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Normal response to tibial neurodynamic test in asymptomatic subjects

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Abstract.
BACKGROUND: The straight leg raise test (SLR) is one of the most performed physical tests for mechanosensitivity and impairment of the nervous system. According to the anatomy of the tibial nerve, ankle dorsiflexion and eversion movements could be used to perform the tibial neurodynamic test (TNT). To date, no study has documented the normal responses of the TNT.
OBJECTIVE: To document normal responses of the TNT in asymptomatic individuals and to investigate influences from sex and leg dominance.
METHODS: A cross-sectional study with 44 asymptomatic volunteer subjects, a total of 88 lower limbs, was carried out. The range of motion (ROM), quality, and distribution of sensory responses were recorded. The hip flexion ROM was measured when subjects reported an intensity of their symptoms of 2/10 (P1) and 7/10 (P2).
RESULTS: The mean ROM for hip flexion at P1 was 44.22 $\pm$ 13.13° and 66.73 $\pm$ 14.30° at P2. Hip flexion was significantly greater at P2 than P1 ($p < 0.001$). However, it was not different between sex or limbs ($p > 0.05$). The descriptor of the quality of sensory responses most often used by participants was stretching (88.6% and 87.5% for P1 and P2, respectively) in the popliteal fossa and posterior calf.
CONCLUSIONS: This study describes the sensory responses of asymptomatic subjects resulting from the TNT. Our findings indicate that TNT responses are independent of the influence of sex or leg dominance.

Keywords: Tibial nerve, sensory response, leg dominance, sex

1. Introduction

Neural tissue has been identified as a possible source of a wide variety of signs and symptoms in recent years [1–4]. Neurodynamic tests consist of a combination of movements aimed to stress different parts of the nervous system according to their sequence [2,5]. These tests produce nerve sliding and tension on the neural structures, and are considered to be able to detect increased nerve mechanosensitivity and/or impairments in nerve function [6–8]. In the lower extremity, the straight leg raise test (SLR) is one of the most performed physical tests to examine mechanosensitivity and impairment of nerve function [9–15]. The SLR has shown to produce mechanical and/or physiological changes [16] on the neural tissues in the lumbar region, and is a valid and reliable tool to assess lumbar nerve root problems [11,17].

Different ankle movements have been proposed to specifically increase forces on each main division of the sciatic nerve down to the leg, i.e. tibial, peroneal and sural nerves [2–4,18–23]. In particular, it has been shown that tibial nerve strain increases with ankle dorsiflexion in cadavers [18,21], and a greater strain occurs when hip flexion is added to ankle dorsiflexion. Due to the anatomy of the tibial nerve when it crosses

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the ankle joint (medially and posterior to the medial malleolus), eversion of the ankle joint also increases its strain [19,24]. Thus, the tibial neurodynamic test (TNT) has been proposed as a combination of hip flexion, ankle dorsiflexion, and eversion movements, while the knee is kept in extension [2–4]. The TNT could be useful for the diagnosis of tibial nerve entrapments such as tarsal tunnel syndrome, described as the entrapment of the posterior tibial nerve behind the flexor retinaculum [25–27]. Although tarsal tunnel syndrome is a commonly diagnosed nerve entrapment, it is not as common as carpal tunnel syndrome [28] in the upper extremity, but its prevalence and incidence are unknown [29,30].

Clinicians assess neurodynamic tests 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 [3,4,12,31,32,34]. When establishing normal values, it has been proposed that sex [10,35,36], age [10,12], or limb-dominance [10,12, 33,35–37] could influence results. However, the existing studies have shown opposite or contradictory results when analysing the relationship between demographic characteristics and normal responses of neurodynamic tests [10,12,33,35–39]. Some authors have proposed that, although inter-limb differences during neurodynamic testing could exist in the healthy population, normal responses could not be affected by demographic factors [12,36].

