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Technical and measurement report

Neurodynamic test of the peroneal nerve: Study of the normal response in asymptomatic subjects

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ABSTRACT

Background: Neurodynamic tests (NDTs) have shown to be useful in evaluating neural tissue involvement. Peroneal nerve reaches high importance in ankle injuries. However, up to date, no study has documented the normal responses for this nerve.
Objectives: The objective of this study was to document normal responses of the peroneal neurodynamic test (NDT_{PER}) in asymptomatic subjects. Differences in sensory response depending on sex and leg dominance were also examined.
Design: A cross-sectional study was designed.
Method: Forty-four asymptomatic subjects with a total of 88 lower limbs were tested. The range of motion (ROM) at the point of first appearance of symptoms (S1) and the point of symptoms tolerance (S2), quality and distribution of sensory responses were recorded.
Results: Hip flexion was significantly higher at S2 than S1 (mean difference, 27.22°; 95% CI: 25.29°, 29.14°; $p < 0.001$). However, it was not different between sex, nor dominance ($p > 0.05$). The descriptor of the quality of sensory responses more often used by subjects was stretching (90.9%) in the external foot (74.6%).
Conclusions: This study provides the normal hip flexion angle and quality and distribution of sensory responses to the NDT_{PER} in asymptomatic subjects. Responses were independent of the influence of sex or leg dominance.

1. Introduction

Peroneal nerve is the most common peripheral source of pain and numbness in the lower limb (Iwamoto et al., 2016). Neurodynamic tests (NDTs) have shown to be useful in evaluating neural tissue involvement (Bueno-Gracia et al., 2015; Nee et al., 2012; Shacklock, 1996; Stankovic et al., 1999; Urban and MacNeil, 2015; Van der Heide et al., 2001). These tests use a sequence of movements that look for stress at different parts of the nervous system and are considered capable of detecting mechanosensitivity alterations (Benjamin S Boyd et al., 2009a,b; Dilley et al., 2005; Schmid et al., 2009). Mechanosensitivity is considered a normal protective mechanism that allows nerves to respond to the mechanical stresses(Nee and Butler, 2006). According to the anatomy of the peroneal nerve when it crosses the ankle joint, the peroneal neurodynamic test (NDT_{PER}) has been proposed as a combination of hip flexion, ankle plantar flexion and inversion movements, while the knee is kept in extension (Butler, 1991, 2000; Shacklock, 2005).

Clinicians evaluate NDTs using range of motion (ROM), and sensory responses such as location or quality of symptoms and compare sides and/or relate results to normal values (Boyd and Villa, 2012; Butler, 1991, 2000; Elvey, 1997; Lohkamp and Small, 2011; Nee et al., 2012; Shacklock, 1995). A test response that differs from a response found in asymptomatic subjects (considered as normal) may indicate a neural tissue involvement (Covill and Petersen, 2012; Herrington et al., 2008; Lai et al., 2012; Lohkamp and Small, 2011; Martínez et al., 2014; Nee et al., 2012; Walsh et al., 2007). When establishing normal values, it has been proposed that gender (Covill and Petersen, 2012; Martínez et al., 2014; Sierra-Silvestre et al., 2017), age (Boyd and Villa, 2012; Sierra-Silvestre et al., 2017) or limb-dominance (Boyd and Villa, 2012; Covill and Petersen, 2012; Lohkamp and Small, 2011; Martínez et al., 2014; Sierra-Silvestre et al., 2017; Van Hoof et al., 2012) could influence results. However, the existing studies have shown contradictory

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results when analysing the relationship between demographic characteristics and normal responses of NDTs (Boyd and Villa, 2012; Covill and Petersen, 2012; Gugliotti et al., 2018; Lai et al., 2012; Lohkamp and Small, 2011; Martínez et al., 2014; Sierra-Silvestre et al., 2017; Van Hoof et al., 2012). For example, some previous studies have shown a relationship between dominance and ROM in neurodynamic testing (Lai et al., 2012; Martínez et al., 2014; Van Hoof et al., 2012). However, other studies did not found this relationship (Boyd, 2011; Boyd and Villa, 2012; Gugliotti et al., 2018; Herrington et al., 2008; Lohkamp and Small, 2011; Sierra-Silvestre et al., 2017; Yaxley and Jull, 1991).

