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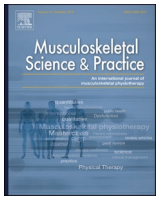

Original article

# Effect of cervical contralateral lateral flexion on the median nerve and fascia at the wrist – Cadaveric study

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ABSTRACT

*Background:* Neurodynamic tests are an essential aspect of the physical examination of the patient when suspicion of neural involvement exists. A manoeuvre that is hypothesised to move nerves differentially relative to other structures (structural differentiation) has been proposed as a necessary part of neurodynamic testing for differential diagnosis. However, although the specificity of structural differentiation for peripheral nerve over muscle has been demonstrated in some body regions, no study has tested specificity of nerve movement relative to fascia.

*Objectives:* The aim of this study was to measure the effect of the cervical contralateral lateral flexion (CCLF) as an structural differentiation manoeuvre for the median nerve compared to fascia (superficial and deep) at the wrist during the upper limb neurodynamic test 1 (ULNT1).

*Design:* A cross-sectional study was performed in 5 fresh frozen cadavers.

*Methods:* Excursion and strain in the fascia (superficial and deep) and the median nerve were measured at the wrist with structural differentiation during the ULNT1. KINOVEA software was used to measure kinematic parameters.

*Results:* CCLF resulted in significant proximal excursion in the median nerve ($p < 0.001$*) but not in the strain. CCLF neither produced changes in strain nor excursion in the superficial and deep fascia ($p > 0.05$).

*Conclusion:* This study showed that CCLF produced significant differential excursion in the median nerve at the wrist compared to the local superficial and deep fascia during the ULNT1. The data support CCLF in mechanical differentiation between nerve and fascia in this area in diagnosis of local sources of wrist pain.

## 1. Introduction

Neurodynamic assessment can be applied clinically for diagnosis of a neural aspect to musculoskeletal disorders and requires study for reasons of mechanical validity and specificity (Herrington et al., 2008). Neurodynamic tests (NDTs) represent a sequence of movements that apply mechanical stress to nerves (Joshi et al., 2013; Shacklock, 1995; Coppieters et al., 2006; Coppieters and Butler, 2008) in assessing their physiological and mechanical capacities (Shacklock et al., 2007; Butler, 2000).

A structural differentiation manoeuvre has been proposed to differentiate between involvement of the neural and musculoskeletal structures (Herrington et al., 2008; Shacklock, 1995; Butler, 2000; Bueno-et al., 2016; Nee et al., 2012). The rationale for structural differentiation is based on the idea that the manoeuvre may produce changes in strain or excursion in the nerve but not in the muscle or fascia at the final test position (Herrington et al., 2008; Butler, 2000; Nee et al., 2012; Shacklock, 2005a; Coppieters et al., 2003; Schmid et al., 2009), despite the long (multiarticular) and continuous nature of both types of tissue (Breig, 2007).

A key issue in neurodynamic testing is whether NDTs are able to produce specific movements of peripheral nerve compared to other

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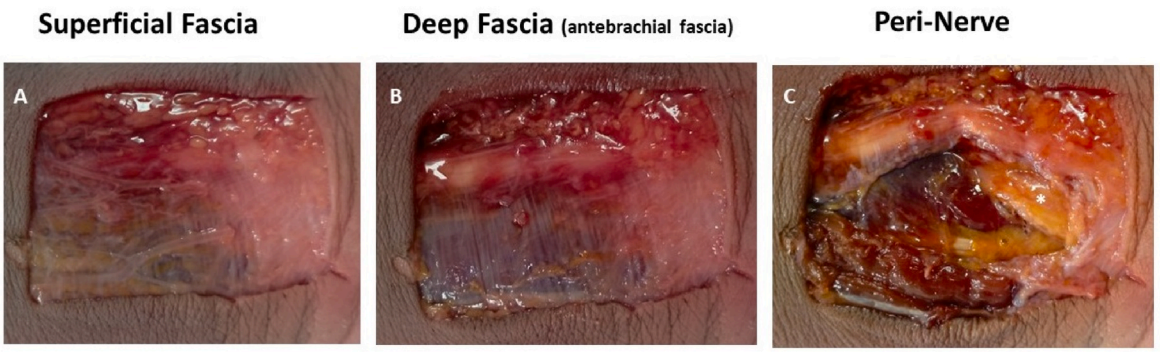