Normal values for the SLR have been previously analysed and described [10,12–14,39]. When performing the SLR test, the normal distribution of the sensory response is posterior, along the sciatic nerve distribution and its distal tributaries, and the mean ROM for the first appearance of symptoms has been described between 30° and 80° of hip flexion [10,12–14,39,40]. The influence of demographic factors or limb dominance on the SLR normal responses have also been analysed and showed different results [10,39,40]. To the best of our knowledge, no study has documented the normal responses of the TNT. Therefore, the aim of this study was to document normal responses of the TNT in asymptomatic individuals. Differences in sensory response depending on sex and leg dominance were also examined.

2. Methods

2.1. Study design

A cross-sectional study was carried out from January to April 2018. The local Ethics Committee approved the protocol of this study.

2.2. Sample

Forty-four healthy subjects (26 male, 18 female) aged between 19 and 53 years (mean age 28.5 $\pm$ 8.85; median 24.5) were recruited. Potential participants were excluded if any of the following was present: pain, neurological signs, range-of-motion limitation in the hip, knee or ankle joint, previous surgery or injury in the cervical, thoracic, lumbar region or lower-limbs, disorders of the central or peripheral nervous system, diabetes or thyroid disorders, or any other health related issues that may interfere with the individual's ability to safely participate in this study. All subjects were required to read an information sheet and sign a consent form prior to participation.

2.3. Procedures

An examiner collected demographic data and determined eligibility to participate based on the inclusion and exclusion criteria. Leg dominance was documented at this time and was determined by asking what leg they would choose to kick a ball. In order to standardize each individual's response, the examiner provided an explanation of the study procedures and instructions to indicate when the intensity of the experienced sensory responses were 2/10 (P1) and 8/10 (P2) [6,10,35] during the TNT. Subjects were also asked to remember the location and quality of the sensory responses. Then, the same examiner performed the testing on both sides in all subjects with 30 seconds between repetitions [33]. The lower extremity tested first was randomly assigned to each participant using the Research Randomizer (version 4.0).

Subjects were asked to lie supine on a standard treatment table with their head resting flat while their trunk and limbs were in a neutral position. Dorsiflexion and eversion of the ankle joint were manually performed with one hand of the examiner while the other hand maintained ventral pressure on the knee [2]. This was to ensure that full knee extension was maintained throughout the entire test [2,4] (Fig. 1). Then, the leg was passively lifted from the table in the sagittal plane and raised until the P1 and P2. The angle of hip flexion was measured at these two points by another examiner. In order to structurally differentiate tissue response, the structural differentiation manoeuvre was performed [10,14,39]. Passive ankle plantar flexion or passive hip extension were performed to determine if it would cause an alteration in the participant's sensory response. The structural differentiation manoeuvre was

Table 1
Pairwise comparisons between hip flexion angle at p1 and p2 during the tibial neurodynamic test

		Women		Men		Difference		
		Mean ± SD	CI 95%	Mean ± SD	CI 95%	Mean ± SD	CI 95%	p-value
P1	Dom	45.94 ± 3.36	38.85–53.04	43.81 ± 2.62	38.41–49.20	−2.13 ± 4.21	−10.63–6.36	0.614**
	Non-Dom	43.39 ± 3.09	36.87–49.91	44.00 ± 2.51	38.83–49.17	0.61 ± 3.96	−7.39–8.61	0.878**
	Difference (CI 95%)	2.55 ± 5.97	−0.41–5.52	−0.19 –5.23	−2.30–1.92			
	p-value	0.087*		0.853*				
P2	Dom	69.83 ± 3.51	62.41–77.25	65.81 ± 2.85	59.93–71.69	−4.02 ± 4.51	−13.12/5.07	0.377**
	Non-Dom	67.61 ± 3.25	67.61–74.47	64.88 ± 2.82	59.07–70.70	−2.72 ± 4.33	−11.48/6.02	0.533**
	Difference (CI 95%)	2.22 ± 7.01	−1.26–5.71	0.92 ± 5.09	−1.14–2.98			
	p-value	0.197*		0.365*				

Abbreviations: Dom, Dominant; Non-Dom, Non-dominant; SD, Standard deviation; CI, Confidence interval. *Paired sample t test. **Unpaired samples t test.