In the lower extremity, the straight leg raise test (SLR) is one of the most performed NDTs to examine for mechanosensitivity of mechanical function of the nervous system (B S Boyd et al., 2009a,b; Boyd and Villa, 2012; Capra et al., 2011; Herrington et al., 2008; Majlesi et al., 2008; Sierra-Silvestre et al., 2017). The SLR has shown to produce mechanical (Rade et al., 2016; Shacklock et al., 2016a, 2016b) and/or physiological changes (Kobayashi et al., 2003) on the neural tissues in the lumbar region and the leg (Capra et al., 2011; Kobayashi et al., 2003; Majlesi et al., 2008; Ridehalgh et al., 2005; Stankovic et al., 1999; Urban and MacNeil, 2015; Walsh et al., 2007). Normal values for the SLR have been previously analysed and widely described (B S Boyd et al., 2009a,b; Boyd and Villa, 2012; Capra et al., 2011; Herrington et al., 2008; Majlesi et al., 2008; Sierra-Silvestre et al., 2017). However, to our knowledge, no study has documented the normal responses for the distal branches of the sciatic nerve, i.e. tibial, peroneal and sural nerves. Thus, the aim of this study was to document normal responses of the NDT_{PER} in asymptomatic subjects. Differences in sensory response depending on sex and leg dominance were also examined.

2. Material and methods

2.1. Study design

A cross-sectional, descriptive study was conducted to analyse and describe the normal response of the NDT_{PER} in asymptomatic subjects. The study was conducted at the research laboratory of the University of Zaragoza. The Ethics Committee of Clinical Research of Aragón approved the protocol of this study. The study followed the ethical requirement established in the Declaration of Helsinki (World Medical Association (WMA), 2013).

2.2. Subjects

Subjects over 18 were invited to participate in the study. Forty-six voluntary subjects were initially recruited for the study. Exclusion criteria for the participation were any injury or pathology; pain, paraesthesia or weakness at the level of the cervical; thoracic, lumbar spine or lower extremity in the previous 6 months; limitation of movement range in lower limb joints; any previous surgery; arthritis or any type of autoimmune disease; diabetes or thyroid disorders; disorders of the central or peripheral nervous system and previous or current psychiatric diseases. Written informed consent was obtained from each subject prior to study participation.

2.3. Procedures

Determined eligibility to participate, based on inclusion and exclusion criteria, subjects were initially screened by the main researcher who collected demographic data (height, weight, sex and leg dominance). Subjects who met the selection criteria were subsequently provided with an explanation of the study procedures and instructions regarding the information they should provide during the NDT_{PER}. The starting position for the test was standardized, so that subjects remained supine without a pillow (thus avoiding any initial neural tension resulting from a flexed cervical spine), their arms along-side their bodies, and lower limbs straight.

Fig. 1. Peroneal Neurodynamic Test. Sequence of movements: plantar flexion/inversion of the ankle, foot, and toes, followed by the hip flexion keeping the knee straight (SLR position).

