The Variation of Cross-Sectional Area of the Sciatic Nerve in Flexion-Distraction Technique: A Cross-Sectional Study

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Abstract

Objective: The purpose of this study was to compare the cross-sectional area of the sciatic nerve in different positions of spinal manipulation using flexion-distraction technique.

Methods: Thirty healthy participants were assessed in 6 different flexion-distraction technique positions of varying lumbar, knee, and ankle positions. Participants stood in the following 3 positions with the lumbar in the neutral position: (A) with knee extended, (B) with knee flexed, and (C) with the knee extended and ankle dorsiflexion. Participants then stood in the following 3 positions with the lumbar flexed: (D) with the knee extended, (E) with the knee flexed, and (F) with knee extended and ankle dorsiflexion. The cross-sectional area (CSA) of the sciatic nerve was measured with ultrasound imaging in transverse sections in the posterior medial region of the left thigh. The CSA values measured at each position were compared.

Results: We analyzed 180 ultrasound images. The cross-sectional area of the sciatic nerve (in mm^2) in position B (mean; standard deviation) (59.71-17.41) presented a higher mean cross-sectional area value compared with position D (51.18-13.81; *P* =.005), position F (48.71-15.16; *P* = .004), and position C (48.37-16.35; *P* = .009).

Conclusion: The combination of knee extension and ankle dorsiflexion reduced the CSA of the sciatic nerve, and flexing the knee and keeping the ankle in the neutral position increased it. (J Manipulative Physiol Ther 2019;xx:1-9)

Key Indexing Terms: *Ultrasonography; Lumbosacral Plexus; Physical Therapy Modalities; Manipulation, Osteopathic*

Introduction

Pain related to the sciatic nerve can be disabling and is characterized by radiating leg pain that may be accompanied by muscle weakness, sensory changes, and diminished reflexes of the affected nerve root.[1] The lifetime incidence of sciatica has been reported to be between 13% and 40% of the population, and sciatic pain is a leading cause of absence from work[2]; nearly a third of patients with sciatica will have persisting symptoms, continuing for up to 2 years.[3]

Conservative treatments for the management of sciatic symptoms aim to reduce pain intensity and prevent chronicity. Nonpharmacological therapies, such as staying active, exercise, and the use of manual therapy (eg, spinal manipulation, mobilization, or soft tissue techniques) in a biopsychosocial model of care are recommended in clinical practice guidelines for the management of low back pain and sciatica.[4] Many pharmacological approaches used to reduce pain in patients with sciatica have little or no evidence of their efficacy,[5,6] such as a recent robust trial of the neuropathic pain medicine pregabalin, which was found to be no better than placebo for reduction in leg pain intensity, back pain, disability, and other outcomes for sciatica patients.[7] The treatment of sciatica remains with an absence of a robust

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recommendation.[8] Therefore, new treatment approaches need to be developed for the treatment of sciatica.

Allied health practitioners frequently manage patients with sciatica. Peripheral nerve mobilization techniques and devices that improve the function of neural tissue have been used by physiotherapists, osteopaths, and chiropractors. Neural tissue mobilization therapy was effective in reducing pain and disability in patients with chronic musculoskeletal pain related to the nerve (ie, lumbar and cervical radiculopathy)[9] and patients with low back pain.[10,11] In the meantime, the flexion-distraction technique (FDT) is advocated to be effective in relieving chronic low back pain with radiculopathy.[12-14] Although few studies have shown a clinical benefit of the FDT in patients with low back pain,[12,15] lumbar stenosis,[16-18] and post-surgical pain syndrome,[19,20] there is no study focused on sciatica patients. Moreover, most studies present a low level of evidence owing to their case report study design.[19-21] Therefore, the efficacy, safety, and effectiveness of the FDT are not well established,[22] especially its effects on the sciatic nerve.