**Fig. 1.** Layers dissection of the left upper limb proximal to wrist crease: a. Superficial fascia, b. Deep fascia and c. Peri-nerve (* peri-nerve of median nerve).

structures such as muscle or fascia (Bueno-et al., 2020; Nee et al., 2012; Shacklock, 2005b). Coppieters et al. (2005) demonstrated that structural differentiation manoeuvres in the slump test and straight leg raise test had no significant effect on pain perception using experimentally induced calf muscle pain. Bueno et al. (Bueno-Gracia et al., 2019; Bueno-Gracia et al., 2020) showed that structural differentiation produced specific excursion and strain in the median and sciatic nerves compared to adjacent muscles during the upper limb neurodynamic test1 (ULNT1) and straight leg raise test in anatomical specimens.

Despite the existing literature, the support for NDTs in differentiating between neural and fascial structures has been considered by some authors to be limited (Di Fabio, 2001), mainly because of alternative explanations due to the continuity of the fascial system (Di Fabio, 2001; Gajdosik et al., 1985). This controversy arises from the definition of fascia as a mesenchymal tissue that surrounds and interpenetrates all the structures of the human body in all directions, is difficult to isolate as a whole, and forms the epi-, peri- and endoneurium for a muscle or a nerve (LeMoon, 2008).

As mentioned above, previous studies have shown the specificity of NDTs for peripheral nerve compared to muscle but none has demonstrated specificity of nerves relative to fascia. One reason for this lack of study is technical difficulties in measuring behaviour of fascia. Due to its thinness, it is not yet possible to place transducers solely into fascia and measure its motion relative to other tissues. Video capture and motion analysis systems have been shown to be effective tools for valid and reliable measurement of motion and could be a useful tool for recording potential fascial and nerve motion.

The aim of this study was to measure the effect of structural differentiation (i.e. cervical contralateral lateral flexion (CCLF)) on the median nerve at the wrist compared to the local superficial and deep fascia during the ULNT1 in cadavers.

## 2. Methods

### 2.1. Study design

An anatomical cross-sectional serial study was designed. Fresh frozen body donors were used to measure the longitudinal excursion and strain of the median nerve and the fascia (superficial and deep) at the wrist during CCLF at the final position of the ULNT1 in human cadavers. Donations were made to the institutional University Anatomy Laboratory of the Universitat Internacional de Catalunya and the institutional ethics committee approved the present study (CBAS-2023-08).