The main researcher performed the NDT_{PER} following a standardized sequence of movement described by Shacklock (2005): plantar flexion/inversion of the ankle, foot, and toes, followed by the hip flexion keeping the knee straight (SLR position) (Fig. 1). The NDT_{PER} was performed slowly, and subjects were instructed to indicate both the point of first appearance of symptoms (S1) and the point of symptoms tolerance (S2), defined as the point at which the subjects were too uncomfortable to continue with the test. Structural differentiation movement was completed at S1 and S2, during which ankle plantar flexion was released in case of proximal symptoms, and hip flexion was released in case of distal symptoms. Once the NDT_{PER} and the structural differentiation movement were performed, characteristics of the response were recorded. The hip ROM at both the S1 and the S2 during the NDT_{PER} were recorded by the second researcher. Hip ROM was measured by the application *Clinometer* (Peter Breitling, Version 2.4, http://www.plaincode.com/products), an application designed using the three inbuilt accelerometers (LIS302DL accelerometer). The application has shown good intra-tester reliability and moderate to good validity (Tousignant-Laflamme et al., 2013). The smartphone was placed 5 cm distal to the anterior tibial tuberosity (Fig. 2) in a way that the screen was not visible for the researcher who was performing the test. The order of testing for the dominant and non-dominant lower limb was randomized. The randomization was obtained by an online software (https://www.random.org) prior to the NDT_{PER} performance.

Subjects were asked to indicate the quality and distribution of the

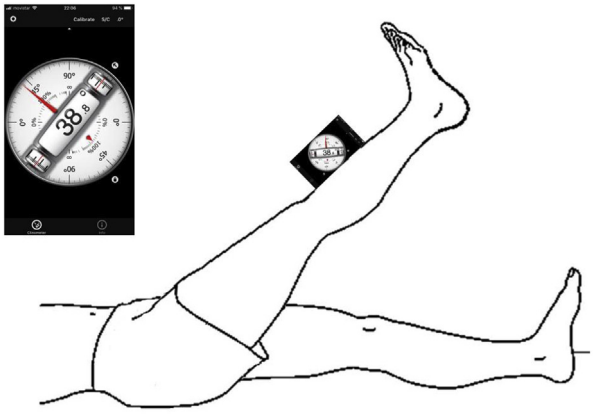

Fig. 2. Placement of digital inclinometer 5 cm distal to the anterior tibial tuberosity.

Table 1
Results of the hip flexion angle at S1 and S2 during the NDT_{PER} (n = 44).

		Women		Men		Difference		p-value
		Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	
S1	**Dom**	40.0 ± 15.1	32.5–47.5	38.0 ± 16.3	31.5–44.6	−2.0 ± 4.9	−11.8–7.8	0.689**
	Non-Dom	39.7 ± 14.2	32.6–46.7	37.6 ± 13.4	32.2–43.0	−2.0 ± 4.2	−10.6–6.5	0.629**
	Difference (95% CI)	0.3 ± 8.3	−3.8–4.5	0.4–10.7	−3.9–4.7			
	p-value	0.867*		0.841*				
S2	**Dom**	68.1 ± 16.0	60.1–76.0	64.7 ± 16.9	57.8–71.5	−3.4 ± 5.1	−13.6–6.8	0.506**
	Non-Dom	68.1 ± 14.1	61.1–75.1	64.0 ± 17.1	57.1–70.9	−4.1 ± 4.9	−13.9–5.7	0.404**
	Difference (95% CI)	−0.1 ± 10.7	−5.4–5.3	0.7 ± 6.8	−2.1–3.4			
	p-value	0.983*		0.630*				

Abbreviations: Dom, Dominant; Non-Dom, Non-dominant; SD, Standard deviation; CI, Confidence interval; S1, Point of first appearance of symptoms; S2, point of symptoms tolerance; NDT_{PER}, Neurodynamic Test of the Peroneal Nerve.
*Paired sample *t*-Test.
** Unpaired samples *t*-Test.

sensory responses once the test was concluded. To describe the quality or nature of perceived symptoms, subjects had to choose between the following descriptors: stretching, pain, tingling, pricking, numbness, burning, or a combination of these (Lohkamp and Small, 2011; Martínez et al., 2014). Subjects could also set different descriptors in an additional section provided for that purpose. To document the distribution of sensory responses, a body chart depicting the left and right lower limb and divided in 6 areas (lateral foot, lateral leg, medial leg, posterior leg, posterior knee, posterior thigh) was used (Gugliotti et al., 2018; Lohkamp and Small, 2011). Subjects were asked to mark the location of their perceived sensory responses on the body chart. The NDT_{PER} was performed once on each limb.