The movements of the FDT and the technique of neural mobilization lead to changes in the sciatic nerve. The FDT has the ability to move smoothly and rhythmically to lower and raise with the combination of several positions on the movable platform. The table movement results in effects similar to those observed in studies of the neural mobilization technique, with changes in transverse diameter and longitudinal movement in the sciatic nerve.[23-25] The decrease of the cross-sectional area (CSA) is perceived as deformation in length and observed as neural tension.[26] Ultrasound imaging analysis of the sciatic nerve showed a tendency to decrease CSA when stretched with a trunk flexion performed.[23] Joint movement generates nerve excursion considering the range of motion, segment position, and number of joints involved in the movement.[24,25] Furthermore, it can be used in real-time movement assessment with an excellent intra-examiner reliability for sciatic nerve.[27] Thus, ultrasound imaging is an adequate method for the evaluation of the changes in nerve area owing to the movement.

The lack of knowledge of the clinical effect of the FDT on the sciatic nerve requires further investigation. Moreover, the potential effect of a particular FDT position on the sciatic nerve implied to investigate individuals free of lumbar radiculopathy since the maximum position obtained by the equipment can replicate the straight leg raising (SLR) test. Accordingly, the aim of the current study is to compare the CSA of the sciatic nerve in different FDT positions in healthy individuals.

Methods

Study Design and Participant Selection

A cross-sectional study, using single-group with repeated-measures design, was conducted in 30 asymptomatic healthy individuals without symptoms suggestive of sciatic nerve dysfunction, including a negative SLR test. Participants were excluded if they had myofascial pain syndrome or neurological, malignant, infectious, or inflammatory pathology of the spine.

The study was approved by the Human Research Ethics Committee of the Federal Institute of Rio de Janeiro (CAAE: 42945315.9.0000.5268), and all participants signed the informed consent form.

Procedures

The participants were instructed to lie down prone for the acquisition of the sciatic nerve images by the ultrasound exam. Acquisitions of the sciatic nerve images were performed only on the left thigh due to the free access of the examiner to the table. Six different positions were performed combining variations of lumbar, knee, and ankle positions (Fig 1). A baseline measure of the ultrasound image was obtained at the prone position. After that, a new ultrasound measure was achieved at each position. All tests were performed during the same day lasting approximately 30 minutes for each participant and conducted at a physiotherapy private office.

Experimental Setup

The participants were instructed to lie in the prone position to undergo the FDT on a table (model Flex Trac 500z, 2010, TechMec, Araras, São Paulo, Brazil), with their heads in a neutral and supported position, upper limbs stretched forward and supported, thoracic and lumbar spine supported on the fixed seats, and pelvis and lower limbs on the movable seat. The table has an electric lift with a system of levers that allows placing the spine and lower limbs in different combinations of positions. The table has a stable platform for the trunk and movable for the pelvis and lower limbs, and produces lowering and raising movements, with speed and time control. The central axis has height adjustment with 6 levels of inclination, with 25 mm of distance between each level, from 0° (neutral position) to 30° (position of maximum flexion), besides accessories of support for arms and legs. The height rod and the footrest are 25 cm in length. Participants remained in 3 positions with the lumbar in the neutral position (initial position) and 3 other similar positions with the lumbar flexed (final position) (Fig 1).

Initial positions with a neutral lumbar were as follows:

- (A) Neutral lumbar position: individual lying in prone, neutral lumbar, knee extended and ankle in neutral position
- (B) Knee flexion position: individual lying in prone, neutral lumbar, knee flexed, neutral ankle with dorsal foot supported on the movable platform, held in the highest position allowed by equipment