Fig. 1. Tibial neurodynamic test.

performed using the most separated/distant joint from the sensory response location [2,4,10,14,34,41].

The hip flexion ROM during the TNT was measured using a digital inclinometer placed on the anterior tibia, 5 cm distal to the tibial tuberosity. The inclinometer was placed in a way that the examiner who performed the TNT could not see the screen and was blinded to the measurement. The digital goniometer is a precise, reliable, and valid tool to quantify limb motion during SLR [6,21,42].

After the TNT, each participant was asked to report the location and quality of the sensory responses. A body chart depicting the left and right lower limb was used to document the distribution of sensory responses [33,39], and each individual was asked to mark the location of his or her perceived sensory responses. Finally, they were asked to report the quality of the sensory responses from a list of quality descriptors, which included: stretching, burning sensation, pricking, or "other sensation" [33,35].

2.4. Intra-tester reliability

Preliminary to the primary component of the study, intra-rater reliability of the ROM of hip flexion during the TNT was previously determined for 20 individuals. The TNT, as described above, was performed twice on each lower limb. Subjects were asked to indicate the P1. The same examiner performed ROM measurements throughout the entire study.

2.5. Statistical analysis

SPSS statistical software version 20.0 for Windows was used for all statistical analyses. The intraclass correlation coefficient (ICC) at a 95% confidence interval (CI) was calculated to determine the absolute reliability of knee flexion angle. Interpretation of ICCs followed Portney and Watkins [43] 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.

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

3. Results

3.1. Intra-tester reliability

The intra-tester reliability for hip flexion ROM at P1

Table 2
Percentages of sensory responses quality reported during the tibial neurodynamic test

	P1				P2			
	Women		Men		Women		Men	
Descriptor	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom
Stretching	94.44%	94.44%	84.61%	84.61%	88.88%	94.44%	80.77%	88.46%
Burning sensation	–	–	11.54%	7.69%	5.56%	–	19.23%	7.69%
Pricking	5.56%	5.56%	–	3.85%	–	5.56%	–	–
Other	–	–	3.85%	3.85%	5.56%	–	–	3.85%
	Dom $p < 0.241$*				Dom $p < 0.194$*			
	Non-Dom $p < 0.853$*				Non-Dom $p < 0.473$*			

Abbreviations: Dom, dominant; Non-Dom, non-dominant; *Fisher's Exact Test.

Table 3
Percentages of sensory response locations during the tibial neurodynamic test

	P1				P2			
	Women		Men		Women		Men	
Location	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom	Dom	Non-Dom
Foot	16.7%	16.7%	11.5%	11.5%	22.3%	11.1%	3.8%	3.8%
Internal malleolus	5.6%	11.1%	3.8%	–	–	–	–	–
Calf	33.3%	16.7%	34.6%	34.6%	22.2%	22.2%	38.5%	26.9%
Popliteal fossa	38.9%	44.4%	38.5%	34.6%	44.4%	55.6%	46.2%	46.2%
Posterior thigh	–	5.6%	11.5%	15.4%	5.6%	5.6%	11.5%	19.2%
Gluteal region	5.6%	5.6%	–	3.8%	5.6%	5.6%	–	3.8%
	Dom $p < 0.663$*				Dom $p < 0.298$*			
	Non-Dom $p < 0.360$*				Non-Dom $p < 0.637$*			

Abbreviations: Dom, dominant; Non-Dom, non-dominant; *Fisher's Exact Test.

during the TNT was ICC = 0.98 (95% CI: 0.96–0.99; SEM = 1.92°).

