



## Original Research

# Neural gliding and neural tensioning differently impact flexibility, heat and pressure pain thresholds in asymptomatic subjects: A randomized, parallel and double-blind study

Carolina Martins <sup>a</sup>, Rebeca Pereira <sup>a</sup>, Inês Fernandes <sup>a</sup>, Joana Martins <sup>a</sup>, Tiago Lopes <sup>a</sup>, Luis Ramos <sup>a</sup>, Joana Pacheco <sup>a</sup>, Anabela G. Silva <sup>a, b, \*</sup>

<sup>a</sup> School of Health Sciences, University of Aveiro, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal

<sup>b</sup> CINTESIS.UA, University of Aveiro, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal

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## ABSTRACT

**Objective:** To compare the effect of neural gliding and tensioning on hamstring flexibility, nerve function (heat and cold thresholds) and pain sensitivity (pain intensity and pressure pain threshold) of the mobilized and non-mobilized lower limbs at post-intervention and 24 h follow up.

**Design:** Randomized, parallel and double blinded trial.

**Setting/participants:** Forty-eight asymptomatic participants.

**Intervention(s):** Participants received neural gliding (n = 23) or tensioning (n = 25).

**Main Outcome Measures –** Straight leg raising (SLR; in degrees), heat and cold threshold (°C), pressure pain threshold (PPT; in Kgf) and pain intensity (visual analogue scale), taken at baseline, post-intervention and at 24 h follow up.

**Results:** There was a significant interaction between time, intervention and limb for SLR ( $F_{2,45} = 3.83$ ;  $p = 0.029$ ). A significant interaction between time and intervention for PPT ( $F_{2,45} = 3.59$ ;  $p = 0.036$ ) and heat threshold ( $F_{2,45} = 5.10$ ;  $p = 0.01$ ). A significant effect of time ( $F_{2,45} = 9.42$ ;  $p < 0.001$ ) and of limb ( $F_{1,46} = 4.78$ ;  $p = 0.035$ ) for pain intensity during SLR, and a significant effect of time ( $F_{2,45} = 3.65$ ;  $p = 0.034$ ) for pain intensity during PPT.

**Conclusion:** Gliding and tensioning had similar and positive effects for flexibility in the mobilized limb, but tensioning was superior for the non-mobilized limb. Gliding was superior to tensioning for pressure pain and heat thresholds.

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## 1. Introduction

The peripheral nervous system is exposed to combinations of tensile, shear and compression forces during body segment movements and postures (Rydevik, Lundborg, & Bagge, 1981; Topp & Boyd, 2006; Wall et al., 1992). However, its structural organization allows it to function while tolerating and adapting to these forces in day-to-day activities and sport (Shacklock, 2005; Silva et al., 2014). This is probably due to the peripheral nervous system ability to glide in relation to adjacent structures and of internal fascicles to glide against each other; to the considerable amount of

connective tissue that surrounds the nerve protecting it and facilitating movement; to the undulatory course of the nerve fibres that appear suited to accommodate movement and to promote dispersion of forces (Gifford and Pitt-Brooke, 1997), as well as to the abundant blood vessels with coiled structure to minimize the impact of movement on the peripheral nervous system normal blood supply (Ugrenovic, Jovanovic, Kovacevic, & Simic, 2013). However, these mechanisms may be disrupted in some pathologies, such as carpal tunnel syndrome or diabetes (Boyd, Gray, Dilley, Wanek, & Topp, 2012; Hough, Moore, & Jones, 2007). Furthermore, both a disrupted response of the sciatic nerve to mechanical forces (Turl & George, 1998) and impaired function of the sciatic nerve (Kouzaki et al., 2017) have been identified in individuals with hamstring injuries. This suggest a potential association between the ability of the sciatic nerve to accommodate mechanical stresses and its function, and may also suggest that disrupted mechanical

\* Corresponding author. School of Health Sciences, University of Aveiro, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal.

E-mail address: [asilva@ua.pt](mailto:asilva@ua.pt) (A.G. Silva).

and physiological nerve responses may either be a consequence or a predisposing factor for injury.

Neural mobilization is an intervention used by physiotherapists to restore normal mechanical and physiological responses of the nervous system to movement and posture (Ridehalgh, Greening, & Petty, 2005). It has been suggested that neural mobilization may induce an array of complex neurophysiologic changes that facilitate nerve function and improve symptoms, such as changes in the viscoelastic properties of the nerve, improved nerve mobility, increased intraneural fluid dispersion, activation of the descending pain inhibition, and reduced concentration of inflammatory mediators involved in nerve pain (Bertolini, Silva, Trindade, & Carvalho, 2009; Calvo-Lobo et al., 2018; Efstathiou, Stefanakis, Savva, & Giakas, 2015; Rodríguez-Sanz et al., 2017; Santos et al., 2012). Different combination of joints and movements allow physiotherapists to target different nerves (Butler, 2000) and to modulate the amount of gliding and stress applied to a nerve (Silva et al., 2014). In general, two types of neural mobilization are used: gliding and tensioning. Gliding techniques consist of simultaneous movements of at least two joints, so that while the nerve is elongated in one joint it is shortened in the other. In contrast, tensioning techniques elongate the nerve in both joints (Beltran-alacreu, Jiménez-sanz, Carnero, & Touche, 2015; Shacklock, 2005). Neural gliding results in larger amounts of nerve excursion in relation to adjacent tissues while neural tensioning results in higher nerve internal pressure (Silva et al., 2014). Conceivably, these different techniques may impact neurophysiological processes differently.