2.4. Intra-tester reliability

Preliminary to the primary component of the study, intra-tester reliability of the NDT_{PER} measurements was determined. Intra-tester reliability was evaluated on 10 asymptomatic subjects (5 male/ 5 female). These subjects were not included in the sample of the study. NDT_{PER}, as described below, was executed twice on each lower limb, with 30 s rest between repetitions (Lohkamp and Small, 2011). For each repetition the hip was flexed until the S1, and the hip flexion angle was recorded.

2.5. Statistical analysis

SPSS statistical software, version 20.0 for windows (IBM Corp, Armonk, NY, USA) was used for all statistical analyses. The intraclass correlation coefficient (ICC) with 95% confidence interval (CI) and standard error of measurement (SEM) was calculated. Interpretation of ICCs followed Portney and Watkins (1993): 0.00 to 0.25 = no to little 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.

Normal distribution of the data was assessed by means of the Shapiro-Wilk test ($p > 0.05$). The data were normally distributed. Descriptive statistics of the mean and standard deviation were used for the degree of hip flexion ROM. Quality and location of symptoms were expressed in terms of percentages. Hip flexion ROM for both lower limbs was analysed using paired *t*-tests. Significance was set at an alpha level of 0.05.

3. Results

3.1. Subjects characteristics

Forty-six voluntary subjects were initially recruited for the study but two subjects were excluded due to previous knee surgery. Therefore, the final simple was composed by 44 subjects (26 male, 18 female), and 88 lower extremities. The mean age was 28.5 ± 8.9, right leg was dominant for 41 subjects (93.2%) and the mean IMC of the sample was 23.5 ± 4.1.

3.2. Inter-rater reliability

The intra-tester ICC for hip flexion ROM at S1 during the NDT_{PER} was 0.99 (95% CI: 0.98–0.99) for the dominant side and 0.99 (95% CI: 0.95–0.99) for the non-dominant side. The SEM for the ROM at S1 for the dominant and non-dominant side was found to be 2.4° and 2.5°, respectively.

3.3. Peroneal neurodynamic test

The mean ROM for hip flexion at S1 was 38.7 ± 14.6° and at S2 was 65.9 ± 16.0°. Hip flexion was significantly greater at S2 than S1 (mean difference, 27.22°; 95% CI: 25.29°, 29.14°; $p < 0.001$). However, there was no statistically significant interaction between dominance or sex for any of the dependent variables ($p \geq 0.404$) (Table 1).

The descriptor of the quality of the sensory responses more often used by subjects was stretching (90.9% and 81.8% for S1 and S2, respectively). Percentages for each subject sensory response are depicted in Table 2.

Sensory responses were principally located in the lateral foot, followed by the lateral aspect of the leg (Fig. 3). Percentages for each subject sensory response location are shown in Table 3.

4. Discussion

To the best of our knowledge, this is the first study to describe normal responses of the NDT_{PER} in asymptomatic individuals. The potential influence of leg dominance and sex on NDT_{PER} normal responses in asymptomatic subjects was also analysed and no influence was found.

Sensory responses were reported at 38.65° and 65.86° of hip flexion for S1 and S2, respectively. Hip ROM values obtained in this study were in concordance to previous findings of responses to the SLR test for the sciatic nerve at ranges of between 30°-150° (Benjamin S Boyd et al., 2009a,b; Boyd and Villa, 2012; Gugliotti et al., 2018; Herrington et al., 2008; Sierra-Silvestre et al., 2017). A difference greater than 20° was found between S1 and S2, which is a common finding reported in previous studies of normal responses to SLR test for the sciatic nerve (Benjamin S Boyd et al., 2009a,b; Gugliotti et al., 2018; Sierra-Silvestre et al., 2017), the ulnar nerve (Martínez et al., 2014) and the median nerve neurodynamic tests (Jaberzadeh et al., 2005). The usual procedure for a clinician using NDTs on a patient is to perform the test to S1

Table 2
Percentages of sensory responses quality reported by the subjects during the NDT_{PER}.