3.2. TNT

The right leg was dominant for 41 subjects (93.18%) and the mean body mass index of the sample was 23.49 ± 4.06. The mean end ROM for hip flexion at P1 was 44.22 ± 13.13° and 66.73 ± 14.30° at P2. Hip flexion was significantly greater at P2 than P1 ($p < 0.001$). However, it was not different between sex or limbs ($p > 0.05$) (Table 1).

The descriptor of the quality of sensory responses most often used by participants was stretching (88.6% and 87.5% for P1 and P2, respectively) during the TNT. Percentages for each individual sensory response are depicted in Table 2.

Sensory responses were principally located in the popliteal fossa (38.6% and 47.7% for P1 and P2, respectively), followed by the calf (30.7% and 28.4% for P1 and P2, respectively), and the foot (18.19% and 9.09% for P1 and P2, respectively) (Fig. 2). Less commonly, participants also reported symptoms in the posterior thigh (9.09% and 11.36% for P1 and P2, respectively), or gluteal regions (3.14% both for P1 and P2). Percentages for each individual sensory response location are shown in Table 3.

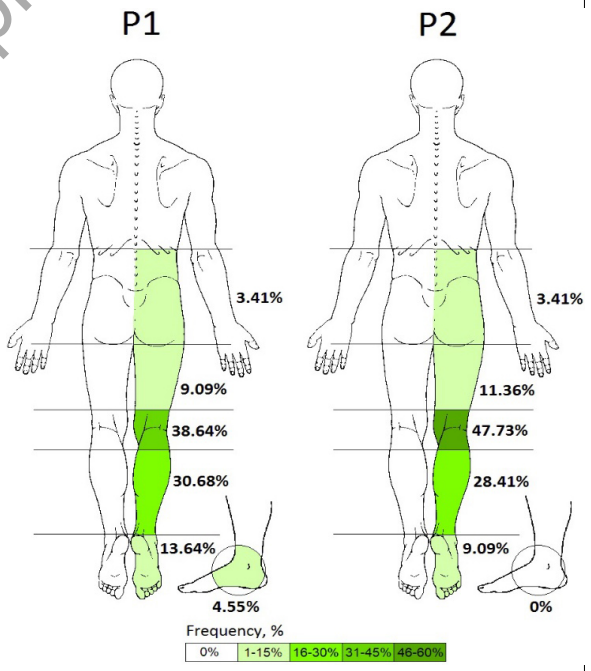

Fig. 2. Sensory response distribution during the tibial neurodynamic test for P1 and P2.

4. Discussion

This is a study of responses to the TNT in asymptomatic individuals including ROM, quality and distribution of sensory responses. To the best of our knowledge, this is the first study that investigates the neurodynamic responses of TNT, and the influence of leg dominance and sex on TNT normal responses in asymptomatic subjects.

Hip flexion ROM ranged from 31.09° to 57.35° for P1 and from 52.43° to 81.03° for P2. These values were in concordance to previous findings of responses to the SLR test at ranges of between 30°–80° [6,10,12,14,39]. Nevertheless, our results were slightly lower. Differences in ROM may be explained by the ankle position used in the present study. The ankle movements elongated the nervous system, and in turn reduced the nerve movement. Due to the sensitization movements, i.e. dorsiflexion and eversion, that were previously added to hip flexion in the TNT, the expected ROM both at P1 and P2 was lower compared to values reported for the SLR in previous studies [6,10,12,14,39]. Differences in hip flexion ROM were also found between the onset and maximally tolerated symptoms. Approximately, a difference of 20° was found between P1 and P2, which is also a common finding reported in previous studies of normal responses to the SLR test [6,10,39] and other neurodynamic tests [35,44]. The distribution and frequencies of sensory responses were reported by all participants to be along the posterior aspect and plantar surface of both lower extremities. The frequency of sensory responses reported on the foot in the present study was higher compared to previous findings of responses to the SLR [6,10,39], especially when dorsiflexion was not added to the SLR. This was expected in the TNT, given the sensory distribution of the calcaneal and plantar branches of the tibial nerve, because it is a common finding that sensory responses during neurodynamic testing tend to localize along the distribution of the assessed nerve [6,10,12,33,35,38,39]. However, because sensory responses to SLR were not analysed in this study, further studies are needed to analyse potential differences in sensory response distribution comparing TNT and SLR in asymptomatic subjects. Regarding the quality of sensory responses, the results of this study are consistent with previous studies conducted for other neurodynamic tests [6,33,35,38,39], with stretching being the most commonly reported sensory response.