Current systematic reviews suggest that neural mobilization is effective in reducing pain and improving disability, pressure pain thresholds, function and flexibility (Ballesteró-Pérez et al., 2016; Neto, Freitas, Marques, Gomes, & Andrade, 2017). However, no reference is made on whether the type of mobilization used impacts results. Conceivably, because there are insufficient studies comparing both techniques. A few previous studies compared the effects of gliding and tensioning techniques and reported conflicting results. For example, there are reports that both techniques have positive and equivalent impact on hamstring flexibility (Sharma, Balthillaya, Rao, & Mani, 2016), hop testing and static postural control (Ferreira & Silva, 2018), that gliding has superior hypoalgesic effects than tensioning (Beltran-alacreu et al., 2015) or that none of the techniques has a positive impact on postural control (Nunes et al., 2017). In addition to the reduced number of existing studies comparing gliding and tensioning, studied effects are limited to immediate post-intervention effects on the ipsilateral side of mobilization. The study of the impact of neural gliding and tensioning on other variables, such as heat and cold thresholds, which give an indication on the function of small nerve fibers in peripheral neuropathies (Chéliout-Hérou et al., 2005), is also of relevance. This study aimed to compare the effect of neural gliding techniques against neural tensioning techniques of the dominant lower limb on lower limb flexibility, heat and cold thresholds, pressure pain threshold and perceived pain intensity of the mobilized (dominant lower limb) and non-mobilized (non-dominant) lower limb, immediately after the intervention and at 24 h follow up. We hypothesized that: i) both techniques will have a positive and similar effect on hamstrings flexibility, ii) that gliding will be superior to tensioning on its impact on heat, cold and pain thresholds and perceived pain intensity, iii) that both techniques will have an impact on the non-mobilized limb, but tensioning will be superior to gliding and that iv) both techniques will have immediate effects that will last 24 h. The use of an asymptomatic sample decreases sample variability and informs on changes in the absence of pathology providing a pattern against which to compare individuals with pathology. This is particularly relevant as, anecdotally, nervous system mobilization is quite used in sports.

## 2. Methods

This was a randomized, controlled and assessor and patient blind trial. Ethical approval was given by the Council of Ethics and Deontology of University of Aveiro and the trial was registered at [ClinicalTrials.gov](https://ClinicalTrials.gov) (NCT03029260) prior to participant recruitment.

### 2.1. Sample

Participants were recruited among asymptomatic University students and were randomly allocated into 2 groups: one group received neural gliding and the other neural tensioning, by a researcher not involved in recruitment or intervention. Randomization to treatment was performed using a blocked sequence generated using the Research Randomizer software (<https://www.randomizer.org/>) and revealed to the researcher performing the intervention immediately before it.

An a priori sample size calculation for each of the two groups was performed using G\*Power 3.1.9.2 and the following parameters: ANOVA - repeated measures within-between interaction as the statistical test, an effect size of 0.25 (medium), an alpha of 5%, and 80% power. It was estimated that 24 participants were required in each group.

To enter the study, participants would have to be 18 years or older, and report no knowledge of nervous system mobilization, no injuries of the lower back and lower limbs in the last 3 months or surgery of the lower back and lower limbs in the last 6 months. Potential participants were excluded if they reported neurological, cancer or rheumatic pathology. All participants provided their written informed consent.

### 2.2. Procedures

Participants were assessed at baseline, after the intervention and at 24 h follow up. Measurements were taken for: heat and cold threshold, pressure pain threshold and hamstrings flexibility. Before conducting the full study, a test-retest reliability analysis was performed using 10 participants not included in the full study.

#### 2.2.1. Sociodemographic data

Participants were asked to provide data regarding age, gender, dominant lower limb (defined as the limb used to kick a ball (van Melick, Meddeler, Hoozeboom, Nijhuis-van der Sanden, & van Cingel, 2017)) and level of education, which were assessed through a questionnaire purposefully developed for this study. Weight and height were also measured.

#### 2.2.2. Heat and cold perception threshold

Heat and cold perception threshold were evaluated using QSense (Medoc Ltd.), a device for quantitative sensory testing, using the limits method in the Medoc Main Station software. To familiarize participants with the procedure, a pre-test was performed in the thenar region. Then, a point corresponding to the region of innervation of the superficial peroneal nerve (the cutaneous branch of the peroneal nerve), defined as a point anterior to the midpoint between the external malleolus and the base of the fifth metatarsus, was marked in both feet. Marking was performed with the participants in supine position and ankle in neutral position. The QSense probe (a cube with about 5 cm) was then fixed to this point (Fig. 1A). Participants were told to press a button as soon as they felt a warm (heat threshold) or cold (cold threshold) sensation on a command they hold in their hand and that would stop the temperature from changing. Participants were asked to have his finger next to the button so that the answer was as fast as possible. Four measurements were taken for each threshold and



**Fig. 1.** Measurement procedures: A) heat and cold threshold; B) PPT and C) hip range of motion during SLR.

lower limb and its mean used in the statistical analysis.