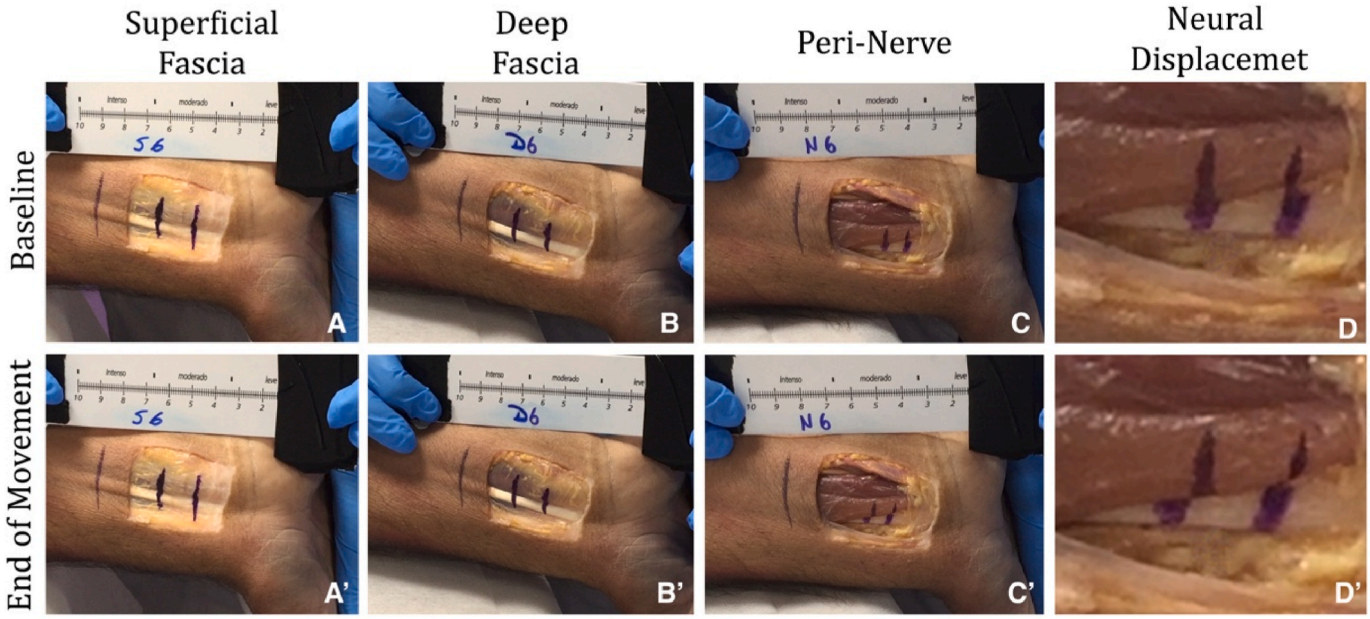


**Fig. 2.** Effect of CCLF on superficial fascia (A and A′), deep fascia (B and B′) and median nerve (C and C′) at the wrist. D and D′ is a magnified image showing the effect of CCLF on the median nerve at the wrist.

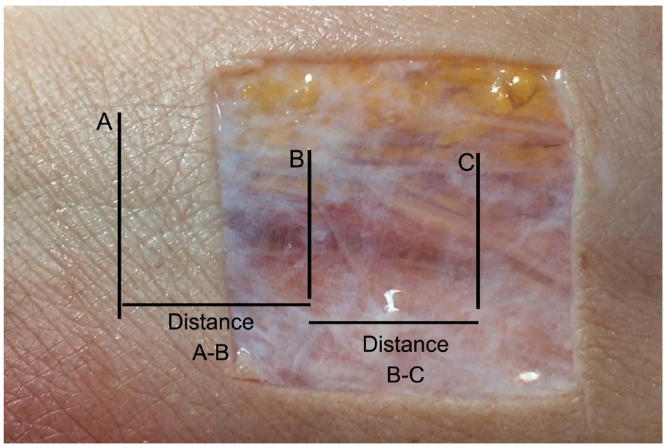


**Fig. 3.** Measurements: A. Reference line - Distance A-B, excursion; Distance B–C - strain.

### 2.2. Cadaver specimens

The study was performed on 10 upper extremities from five fresh frozen body donors (2 males and 3 females, aged 69.8 ± 9.66 years). None of the cadaveric specimens used for this study had evidence of traumatic injury or surgical scarring. Bodies were excluded from the study if they had less than 90° shoulder abduction, 90° shoulder external rotation, full elbow extension or 60° wrist extension (Byl et al., 2002). Samples were stored at 3 °C and brought to room temperature before testing.