Descriptor	S1				S2			
	Women		Men		Women		Men	
	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom
Stretching	94.4%	94.4%	88.5%	88.5%	94.4%	94.4%	65.4%	80.8%
Pain	–	–	–	–	–	–	–	–
Tingling	–	–	–	–	–	–	–	–
Burning sensation	–	–	7.7%	11.5%	5.6%	5.6%	23.1%	15.4%
Numbness	–	–	–	–	–	–	–	–
Pricking	5.6%	5.6%	–	–	–	–	7.7%	3.9%
Other	–	–	3.9%	–	–	–	3.8%	–

Abbreviations: Dom, dominant; Non-Dom, non-dominant; S1, Point of first appearance of symptoms; S2, point of symptoms tolerance.

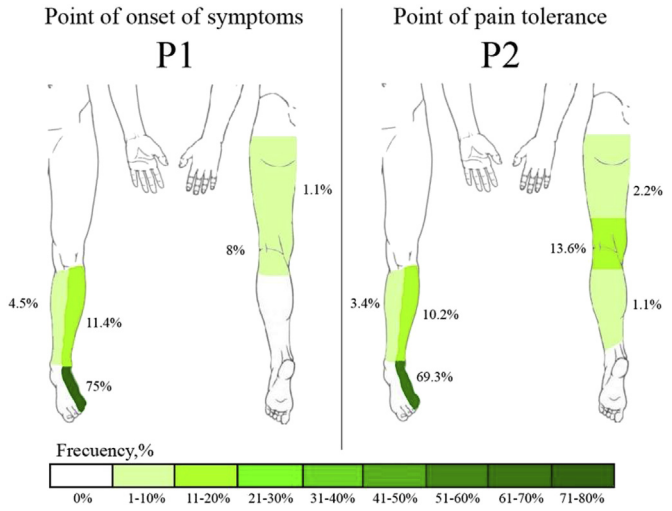

Fig. 3. *Sensory responses distribution during the peroneal neurodynamic test for S1 and S2.* Sensory responses were principally located in the lateral foot, followed by the lateral aspect of the leg.

or S2 (Bueno-Gracia et al., 2015; Capra et al., 2011; Ekedahl et al., 2010; Nee et al., 2012; Shacklock, 1996; Trainor and Pinnington, 2011; Vanti et al., 2011). Therefore, these differences in ROM between S1 and S2 should be taken into account when diagnosing a neural condition and clinicians should expect a higher ROM when using S2 as a reference point to stop the test.

The most common location of sensory responses reported by subjects during the NDT_{PER} was the external foot (75% and 69.3% for S1 and S2, respectively). It was expected that sensory responses were along the sciatic and peroneal nerves distribution, because it is a common finding that sensory responses during neurodynamic testing tend to localize along the distribution of the evaluated nerve (Benjamin S Boyd et al., 2009a,b; Boyd and Villa, 2012; Gugliotti et al., 2018; Lai et al., 2012; Lohkamp and Small, 2011; Martínez et al., 2014; Sierra-Silvestre et al., 2017). In the present study, sensory responses were mainly referred in the distal part of the lower limb, along the peroneal nerve distribution. This finding suggest that the NDT_{PER} sensitizes the peroneal nerve quite specifically. In regard to the quality of sensory responses, "stretching" was the most commonly reported descriptor and these results are consistent with those of previous studies on asymptomatic subjects (Benjamin S Boyd et al., 2009a,b; Gugliotti et al., 2018; Lai et al., 2012; Lohkamp and Small, 2011; Martínez et al., 2014).