### 2.2.3. Pressure pain threshold

For the evaluation of the pressure pain threshold (PPT) a pressure algometer (JTECH Medical Industries, Salt Lake City, US) was used. The pressure reading device was attached to a rubber tip of 1 cm<sup>2</sup>. Participants were in supine position with knees and hips bent and feet together and fully supported on the bed. PPTs were measured at a point anterior to the midpoint between the external malleolus and the base of the fifth metatarsus. Pressure was applied at a rate of approximately 3 N/s and perpendicularly to the surface (Fig. 1B). Participants were instructed to say the word “pain” as soon as the feeling of pressure changed from pressure to pain. A pre-test was performed in the thenar region for participants to get familiar with the procedures. Three measurements were performed at both lower limbs. PPT measurements were found to have acceptable intra and inter-observer reliability (intraclass correlation coefficient, ICC  $\geq$  0.7) (Fingleton, Dempsey, Smart, & Doody, 2014) and small measurement error (Romero-Morales et al., 2017).

### 2.2.4. Flexibility

Lower limb flexibility was assessed using the passive Straight Leg Raising (SLR) test. Each participant was in supine position, in comfortable clothing that did not limit the mobility of the lower limbs. One researcher performed hip flexion with the knee in extension and the ankle dorsiflexed and stopped when participants first reported pain. A second researcher measured the range of hip flexion with a universal goniometer (EZ Read JamarVR Q7 Goniometer). The axis of the goniometer was centered at the greater trochanter, the fixed arm was parallel to the bed (alignment was maintained with the help of a bubble level) and the movable arm was aligned with the mid line of the hip, which was previously

marked as the line joining the greater trochanter and the lateral epicondyle of the femur (Fig. 1C). Three measurements were taken, and their mean was considered for the purposes of statistical analysis. In previous studies, the passive SLR test showed a test-retest reliability coefficient of 0.87 (Cejudo, Sainz de Baranda, Ayala, & Santonja, 2015) and an inter-observer reliability coefficient of 0.94–0.96 (Castellote-Caballero, Valenza, Puenteadura, Fernández-de-Las-Peñas, & Alburquerque-Sendín, 2014).

All measurements were performed by a researcher that was blind to the type of intervention that each participant received.

### 2.2.5. Pain intensity

A Visual Analogue Scale (VAS) was used to quantify pain perceived by participants during PPTs and straight leg raising. It consists of a straight line of 10 cm, anchored with “0 – no pain” and “10-worst pain imaginable” (Kersten, White, & Tennant, 2014). Its test-retest reliability has been shown to be high among literate participants (ICC = 0.94, P < 0.001) (Hawker, Mian, Kendzerska, & French, 2011).

## 2.3. Intervention

### 2.3.1. Tensioning

Tensioning neural mobilization was performed on the dominant limb using the Straight Leg Raising (SLR) test and a combination of movements to stress the peroneal nerve (Shacklock, 2005). Participants were in supine. The investigator placed the ankle in inversion and plantar flexion and the knee in extension and while maintaining these joint positions, took the hip to maximum flexion. As soon as the participant felt pain or discomfort, the investigator decreased hip flexion by 5–10° to a hip position where no pain was felt. The mobilization consisted of taking the hip from this position to mid of available flexion and then again to extension (4 series of 10 repetitions with an approximate rhythm of 6 s per cycle, and an interval of 1 min between series), while maintaining knee extension and ankle plantar flexion and inversion (Fig. 2).

### 2.3.2. Gliding

Gliding was performed with participants in the same position as described for tensioning and movements also targeted the peroneal nerve. From an initial position consisting of ankle dorsiflexion, knee and hip extension the researcher simultaneously performed ankle plantar flexion and inversion, total knee flexion and hip flexion to 90, returning to the initial position (Fig. 3). A total of 4 series of 10 repetitions with an approximate rhythm of 6 s per cycle, and an interval of 1 min between series were performed.

## 2.4. Statistical analysis

All data analyses were performed using SPSS 24.0 for Windows (SPSS Inc, Chicago, IL). Mean and standard deviation and count and



**Fig. 2.** Tensioning mobilization: A) participants' maximum hip flexion; B) participants' maximum hip flexion minus 5 to 10°; B to C/C to B) range of hip flexion used in tensioning mobilization maintaining knee extension and ankle dorsiflexion.