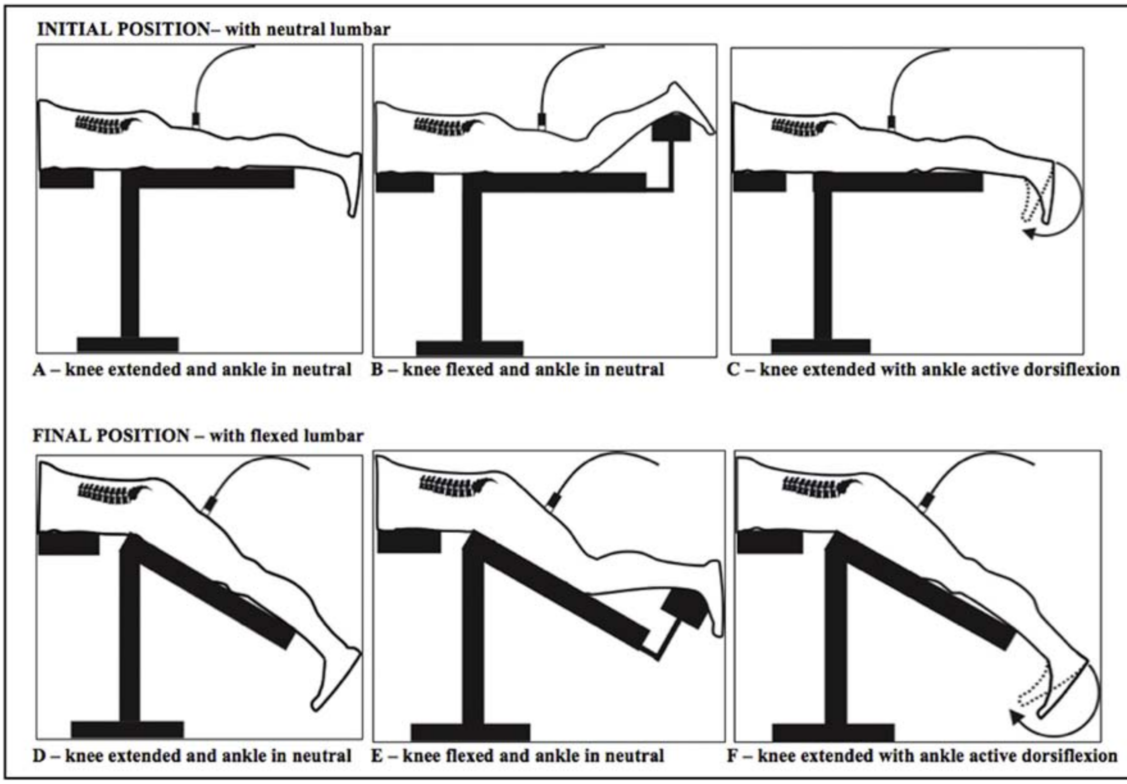

Fig 1. *Illustration of the 6 different combinations of positions in the flexion-distraction table used to evaluate the cross-sectional area of the sciatic nerve in healthy participants (n = 30).*

- (C) Ankle dorsiflexion position: individual lying in prone, neutral lumbar, knee extended, ankle in maximal active dorsiflexion

Final positions with flexed lumbar were as follows:

- (D) Flexed lumbar position: individual lying in prone, flexed lumbar, knee extended and ankle in neutral position
- (E) Knee flexion position: individual lying in prone, flexed lumbar, knee flexed and neutral ankle with dorsal foot supported on the movable platform, held in the highest position allowed by the equipment
- (F) Ankle dorsiflexion position: individual lying in prone, flexed lumbar, knee extended and ankle in maximal active dorsiflexion

Measurement of Cross-Sectional Area

Ultrasound Imaging. Participants included in the study were initially advised to remain in lateral decubitus to perform the identification of the sciatic nerve. The site was defined by measuring the mean distance of the posterior face of the left thigh between the trochanter and the knee joint, approximately 15 cm above the popliteal fossa. The ultrasound transducer was positioned at this point inside a strip of Velcro specially made with a rectangular opening in the middle.

Ultrasound images were obtained in B-mode on the Mindray DP-2200 portable model, with a 2.5- to 5.0-MHz convex transducer (Mindray Medical International Co, Shenzhen, China). The acquisitions of the sciatic nerve images were in 5-MHz transverse sections with a transducer positioned perpendicular to the nerve pathway, coupled with an aqueous gel. The frequency of 4 to 7 MHz has been used to analyze the sciatic nerve in the posterior thigh.[28] All images were obtained by the same researcher (M.A.M.P.), with more than 5 years of experience in the use of the equipment. During the ultrasound examination, ankle dorsiflexion and plantar-flexion movements were requested to the participant to help locate the sciatic nerve among other structures. After each acquisition, vertical lines were made in the right corner of the image, and the distance in millimeters was measured as a calibration measure. Then, each image was copied with the nerve area delimited for confirmation of the location.[29]

Ultrasound Image Processing. Image processing was performed in ImageJ software, version 1.43 (National Institutes of Health, Bethesda, Maryland). The nerve area was manually delimitated, and the software calculated the CSA. The program analyzes different image formats and calculates the area and provides pixel statistics, besides performing the calibration in centimeters or millimetres.[30] The CSA of the sciatic nerve was delimited by the continuous tracing technique with a thin inner border of the hyperechoic epineural contour[31] and processed in