In relation to the influence of leg dominance or sex on TNT normal responses, results of the present study showed that hip flexion ROM was not influenced by any of these two demographic characteristics. With regards to leg dominance, some previous studies observed differences in ROM between the dominant and the non-dominant side [35,37,38]. Nevertheless, they found contradictory results. Lai et al. [38] found that the non-dominant side had smaller ROM compared to the dominant side in the femoral slump test. However, Martínez et al. [35] performed the SLR test and Van Hoof et al. [37] performed the upper limb neurodynamic test 1. The two studies observed a significant restriction of the ROM on the dominant side in comparison with the non-dominant side. Van Hoof et al. [37] explained the restriction of the ROM in the dominant side was caused by the increased activity of the limb during daily activities, which means that, over time, the dominant side is more exposed to upper limb stiffness regulation than the non-dominant side. Finally, it is remarkable that in these studies [35,37,38] the difference in ROM was close to what would be considered measurement error, and may not be clinically significant. On the other hand, most previous studies found that ROM was not different between the dominant and the non-dominant side in asymptomatic subjects [10,12,14,33,39,40,45], i.e. limb dominance, was not relevant to ROM in neurodynamic testing. Although not a significant difference between limbs was found in previous studies nor in the present study, it should be noted that the response between limbs was not identical in any of these studies. This finding could be relevant in diagnosing with neurodynamic tests, and some degree of asymmetry in isolation might be interpreted as a non-clinically relevant finding [14]. Due to conflicting results in the existing literature regarding the influence of hand dominance and its relevance to interpretation of neurodynamic tests, further studies are needed to clarify the effect of limb dominance on ROM.

A similar controversy exists in relation to the sex influence in the normal response of neurodynamic testing [10,12,14,33,35,38,46]. The results of the present study are in line with previous studies, which found no influence of sex in ROM [12,33,38,46]. However, results of the present study contrast other studies [10,14,35] which found influence of sex in ROM. Sierra-Silvestre et al. [10] and Herrington et al. [14] found that women had greater ROM than men in SLR. A potential explanation for this finding was that women are more flexible than men in the healthy population [10]. On the other hand, the study of Martínez et al. [35] found that women demonstrated less ROM than men during the application of the upper limb neurodynamic test 3 (ulnar nerve). Differences between

studies in terms of sample characteristics or methodology might have contributed to those differences. Again, further research is needed to explain these differences.

This study presents several limitations. First of all, participants in this study were mainly right leg dominant, which might have influenced the results. Equal distribution of right and left leg dominance was not sought in the sample. In addition, the performance of asymmetrical activities, which implied the lower limbs, was not taken into account and this could have been a confounding variable. Although the sample size of the present study was similar to previous studies on the normal response to neurodynamic testing, the power calculation was not performed. In relation to the TNT, hip rotation or abduction/adduction were not measured in the present study. Although caution was taken in preforming isolated hip flexion, other hip movements were not measured in the present study.

5. Conclusion

This study describes the sensory responses of asymptomatic subjects resulting from the TNT. Most commonly, the normal distribution of the sensory response is posterior, along the tibial nerve distribution, and the nature of the response was mainly a stretching sensation. The hip ROM at P1 and P2 is quite variable but it is not affected by demographic characteristics such as sex or leg dominance in asymptomatic individuals. Further studies should focus on the responses of TNT in symptomatic subjects and the validity of diagnosing problems related to tibial nerve.

Conflict of interest

None to report.

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