### 2.3. Procedure

A skin flap was created immediately proximal to the wrist crease. Subcutaneous tissues were kept intact as much as possible in order not to compromise fascia and nerve behaviour. Dissection was performed at three depths (layers) in each specimen: a. superficial fascia, b. deep fascia and c. median nerve on the ventral surface of the forearm. In order to prevent drying of the tissues, data collection began immediately after the dissection (Fig. 1)

After dissection, the specimens were placed in the supine position, in the final position of the ULNT1: 90° shoulder abduction, shoulder external rotation (to the horizontal plane), full forearm supination, full wrist extension and 30° elbow flexion (Shacklock, 2005b). Maximal joint positions were determined by a marked resistance felt by the examiner. Arm position was maintained by external fixation. The head was initially in the neutral position. Once the arm position was fixed, the neck was moved by one examiner from the neutral position to 20° CCLF and measurements were recorded. The examiner who moved the neck was blinded to the effects of the neck movement on the fascia or the nerve.

### 2.4. Excursion and strain measurements

A video of potential longitudinal excursion and strain of the superficial fascia, deep fascia and median nerve at the wrist during the CCLF was recorded by a 2D camera positioned perpendicular to the skin flap and fixed to a tripod at a distance of 20 cm. A ruler was placed next to the specimen and included in the recordings to calibrate the length of the film frames and obtain reliable measurements. For calibration and kinematic measurements, the software KINOVEA (open source) version 0.8.24 was used. The measurement tool of this software has proven to be a reliable way of measuring lengths with an accuracy of tenths of a millimetre (Puig-Diví et al., 2019). Measurements were taken with the cervical spine in neutral and after CCLF in the ULNT1 position for each tissue.

Once the arm was fixed, recordings and measurements were made in the following order: (1) superficial fascia, (2) deep fascia and (3) median nerve. Two ink landmarks were made with a surgical skin marker on each structure (superficial fascia, deep fascia and median nerve), perpendicular to the expected direction of the movement and one mark was made at a random point on the proximal skin (Fig. 2). The point on the proximal skin was the reference point, as it was for all three measurements.

The following primary dependent variables were included: (1) longitudinal excursion, considered as the increase in the distance between the landmark of the structure being analysed (fascia or nerve) and the landmark of the skin (A-B distance), and (2) strain, considered as the increase in the distance between the landmarks of the structure being analysed (B–C distance) (Fig. 3). Measurements were recorded in mm using the KINOVEA length measurement tool prior and posterior to the manoeuvre. All the procedures were tested in a pilot study on four additional upper extremities and the reliability of excursion and strain measurements was calculated prior to the commencement of the actual experiment.

Because it was not possible to randomize the order of the measurements in the different tissues (dissection needed to be from superficial to deep) and to determine whether that the repetition of the CCLF movement had no influence on the measurements of the fascia and the nerve at the level of the wrist, measurements of the repetitive effect of the CCLF on displacement or strain of the median nerve at the level of the arm were performed on one specimen. A skin flap was opened in the inner proximal arm, allowing visualization of the median nerve at this level and the potential strain and excursion of the nerve were analysed while performing the same procedure described above. No statistically significant difference was found ($p > 0.05$) was found between the three measurements (deep fascia, superficial fascia and median nerve) in either strain or excursion of the median nerve in the arm, ensuring that the repetition of the technique did not modify the capacities of strain or excursion of the median nerve.

### 2.5. Statistical analysis

The intra-class correlation coefficient ($ICC_{3,1}$) at a 95% confidence level (CI), the standard error of measurement (SEM) and the minimum detectable difference (MDD95%) were calculated for the strain and excursion of the median nerve and the superficial and deep fascia in the aforementioned pilot study. Interpretation of ICCs followed Portney and Watkins (1993) and included 0.00 to 0.25 = little to no relationship, 0.26 to 0.50 = fair degree of relationship, 0.51 to 0.75 = moderate to good relationship, and 0.76 to 1.00 = good to excellent relationship.

Statistical analysis was conducted with the SPSS 23.0 package (IBM, Armonk, New York. A repeated-measure analysis of variance (ANOVA) with time (cervical spine neutral and CCLF) and tissue was conducted to determine changes in the outcomes. When a statistically significant effect was observed, a post hoc analysis was performed, and the Bonferroni correction was used to adjust for multiple comparisons. If the assumption of sphericity was violated, the Greenhouse-Geisser correction was utilized for interpretation. Between-tissue differences were analysed using one-way ANOVA. Effect sizes (ES) were calculated using partial eta squared (ŋ2). Considering an effect size >0.140 as large; around 0.060 are medium; and <0.039 small (Lakens, 2013). The level of significance was set at $p < 00.05$.