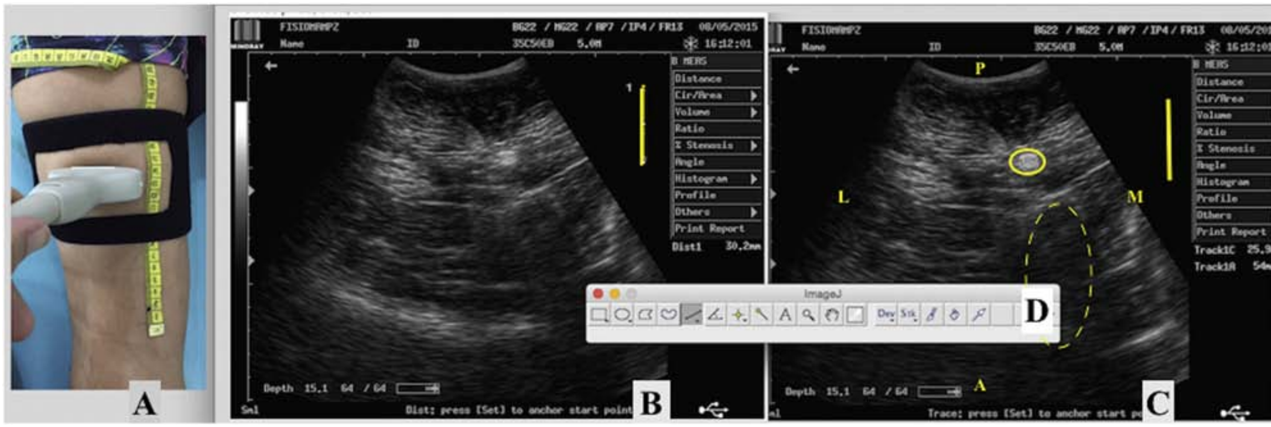

Fig 2. *(A) Positioning of the ultrasound transducer at posterior left thigh. (B) Image obtained from the sciatic nerve. (C) The cross-sectional area of the sciatic nerve (full circle) and femoral bone (dashed circle). (D) ImageJ software.*

640×480 pixel, 8-bit, 300k images (Fig 2) for calculation of the area and standard deviation (SD). The inter-examiner reliability of the measure was performed by 2 examiners (A and B). The intra-examiner reliability of the measurement was carried out at 2 different times (A1 and A2). Examiner A (M.A.M.P.) has experience in identifying images with ultrasound, and examiner B (L.A.C.) has no experience in imaging. Reliability studies have shown that ImageJ has obtained acceptable results of precision for clinical and research use in the measurement of pain areas[32] and the CSA of the lumbar multifidus.[33]

Statistical Analysis

The sample size calculation was based on values obtained from a pilot study with 6 healthy male participants. The values considered for the calculation were the mean and SD of the sciatic nerve CSA at 2 FDT positions, recorded by the ultrasound imaging in the posterior medial third of the left thigh and calculated by the ImageJ software. The mean and SD observed at initial position A (neutral lumbar) on Figure 1 were mean 68.04 (SD 22.29 mm^2). The highest stress position of the sciatic nerve proposed in the experiment was obtained in the final position F on Figure 1 (lumbar flexed, ankle dorsiflexion), which presented the mean 51.57 (SD 15.73 mm^2). Thus, the effect size of the sample was calculated as 0.81. Considering the level of significance of 0.05 and a power of 0.95, 23 participants matched in both conditions were estimated in the Wilcoxon signed-rank test for paired samples. The sample was calculated in the G*Power software (version 3.1).