Fig. 3. Initial (left) and final (right) position for gliding mobilization.

proportion were used to describe continuous and categorical variables, respectively. Data was assessed for outliers, normality and homogeneity of variance. Between group differences for baseline characteristics were explored using a Student's *t*-test (continuous variables). An intraclass correlation coefficient (ICC; two way random, absolute agreement) and respective 95% confidence interval were used for relative reliability analysis and interpret as poor (ICC < 0.50), moderate (ICC = 0.50–0.75), good (ICC = 0.75–0.90) and excellent (ICC ≥ 0.90) (Portney & Watkins, 2000). In addition, the standard error of measurement (SEM) was calculated as  $SEM = SD * \sqrt{1 - ICC}$  (Weir, 2005). A general linear model of repeated measures using time (T0, T1 and T2), intervention (sliding vs. tensioning) and limb (dominant vs. non-dominant) as the factors was used to compare the effects of the interventions. Post hoc comparisons (Bonferroni) were used when a significant main effect was found for time. A significant level was set at  $p < 0.05$ . Partial eta square was used as an indicator of effect size and interpreted as small (0.01), medium (0.06), and large (0.14) effect size (Richardson, 2011). Significance was set at  $p < 0.05$ .

### 3. Results

#### 3.1. Reliability

Before conducting the full study, a reliability analysis was performed using the same measurements procedures as for the full study with 10 participants not included in the full study. ICC values were moderate to excellent (Table 1).

#### 3.2. Sample characteristics

Fifty asymptomatic volunteers were recruited but for technical reasons (i.e. an error occurred when saving data into an excel file), data from 2 participants could not be included (Fig. 4). A total of 48 participants (35 females and 13 males) were included in the analysis. There were no significant differences between groups at baseline (Table 2).

**Table 1**  
Intra-rater reliability analysis (n = 10).

Outcome	ICC (95% CI)	SEM
Heat (D)	0.88 (0.74; 0.97)	0.76 °C
Heat (ND)	0.90 (0.74; 0.97)	0.71 °C
Cold (D)	0.60 (0.30; 0.86)	1.18 °C
Cold (ND)	0.59 (0.28; 0.85)	0.50 °C
PPT (D)	0.97 (0.89; 0.99)	1.63 Kg
PPT (ND)	0.95 (0.87; 0.99)	2.14 Kg
SLR (D)	0.88 (0.69; 0.96)	2.03°
SLR (ND)	0.89 (0.72; 0.97)	1.97°

Legend: D – dominant lower limb; ND – non-dominant lower limb; SEM – standard error of measurement; MDD – minimal detectable difference.

#### 3.3. Effect of the interventions

A significant interaction between time, intervention and limb was found for lower limb flexibility ( $F_{2,45} = 3.83$ ;  $p = 0.029$ ; partial  $\eta^2 = 0.15$ ). Pairwise comparisons revealed a significant increase from T0 to T1 ( $p < 0.001$ ) and from T0 to T2 ( $p = 0.01$ ), but not from T1 to T2 ( $p > 0.05$ ). Data (Fig. 5; Supplementary material) suggests similar effects between techniques for the dominant limb, but higher increases in the tensioning group for the non-dominant limb. A significant effect of time ( $F_{2,45} = 9.42$ ;  $p < 0.001$ ; partial  $\eta^2 = 0.30$ ) and a significant effect of limb ( $F_{1,46} = 4.78$ ;  $p = 0.035$ ; partial  $\eta^2 = 0.09$ ) were found for pain intensity during SLR, but no significant interaction ( $p > 0.05$ ). Pairwise comparisons revealed a decrease in pain intensity between T0 and T1 ( $p = 0.001$ ) and between T0 and T2 ( $p < 0.001$ ), but not from T1 to T2 ( $p > 0.05$ ) (see Fig. 5).

A significant interaction between time and intervention was found for PPT ( $F_{2,45} = 3.59$ ;  $p = 0.036$ ; partial  $\eta^2 = 0.14$ ). Pairwise comparisons revealed a significant increase from T0 to T2 ( $p = 0.007$ ), and from T1 to T2 ( $p = 0.021$ ), but not from T0 to T1 ( $p > 0.05$ ). Data (Fig. 6; Supplementary material) suggests that this increase was higher in the gliding group. There was a significant effect of time ( $F_{2,45} = 3.65$ ;  $p = 0.034$ ; partial  $\eta^2 = 0.14$ ) for pain intensity during PPT, but no significant interaction ( $p < 0.05$ ). Pairwise comparisons revealed a significant decrease from T0 to T1 ( $p = 0.013$ ) and from T0 to T2 ( $p = 0.011$ ), but not from T1 to T2.

A significant interaction between time and intervention was found for heat threshold ( $F_{2,45} = 5.10$ ;  $p = 0.01$ ; partial  $\eta^2 = 0.19$ ). Data analysis (Fig. 6; Supplementary material) suggests a higher increase in the gliding group compared to the tensioning group. Pairwise comparisons revealed a significant increase from T0 to T1 ( $p = 0.001$ ), and from T0 to T2 ( $p = 0.002$ ), but not from T1 to T2 ( $p > 0.05$ ).

No significant main effects were found for cold threshold ( $p > 0.05$ ).

### 4. Discussion

This study compared the effects of two neural techniques, gliding and tensioning, both at post-intervention and at 24 h follow up and results partially support our hypothesis. Findings suggest that i) both techniques have similar and positive effects for flexibility in the mobilized limb, but tensioning is superior to gliding for flexibility in the non-mobilized limb; ii) gliding is superior to tensioning for pressure pain thresholds and heat thresholds with similar effects on the mobilized and non-mobilized limb; iv) both techniques have positive and similar effect for perceived pain intensity during SLR and PPT and v) that these effects are of moderate to large magnitude and maintained at 24 h follow up. None of the techniques had an impact on cold thresholds.