## 3. Results

### 3.1. Reliability

The reliability coefficients of the strain and excursion measurements of both the median nerve and the superficial and deep fascia were excellent (>0.99). The SEM was <0.0007 mm, and the MDD was <0.002 mm at the 95% confidence level.

**Table 1**
Strain and excursion measurement for the superficial fascia, deep fascia and median nerve at the wrist during structural differentiation.

| | | Cervical Spine Neutral | Cervical Contralateral Lateral Flexion | Difference |
|---|---|---|---|---|
| | | Mean ± SD | Mean ± SD | Mean ± SD |
| Excursion (mm) (Distance A-B) | Superficial Fascia | 25.71 ± 3.45 | 25.71 ± 3.42 | 0.00 ± 0.05 |
| | Deep Fascia | 23.09 ± 2.83 | 23.13 ± 2.81 | 0.04 ± 0.05 |
| | Median Nerve | 25.49 ± 5.86 | 27.61 ± 5.35 | 2.12 ± 1.26 |
| Strain (mm) (Distance B–C) | Superficial fascia | 14.97 ± 2.59 | 14.99 ± 2.59 | 0.02 ± 0.11 |
| | Deep Fascia | 13.67 ± 2.60 | 13.68 ± 2.58 | 0.01 ± 0.12 |
| | Median Nerve | 9.79 ± 1.29 | 10.06 ± 1.52 | 0.27 ± 0.38 |

Strain percentage change: Nerve: 2.32%; Deep Fascia: 0.09%; Superficial fascia 0.14%.

### 3.2. Excursion measurements

The repeated measures ANOVA revealed significant Tissue × Time interaction in excursion ($F = 25.168$, $p < 0.001$, $\eta 2 = 0.68$), for Tissue ($F = 1008.271$, $p < 0.001$, $\eta 2 = 0.98$) and for Time ($F = 25.168$, $p < 0.001$, $\eta 2 = 0.68$).

The application of structural differentiation resulted in a significant increase in median nerve excursion at the level of the wrist. The mean increase in nerve excursion was 2.12 mm ($p < 0.001$). This excursion was proximal for all specimens (Table 1). Applying the structural differentiation maneuver produced a statistically significant difference between the nerve and the fascia (deep and superficial) ($p < 0.001$) (Table 2).

### 3.3. Strain measurements

For the strain variable, ANOVA revealed no significant Tissue × Time interaction ($F = 3.255$, $p = 0.056$, $\eta 2 = 0.16$), for Tissue ($F = 12.104$, $p < 0.001$, $\eta 2 = 0.50$), and for Time (($F = 4.681$, $p = 0.041$, $\eta 2 = 0.16$).

The application of structural differentiation no resulted in a significant increase in the tissues (superficial fascia, deep fascia and median nerve) strain at the level of the wrist (Table 1). No difference in strain was found between the superficial fascia, deep fascia and median nerve at the wrist during structural differentiation ($p > 0.05$) (Table 2).

## 4. Discussion

The primary aim of this study was to measure the effect of structural differentiation on the nerve compared to the fascia because, despite the existing literature, the diagnostic value of the neurodynamic tests in differentiating between neural and fascial structures has been regarded by certain authors to be limited (Di Fabio, 2001) due to the continuity of the fascial system (Di Fabio, 2001; Gajdosik et al., 1985). Previous studies had shown the specificity of CCLF in structural differentiation of the median nerve at the wrist compared to the flexor digitorum superficialis. However, no previous studies have analysed the specificity of the cervical motion in the nerve in relation to the fascia. This location was chosen because this is where neural biomechanics has been most studied (Coppieters and Butler, 2008; Bueno-et al., 2020; Dilley et al., 2003; Bay et al., 1997)

