder external rotation, and shoulder abduction. The experimental maneuver was performed with a non-continuous, passive, distal-to-proximal sequence of wrist/finger extension with forearm pronation, shoulder abduction, elbow flexion to 90°, shoulder internal rotation, and continued elbow flexion (Appendix 1). In order to achieve full available shoulder internal rotation without obstruction from the cadaver's torso, it was necessary to divide the components of elbow flexion into two separate stages. Each cadaver was tested one time with each of the two maneuvers; therefore, a total of 12 maneuvers were performed on the six cadavers.

Linear excursion and strain measurement

The linear excursion and strain of the ulnar nerve were measured by a differential variable reluctance transducer (DVRT; Lord MicroStrain Corporation, Williston, VT, USA) with a 9-mm length and a resolution of 4.5- μ m. The ulnar nerves of the left upper extremities of the six cadavers were exposed via a 16.5 cm incision into the medial aspect of each arm (beginning 11.5 cm proximal to and ending 5 cm distal to the medial epicondyle). The DVRT was attached to the ulnar nerve just proximal to the

Figure 2 Total linear excursion during the traditional and experimental versions of ULNT₃ for each cadaver.

Figure 3 Correlation of linear excursion between the traditional and experimental versions of ULNT₃ ($r=0.98$, $P=0.001$).

cubital tunnel with two barbed screws inserted into, but not through, the nerve tissue. The total distance between the barbed screws was 4 cm. Linear excursion and strain measurements were specific to this 4 cm length of ulnar nerve. The output of the DVRT was collected by using Microstrain Smart Motherboard Software version 2.1.3 (Lord MicroStrain Corporation, Williston, VT, USA) on an ASUS Eee laptop computer (ASUS, Taipei, Taiwan) running Windows XP (Microsoft, Redman, WA, USA). The absolute measurement of linear excursion (mm) was converted to percentage change in strain using the formula $[(\text{component end length}-\text{start length})/\text{start length}] \times 100$.

Goniometric measurement

All goniometric measurements for range of motion (ROM) were performed by only one researcher. A standard 8-inch goniometer was used to measure joint movement. All stationary and moving arm placements were utilized as outlined by both Clarkson⁸ and Norkin

Figure 4 Total percent strain during the traditional and experimental versions of ULNT₃ for each cadaver.

and White.⁹ Goniometric measures were performed at the end of each sequentially imparted passive motion.

Statistical analysis

Statistical analyses were performed by SPSS (Version 22.0, IBM, Armonk, NY, USA). Pearson product-moment coefficient of correlation (r) was used to determine the relationship of the two averages (linear excursion and percent strain) between the traditional and experimental maneuvers. Significance was set at an alpha level of 0.05.

Results

Goniometric measurements

All goniometric measures are provided in Table 1.

Linear excursion

The total means $\pm$ SD of linear excursion for the traditional and experimental maneuvers were 2.11 ± 0.89 and 2.09 ± 0.92 mm, respectively. Total linear excursion during maneuvers for each cadaver is displayed in Fig. 2. Additionally, the linear excursion measured during the experimental maneuver was found to be significantly correlated with the results from the traditional ULNT₃ ($r=0.98$, $P=0.001$) (Fig. 3). The upward slope of the trend line depicts a positive correlation between the traditional ULNT₃ and the experimental maneuver.

Strain

The total means $\pm$ SD of strain for the traditional and experimental maneuvers were 5.274 ± 2.223 and $5.241 \pm 2.308\%$, respectively. Total percent strain during maneuvers for each cadaver is displayed in Fig. 4. Additionally, the percent strain calculated for the experimental maneuver was found to be

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

	Traditional mean $\pm$ SD	Experimental mean $\pm$ SD
Wrist extension ($^{\circ}$) (with full finger extension/pronation)	67.0 $\pm$ 9.3	70 $\pm$ 5.8
Elbow flexion	134.5 $\pm$ 5.9	122.7 $\pm$ 8.1
Shoulder external rotation ($^{\circ}$)	64.7 $\pm$ 15.5	
Shoulder internal rotation ($^{\circ}$)		78.7 $\pm$ 9.0
Shoulder abduction ($^{\circ}$)	90.3 $\pm$ 1.5	90.1 $\pm$ 1.0

Figure 5 Correlation of percent strain between the traditional and experimental versions of ULNT₃ ($r=0.98$, $P=0.001$).

significantly correlated with the results from the traditional ULNT₃ ($r=0.98$, $P=0.001$) (Fig. 5). The upward slope of the trend line depicts a positive correlation between the traditional ULNT₃ and the experimental maneuver.