#### 4.1. Flexibility

The finding that both gliding and tensioning neural mobilization have an impact on hamstring flexibility is in line with a previous study (Sharma et al., 2016). The current study adds to previous research by showing that improvements are still present at 24 h follow up and that tensioning neural mobilization is superior for the non-mobilized limb. Furthermore, the decrease in perceived pain intensity at the end of the SLR, supports previous claims that neural mobilization contributes to increase flexibility by means of decreased mechanosensitivity. However, and considering that there was a decrease in perceived pain intensity in both limbs and no significant effect of the intervention, this is unlikely to be the only mechanism and one that does not seem to explain the

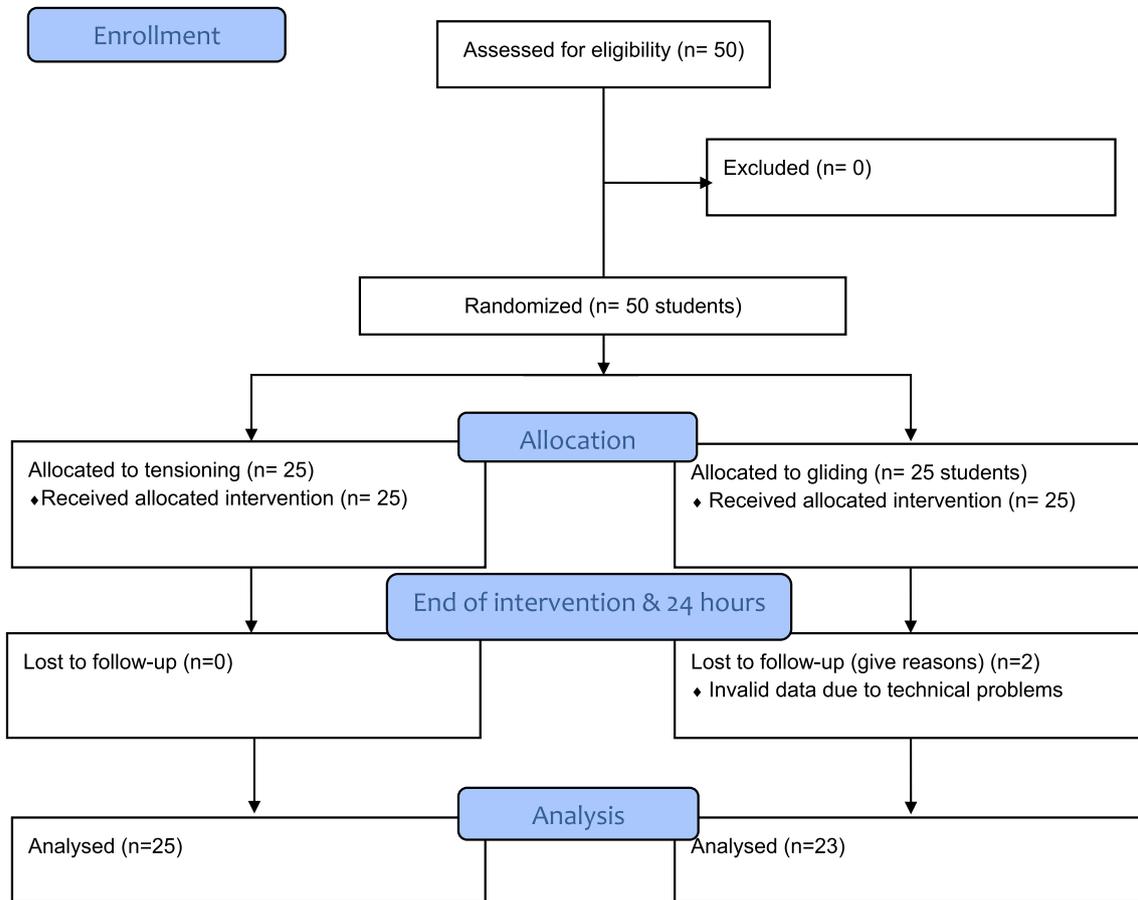


Fig. 4. Flowchart of the trial.