Of the two variables measured in the study, *i.e. excursion and strain*, a significant change was only observed in the excursion, specifically, of the median nerve. The results of this study showed that the CCLF was specific for moving the nerve proximally relative to the superficial and deep fascia, whereas this excursion did not occur in the fascia. The mean nerve excursion was 2.12 mm, similar to previous studies (0.71mm[17] to 1.9mm[30]). The small differences in the mean value among studies could be related to the type of study (*in vivo* or *in vitro*), and the sequence of movements used to perform the ULNT1. In all the studies, the direction of the excursion was proximal, i.e., towards the region/joint where tension is increasing, a mechanism known as "convergence" (Shacklock, 2005b).

Regarding strain, although strain in the nerve was greater than in the fascia, which is practically negligible, the statistical analysis did not show significant results for either structure. Other previous studies have reported significant increase in median nerve strain at the wrist caused by neck motion, between 0.29 mm and 1.39 mm[17,21]. In these studies, strain measurement was performed with motion transducers, which are highly sensitive to small changes in tissue strain. However, due to the technical difficulties of placing these transducers in the thin fascia, strain was calculated with millimetre measurements on the structures themselves. These millimetric measurements may be less sensitive and, although a separation was observed between the two marked points on the nerve (which would imply an increase in strain), the observed increase was not statistically significant.

As far as we know, the present study is the first to show that CCLF resulted in specific movement of the median nerve compared to the fascia (superficial and deep) at the wrist, which is a common area of symptoms during the ULNT1. It seems that the results of the present study may at some point further support the idea of using CCLF as a differentiating manoeuvre during the ULNT1 when the clinical problem is located distally.

### 4.1. Study limitations

The present study has several limitations. First, because the aim of this study was to measure the specificity of the structural differentiation on the median nerve at the wrist to validate the manoeuvre, potential changes in strain or excursion in the nerve or fascia were not measured throughout the entire ULNT1. Second, some properties of the nerve and the surrounding soft tissues may differ from the *in vivo* situation. To prevent drying of the tissues, measurements and data collection began immediately after the dissection. Therefore, the results should be interpreted accordingly and with caution.

## 5. Conclusions

This study showed that the CCLF produced significant changes in the median nerve excursion at the wrist compared to fascia (superficial and deep) during the ULNT1, demonstrating a differential behaviour

**Table 2**
Difference between tissues to excursion and strain measurement for the superficial fascia, deep fascia and median nerve at the wrist during structural differentiation.

| | Difference Superficial Fascia vs Deep Fascia | p | Difference Superficial Fascia vs Median Nerve | p | Difference Deep Fascia vs Median Nerve | p |
|---|---|---|---|---|---|---|
| | Mean difference (95% CI) | | Mean difference (95% CI) | | Mean difference (95% CI) | |
| Excursion (mm) (Distance A-B) | 0.022 mm (−0.862; 0.907) | 1.000 | 2.122 mm (1.238; 3.007) | 0.000 | 2.100 mm (1.216; 2.984) | 0.000 |
| Strain (mm) (Distance B–C) | 0.011 mm (−0.280; 0.303) | 1.000 | 0.244 mm (−0.047; 0.536) | 0.123 | 0.256 mm (−0.036; 0.547) | 0.100 |

between the nerve and the fascia at the wrist. This supports the use of CCLF as a structural differentiation manoeuvre in the diagnosis of wrist pain.

## CRediT authorship contribution statement

**Albert Pérez-Bellmunt:** Writing – review & editing, Resources, Investigation, Conceptualization. **Carlos López-de-Celis:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Elena Estébanez-de-Miguel:** Methodology, Formal analysis, Data curation. **Jorge Pérez-Rey:** Writing – original draft, Methodology, Data curation. **Michael Shacklock:** Writing – review & editing, Investigation, Conceptualization. **Sara Ortiz-Miguel:** Investigation, Data curation. **Elena Bueno-Gracia:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization.

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