Discussion

The pattern of ulnar nerve strain was consistent throughout both non-continuous maneuvers. It increased as each component was added to complete the entire passive motion. Comparison of the two total percent strain averages showed a very strong correlation ($r=0.98$) and resultant significance ($P=0.001$). The mean strain for each component movement was proximal to distal with the largest increase in percent strain seen with the added component motion of elbow flexion and shoulder abduction during both maneuvers. This is consistent with the previous findings of Byl *et al.*⁶ They assessed the quantity of strain produced along the ulnar nerve during ULNT₃ testing of four fresh cadavers and found a 2.1% increase in summative strain along the ulnar nerve with the largest increase (0.9%) during the component motion of shoulder abduction.

The pattern of ulnar nerve linear excursion was also consistent throughout both maneuvers. It increased as each component was added to complete the entire passive motion. Comparison of the two total linear excursion averages showed a very strong correlation ($r=0.98$) and resultant significance ($P=0.001$). The linear excursion for each component movement was proximal to distal with the largest increase in linear excursion seen during elbow flexion. This is consistent with the previous findings of Wright *et al.*⁷ They examined the ulnar nerve excursion required for unimpeded upper extremity motion during similar movement testing of five fresh cadavers and found the greatest excursion during elbow and wrist movements.

The range of motion measured throughout both maneuvers was consistent with accepted values described in the literature.^{8,9} Examination of our

data revealed less limitation with shoulder internal rotation (78.7°) than with external rotation (64.7°). The accepted value for full normal range of both rotations is 90° . Given the mean age of the cadavers (80.3 ± 9.13), it is likely that the aging process contributed to the loss of mobility. Limitations of movement in peripheral joints have been well documented in the aging population.^{10–14} Changes in the cellular matrix of the joint capsule often lead to cross-linking of the fibers resulting in capsular hypo-mobility.^{15–17} These changes can occur in both men and women (men > women) as early as the fifth decade of life.¹⁰ Cyriax¹⁸ and Kaltenborn¹⁹ have described this limitation as a capsular pattern. Each joint has its own unique capsular pattern of limitation. For the glenohumeral joint, the capsular pattern is the greatest proportional loss of external rotation followed by abduction and internal rotation. Barnes *et al.*¹⁰ demonstrated that glenohumeral joint internal rotation improves in individuals in their forties, while the other motions become more limited. The clinical implications of these findings would suggest that the experimental ULNT₃ maneuver used in the present study may prove beneficial when treating middle-aged and senior patients with limited ulnar nerve neurodynamics and decreased glenohumeral mobility.

Limitations

Potential limitations of this study include the cadavers' variability in time of death and the effects of the embalming process on the articular and soft tissues. Prior studies do, however, validate the use of embalmed cadavers compared to unembalmed when neurodynamic properties are being examined.^{20,21} The age of our cadavers was also a concern due to the susceptibility of progressive degenerative changes of articular structures and their contribution to movement limitations. In addition, each of the cadavers of this small sample size only received a single application of both maneuvers to the same arm without randomization. This may have unintentionally conditioned and/or influenced the ulnar nerve segment being studied. Also, examiner reliability was never tested prior to the use of the DVRT. Establishing reliability of the examiner(s) is essential to minimize measurement error.

Conclusion

This study provides evidence that the substitution of shoulder internal rotation for external rotation during the ULNT₃ provides a comparable strain along the ulnar nerve. Patients who exhibit limitation of shoulder external rotation mobility may benefit from this substitution when also presenting with signs of ulnar nerve pathodynamics. Further studies involving the use of patients will be needed 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.

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Conflicts of interest The authors report no conflict of interest.

Ethics approval Although 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', this study only incorporated the use of human cadavers. It was approved through expedited review by the Institutional Review Board of New York Institute of Technology.

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Appendix 1

Figure 6 Shoulder girdle depression.

Figure 8 Shoulder abduction.

Figure 7 Wrist/finger extension with pronation.

Figure 9 Elbow flexion to 90°.

Figure 10 Shoulder internal rotation.

Figure 11 Full elbow flexion.

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