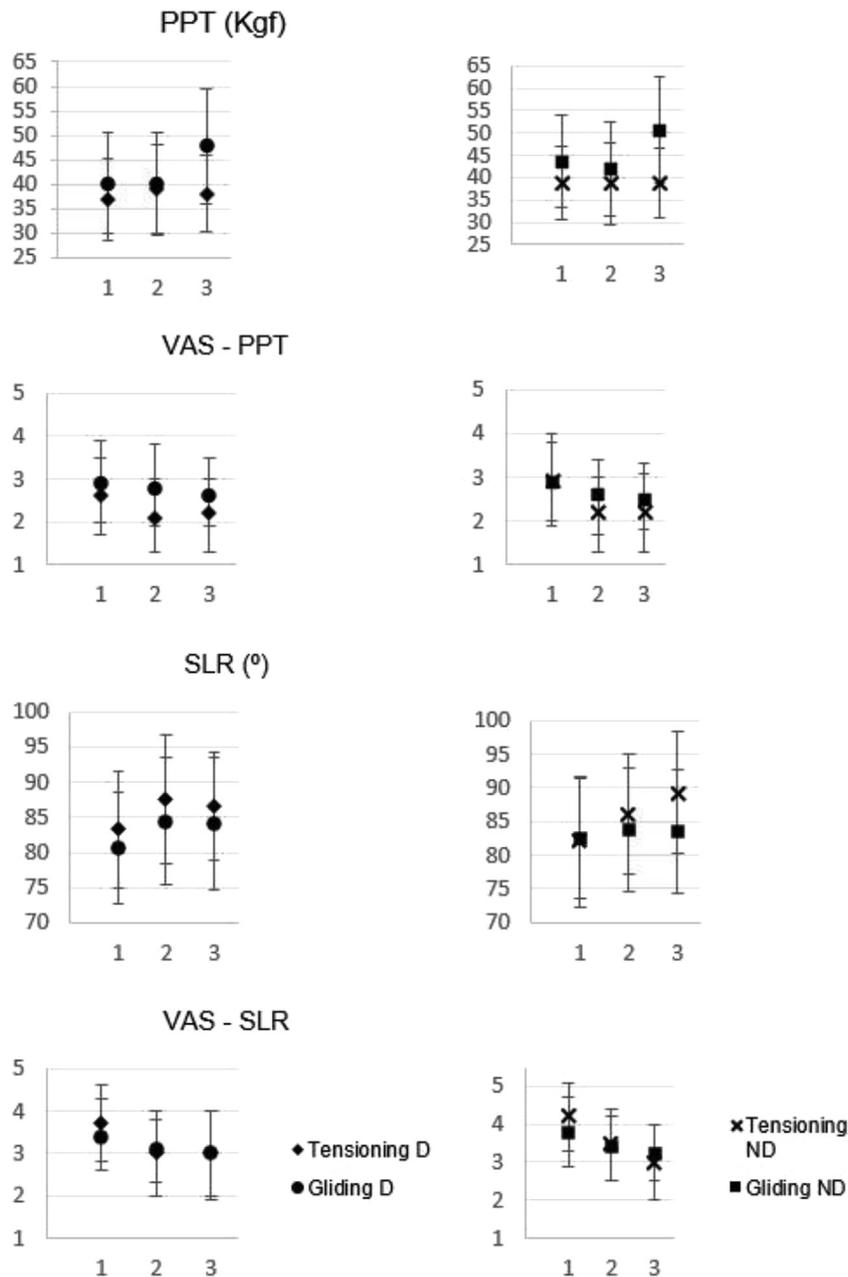
**Table 2**  
Sample characteristics and baseline measurements.

Outcome		Tensioning (n = 25)	Gliding (n = 23)	p
Age	years	19.4 ± 1.2	19.6 ± 1.5	0.393
Height	cm	165.1 ± 8.1	169.9 ± 10.1	0.089
Weight	Kg	61.2 ± 11.7	62.5 ± 8.4	0.297
Body mass index	Kg/cm <sup>2</sup>	22.5 ± 3.0	21.6 ± 1.7	0.220
Heat Threshold (D)	°C	35.7 ± 1.8	36.1 ± 2.3	0.195
Heat Threshold (ND)	°C	35.7 ± 1.5	36.2 ± 1.9	0.152
Cold threshold (D)	°C	30.1 ± 1.1	30.1 ± 1.4	0.388
Cold threshold (ND)	°C	30.4 ± 0.7	30.1 ± 1.0	0.329
PPT (D)	Kgf	36.9 ± 22.2	40.2 ± 17.5	0.612
PPT VAS (D)		2.6 ± 2.3	2.9 ± 2.3	0.714
PPT (ND)	Kgf	38.8 ± 20.1	43.7 ± 23.7	0.389
PPT VAS (ND)		2.9 ± 2.6	2.9 ± 2.2	0.117
SLR (D)	°	83.2 ± 21.2	80.7 ± 18.3	0.990
SLR VAS (D)		3.7 ± 2.2	3.4 ± 2.0	0.547
SLR (ND)	°	82.0 ± 23.6	82.5 ± 20.5	0.866
SLR VAS (ND)		4.2 ± 2.4	3.8 ± 2.0	0.538

D – Dominant limb; ND – non-dominant limb; VAS – visual analogue scale; SLR – straight leg raising.

different impact of gliding and tensioning on the non-mobilized limb. Tensioning is performed near the end of available range of motion and it is possible that this position has a greater impact on the mechanical characteristics of the nerve and that its effects,