The responses to the NDT_{PER} were not influenced by dominance or sex. Several studies in asymptomatic subjects on other nerves have found that ROM was not different between the dominant and the non-dominant side (Boyd, 2011; Boyd and Villa, 2012; Gugliotti et al., 2018; Herrington et al., 2008; Lohkamp and Small, 2011; Sierra-Silvestre et al., 2017; Yaxley and Jull, 1991). Other studies, on the other hand, observed differences in ROM between the dominant and the non-dominant side (Lai et al., 2012; Martínez et al., 2014; Van Hoof et al., 2012), with inconsistent results in terms of which side was associated with decreased ROM (Martínez et al., 2014; Van Hoof et al., 2012). Differences between the studies in terms of methodology (number of test repetitions) or characteristics of the sample might have contributed to this inconsistency. Similar controversy exists on the literature in relation to the sex influence in the normal response of neurodynamic testing. Most studies found no influence of sex in ROM (Boyd and Villa, 2012; Lai et al., 2012; Lohkamp and Small, 2011; Pullos, 1986), whereas others did find this relationship, further research in needed to explain these differences. Sierra-Silvestre et al. (2017) and Herrington et al. (2008) found that women had greater ROM than men during SLR when examining the sciatic nerve. A potential explanation for this finding is that women are more flexible than men in healthy population (Sierra-Silvestre et al., 2017). In contrast, in the study of Martínez et al. (2014) women demonstrated less ROM than men during the application of the ULNT3.

The results of this study provide further evidence that

Table 3
Percentages of sensory responses location reported by the subjects during the NDT_{PER}.

Location	S1				S2			
	Women		Men		Women		Men	
	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom
Lateral foot	72.2%	77.7%	77%	73.1%	66.6%	77.7%	65.3%	69.3%
Lateral leg	11.1%	5.6%	11.5%	15.4%	16.7%	11.1%	7.7%	7.7%
Medial leg	11.1%	11.1%	–		11.1%	5.6%	–	–
Posterior leg	–	–	–		–	–	3.8%	–
Posterior knee	5.6	5.6%	11.5%	7.7%	5.6%	5.6%	19.2%	19.2%
Posterior thigh	–	–	–	3.8%	–	–	3.8%	3.8%

Abbreviations: Dom, dominant; Non-Dom, non-dominant; S1, Point of first appearance of symptoms; S2, point of symptoms tolerance.

neurodynamic responses occur during the performance of NDTs in asymptomatic subjects, with a variety of sensory responses. The normative data provided in the present study could help in the clinical reasoning process.

This study presents several limitations. In relation to the NDT_{PER} performance, hip movements (such as hip rotation or abduction/adduction) and ankle plantar flexion and inversion were not measured in the present study that could influence the results. Although caution was taken in performing isolated hip flexion, other hip movements were not measured in the present study. Another potential limitation is that the hip flexion ROM achieved at S1 and S2 during the NDT_{PER} was considered as a reflection of pain tolerance of the subjects, influenced by subject characteristics. Therefore, the willingness to tolerate more pain before deciding to stop the test might have influenced the results. Finally, the fact that only asymptomatic population was examined in this study limits generalization of its findings. Further studies are needed to know whether similar responses will result in symptomatic population.

5. Conclusion

This study describes the sensory responses to the NDT_{PER} in asymptomatic subjects. The mean ROM for hip flexion at S1 was 38.7 ± 14.6° and at S2 was 65.9 ± 16.0°. Those responses do not differ based on sex or leg dominance of the subjects. Most commonly, sensory responses in healthy subjects occurred in the area of peroneal nerve distribution (external foot), and the nature of the response was mainly a stretch sensation.

Ethics Committee approval of the study protocol

Ethics Committee of Clinical Research of Aragon - reference number CEICA 03–2018.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.06.005.

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