Descriptive analysis of the participants was performed, including mean (M) and SDs for continuous variables, and absolute frequencies (N) and proportions (%) for categorical variables. The normal distribution of the primary outcome of the study (cross-sectional area of the sciatic nerve) was verified by the Shapiro-Wilk test. The comparison of the mean scores of the 6 positions in the FDT was performed by repeated-measures analysis of variance, using each position as time. The Bonferroni post hoc test was used when a significant F value was found. In addition, the mean difference between pairs of FDT positions and their CI was calculated. The plot was done using the GraphPad Prism software, version X7.Oa (San Diego, California). A reliability analysis was conducted to ensure the replicability of the CSA measurement in the 6 positions. The intra- and interrater reliability of measurements were calculated using a 2-way random-effects model of the intraclass correlation coefficients (ICCs) ($ICC_{2,1}$) with the consistency type. Intrarater reliability was calculated using both the first and second measurements from the observer A (A1 and A2). The interrater reliability was calculated using the first measurement of each examiner (observers A1 and B1). An ICC less than 0.5 was considered poor, an ICC between 0.5 and 0.75 was considered moderate, an ICC between 0.75 and 0.9 was considered good, and an ICC $\geq$0.9 was considered excellent. The standard error of the measurement ($SEM = SD^{*}_{pooled}\sqrt{1-ICC}$) was estimated. All significant tests were 2-sided, with an α of 0.05 ($P < .05$). The statistical analysis was performed using SPSS version 22.0 (IBM Corp, Armonk, New York).

Results

A total of 180 ultrasound images were obtained from 16 women (53.3%) and 14 men (46.7%), aged between 28 and 56 years and body mass index mean of 24.4 (SD 3.8 kg/m^2). The characteristics of the study participants are described in Table 1.

The results of the CSA of the sciatic nerve (in mm^2) presented normal distribution and were described in decreasing order of FDT positions, in mean and CI of 95% for position B (59.71; 53.21-66.21), position A (54.34; 49.21-59.47), position E (53.57; 48.57-58.56), position D (51.18; 46.03-56.34),

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Table 1. *Demographic Characteristics of Participants*

Variable	Frequency (%)	Mean (SD)
Sex (female)	16 (53.3)	-
Age (y)	-	35.5 (6.2)
Body mass index (kg/m^2)	-	24.4 (3.8)
Height (m)	-	1.71 (0.1)
Weight (kg)	-	72.1 (16.1)

SD, standard deviation.

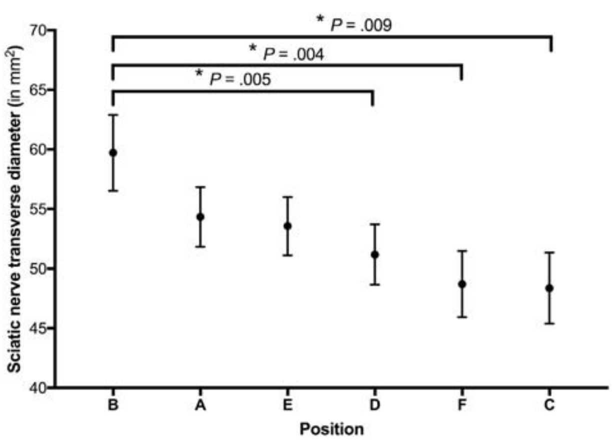

Fig 3. *Comparison of cross-sectional area of the sciatic nerve in the 6 different positions of the flexion-distraction table. Values were described in mean and standard error.*

position F (48.71; 43.05-54.37), and position C (48.37; 42.26-54.47). The results of the repeated-measures analysis of variance test showed changes with statistical significance ($P < .05$) of CSA of the sciatic nerve, in different combinations of FDT positions. The initial positioning B obtained the higher mean CSA value when compared with the final positions D and F and the initial position C. The values of the CSA of the sciatic nerve are presented in Figure 3.

The results of the mean difference of the CSA variations of the sciatic nerve in pairs of FDT positions are presented in Table 2 with their CI and percentage. The comparison between the lumbar starting positions with final positions showed no significant variations of the CSA of the sciatic nerve. Conversely, the initial position B (neutral lumbar with flexed knee) presented a higher mean CSA value of the sciatic nerve compared with the final position D (flexed lumbar with extended knee), the final position F (flexed lumbar, knee extended with active ankle dorsiflexion), and the initial position C (neutral lumbar, knee extended with active ankle dorsiflexion).

The inter- and intraexaminer reliability of the measurements performed on the ultrasound images were moderate to good, with interexaminer $ICC_{2,1}$ between 0.72 and 0.85 and for intraexaminer between 0.65 and 0.86. The reliability results are presented in Table 3.