physiological or mechanical, reach farther. The nerves have been shown to exhibit a time-dependent viscoelastic behavior, including its gradual elongation with time in response to tension (Kwan, Wall, Massie, & Garfin, 1992). Furthermore, Andrade et al. (2018) have shown that increased ankle range of motion was correlated with decreased stiffness of the ipsilateral sciatic nerve after 6 min of stretching of the ipsilateral sciatic nerve. It has also been suggested that contralateral tensioning mobilization might reduce electromyographic activity for patients with stroke (Castilho et al., 2012). Conceivably, the different effects of gliding and tensioning on the non-mobilized limb may be due to a greater impact of tensioning on contralateral nerve stiffness and electromyographic activity. These hypotheses require further investigation in future studies. However, the contribution of non-neural structures to the increased flexibility cannot be completely discarded, particularly for tensioning neural mobilization, as the maintenance of the lower limb near end range positions can stretch muscles and other continuous structures such as fascia. Nevertheless, both gliding and tensioning have been shown to be superior to muscle stretching for hamstring flexibility (Sharma et al., 2016) and fascia seems to require particularly high forces before deformation as a previous study showed that daily stretching for 1 month did not affect shear strain of the fascia (Langevin, Bishop, Maple, Badger, & Fox, 2018). The impact of neural tensioning on the contralateral lower limb flexibility may be of clinical relevance in acute sports injuries or immediate post-surgical rehabilitation when the mobilization of the affected limb may be contra-indicated.



**Fig. 5.** Mean and 95% confidence interval of the mean for PPT, SLR and VAS at baseline (1), post-intervention (2) and 24 h follow up (3) for both the dominant (D) and non-dominant (ND) limb.

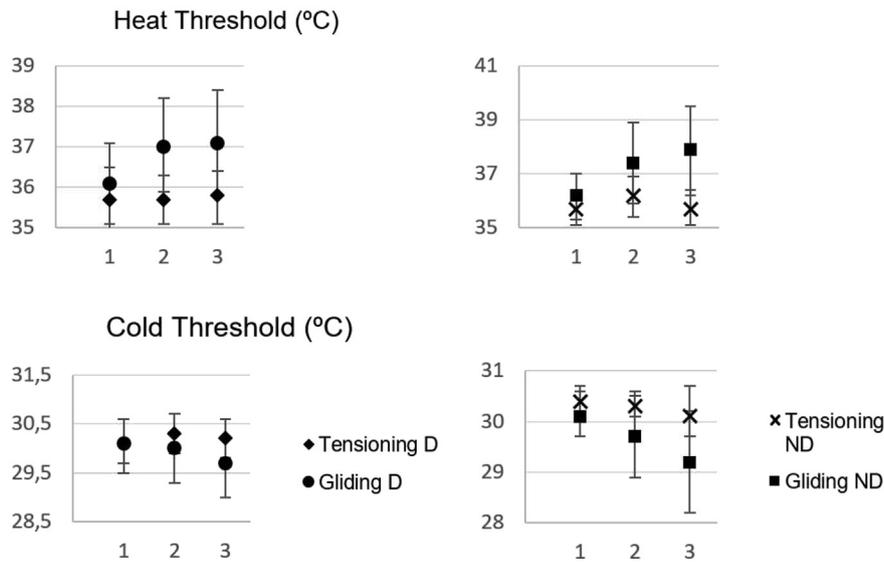
Figure legend: PPT - time x intervention ( $F_{2,45} = 3.59$ ;  $p = 0.036$ ; partial  $\eta^2 = 0.14$ ); Flexibility - time x intervention x limb ( $F_{2,45} = 3.83$ ;  $p = 0.029$ ; partial  $\eta^2 = 0.15$ ); Pain intensity at the end of SLR - time ( $F_{2,45} = 9.42$ ;  $p < 0.001$ ; partial  $\eta^2 = 0.30$ ), limb ( $F_{1,46} = 4.78$ ;  $p = 0.035$ ; partial  $\eta^2 = 0.09$ ), interaction ( $p > 0.05$ ); Pain intensity during PPT - time ( $F_{2,45} = 3.65$ ;  $p = 0.034$ ; partial  $\eta^2 = 0.14$ ).

#### 4.2. PPT

Results suggest that gliding is superior to tensioning in promoting hypoalgesia at 24 h follow up and for body sites located in both the mobilized and non-mobilized limb. The effects distant to the mobilized limb suggest that hypoalgesia is mediated by central mechanisms such as the descending inhibition (Beltran-alacreu et al., 2015) and opioids (Santos et al., 2014). Santos et al. (Santos et al., 2014) found that neural mobilization of injured rats increased the expression of opioid receptors in the Periaqueductal Grey (PAG) region, suggesting that these effects may occur through activation of endogenous opioid-mediated pain modulatory

systems. Santos et al. (Santos et al., 2012) reported a decrease of the nerve growth factor and glial fibrillary acidic protein, which are involved in hyperalgesia, in dorsal root ganglion after treating injured rats with neural mobilization. Inhibition of temporal summation has also been reported in asymptomatic persons (Beneciuk, Bishop, & George, 2009) and in persons with carpal tunnel syndrome (Bialosky et al., 2009) after neural mobilization. Temporal summation reflects facilitator mechanisms at the dorsal horn and is mediated by C-fibers.

It has been suggested that the amount of mechanical stimulus may impact hypoalgesia (McLean, Naish, Reed, Urry, & Vicenzino, 2002), raising the question as to whether the greater movement



**Fig. 6.** Mean and 95% confidence interval of the mean for heat and cold thresholds at baseline (1), post-intervention (2) and 24 h follow up (3) for both the dominant (D) and non-dominant (ND) limb.

Figure legend: Heat threshold - time x intervention ( $F_{2,45} = 5.10$ ;  $p = 0.01$ ; partial  $\eta^2 = 0.19$ ); Cold threshold: no significant main effect ( $p > 0.05$ ).

excursion occurring at a higher number of joints may account for the higher hypoalgesic effects of gliding. This is likely to result in greater stimulation of the large non-nociceptive afferent fibers, increasing the mechanical afferent input from muscles and joints arriving at the dorsal horn. It is also possible that the larger excursion of the nerve in gliding techniques has a greater mechanical impact on the intrinsic innervation of nerve sheaths, the *nervi nervorum*, which has been shown to have fibers that function as nociceptors but also as mechanoreceptors (Sauer, Bove, Averbeck, & Reeh, 1999), potentiating hypoalgesic effects. In contrast, the higher elongation of nerves during tensioning may have a greater impact on *vasa nervorum* (Qureshi, Saleem, Ahrar, & Raja, 2017) elongation decreasing nerve vascularization. Beltran-Alacreu and colleagues (Beltran-alacreu et al., 2015) reported neural gliding to have a wider hypoalgesic effect than neural tensioning and suggested that the increased hypoalgesic effects of neural gliding was due to its smaller impact on nerve elongation and, consequently, on internal nerve pressure. Future studies could further explore the mechanisms behind gliding and tensioning induced hypoalgesia.

#### 4.3. Heat and cold threshold

Neural gliding seems to have a larger impact than neural tensioning on increasing heat threshold, suggesting that neural gliding may contribute to desensitize C fibers in the presence of pain, but raising questions as to the significance of this finding for C-fiber nerve function in non-painful conditions where there is a loss of function and increased threshold. The desensitization of C-fibers may be of great relevance in C-fiber mediated pain syndromes and central sensitization as increased C-fiber activity seems to contribute to the appearance and maintenance of central sensitization (Hathway, Vega-Avelaira, Moss, Ingram, & Fitzgerald, 2009; McLean et al., 2002) and is associated with increased activation in pain processing areas of the brain (Staud, Craggs, Perlstein, Robinson, & Price, 2008). This suggests that neural gliding may be of clinical relevance when aiming to prevent or reverse signs and symptoms of central sensitization, but this requires further investigation in future studies.

Neural mobilization is believed to improve nerve function by

improving its viscoelastic properties, its mobility and by increasing intraneural fluid dispersion (Bertolini et al., 2009; Brown et al., 2011). Conceivably, the impact of neural mobilization on C-fiber function may differ depending on the condition of the individual. Future studies can explore the impact of neural mobilization on conditions that present with C-fiber loss of function.

None of the techniques significantly impacted cold threshold. While heat threshold is mediated by C fibers, cold threshold is mediated by A $\delta$  fibers. Previous research has shown a different behavior of C and A $\delta$  fibers to thermal stimuli (Palmer, Martin, Steedman, & Ravey, 2000) as well as an impact of neural tensioning on C but not on A $\delta$  fibers (Beneciuk et al., 2009). Taken together, these findings suggest that neural mobilization impacts the function of C and A $\delta$  fibers differently, at least in asymptomatic individuals.

#### 4.4. Limitations

First, participants were asymptomatic subjects and, therefore, findings may not apply to patients with pain and pathology. The dose of mobilization was chosen based on our previous experience as it varies greatly among studies (Neto et al., 2017) and there is no evidence-based recommendation for the amount of neural gliding or tensioning that should be used. We used the SLR to characterize lower limb flexibility, but it has been suggested that contralateral hip flexor length and increased pelvic rotation can confound the results (Davis, Quinn, Whiteman, Williams, & Young, 2008). Future studies could explore whether measurement procedures impact results on flexibility. We measured pain threshold at one body site only, which corresponded to the cutaneous innervation of the peroneal nerve but was close to the cutaneous innervation of the sural nerve. However, this prevented us from characterizing the extension of hypoalgesia. This would have been interesting as the neural mobilization used impacted all nerves in the lower limb. Similarly, this could also have been done for cold and heat threshold. Nevertheless, including more measurements would have increased the duration of the protocol with a potential impact on participants concentration and fatigue.

## 5. Conclusions

Our results suggest that neural gliding and tensioning impact both the mobilized and the non-mobilized limb and both impact perceived pain intensity to stretch and pressure to a similar extent; both techniques improved flexibility, but tensioning was superior for flexibility of the contra-lateral limb and neural gliding was superior to tensioning for hypoalgesia to mechanical pressure and heat threshold. Furthermore, most effects are maintained at 24 h follow up and increased PPT was identifiable 24 h post-intervention only. The fact that neural mobilization impacts both the mobilized and the non-mobilized limb suggests that it could be used for contralateral treatment of limbs that are immobilized or for which mobilization is contra-indicated or could aggravate symptoms. The slightly different effects of neural gliding and neural tensioning suggest that the choice of the techniques may depend on the treatment aim.

## Conflicts of interest

Authors declare no conflicts of interest.

## Ethical approval

Ethical approval was given by the Council of Ethics and Deontology of University of Aveiro.

## Clinical trial registry name and registration number

ClinicalTrials.gov (NCT03029260).

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ptsp.2019.01.008>.

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