Discussion

The main finding of the study was the variation of the CSA of the sciatic nerve in different FDT positions. The addition of lumbar flexion in the FDT did not reveal relevant changes in the CSA of the sciatic nerve. The positioning that combined the neutral lumbar, flexed knee, and neutral ankle position (position B) showed higher mean CSA measurement of the sciatic nerve, whereas the positioning that combined the neutral lumbar, extended knee, and ankle dorsiflexion presented lower CSA of the sciatic nerve (position C). This finding evidences the importance of the combination of the position of the knee and ankle to the accommodation of the CSA of the sciatic nerve and consequent management of the neurodynamic tension of the sciatic nerve because the decrease of the CSA of the nerve is interpreted as an increase of neural tension.[26]

The positioning commonly used in the descent phase of the FDT, leading to lumbar flexion with the extended knee (final position D), evidenced decreased CSA of the sciatic nerve when compared with the starting position of the neutral lumbar with flexed knee (initial position B). Coppieters et al[24] and Ellis et al[23] showed increased tension with the combination of 2 joints, with flexed hip and extended knee, and consequent decrease of neural excursion when tensioning this position. The obtained values of reduction of the CSA in the final position D indicate that such positioning should be avoided in patients with sciatica. Clijsters et al[13] pointed out that 29% of Australian chiropractors chose the FDT in cases of lumbar disc syndromes associated with radiculopathy, and about 18% chose it as the first treatment option.

Adding lumbar flexion did not result in CSA change in the sciatic nerve. The comparison between 2 common positions used in clinical practice (initial position A vs final position D) did not reveal a decrease in CSA of the sciatic nerve. Also, the comparison between initial position B and final position E found identical values of the CSA of the sciatic nerve. Similar results were found by Gürkan et al,[34] who also did not obtain

Table 2. *The Mean Difference, CI, and Percentage of the Cross-Sectional Area Variations of the Sciatic Nerve in Different Positions of the Flexion-Distraction Technique*

Position	Position	Mean Difference (CI 95%)	%
A: Knee extended and neutral ankle	D: Knee extended and neutral ankle	31.54 (-51.43 to 114.52)	-6
B: Knee flexed and neutral ankle	E: Knee flexed and neutral ankle	61.44 (-22.33 to 145.13)	-10
C: Knee extended and ankle dorsiflexion	F: Knee extended and ankle dorsiflexion	-3.43 (-93.43 to 86.55)	+1
B: Knee flexed and neutral ankle	D: Knee extended and neutral ankle	85.27 (18.78 to 151.76)	-14 [a]
B: Knee flexed and neutral ankle	F: Knee extended and ankle dorsiflexion	110.02 (24.41 to 195.63)	-18 [a]
B: Knee flexed and neutral ankle	C: Knee extended and ankle dorsiflexion	113.46 (19.35 to 207.56)	-19 [a]

CI, confidence interval.
[a] *P* value < .05.

Table 3. *Inter- and Intraexaminer Reliability, SEM of the Cross-Sectional Area of the Sciatic Nerve Found by Ultrasound Imaging in the Posterior Region of the Thigh*

Examiners	$ICC_{2,1}$ (CI 95%)	SEM	*P* Value
A1 and B1	-	-	-
Position A	0.85 (0.68-0.93)	5.71	<.001
Position B	0.76 (0.49-0.89)	10.42	<.001
Position C	0.76 (0.49-0.89)	8.06	<.001
Position D	0.73 (0.43-0.87)	7.86	<.001
Position E	0.72 (0.41-0.87)	7.99	.001
Position F	0.75 (0.47-0.88)	8.50	<.001
A1 and A2	-	-	-
Position A	0.80 (0.59-0.91)	5.67	<.001
Position B	0.79 (0.55-0.90)	7.51	<.001
Position C	0.65 (0.26-0.83)	8.89	.003
Position D	0.86 (0.70-0.93)	5.15	<.001
Position E	0.84 (0.67-0.92)	4.90	<.001
Position F	0.86 (0.70-0.93)	5.22	<.001

CI, confidence interval; *ICC*, intraclass correlation coefficient; *SEM*, standard error of measurement.

significant variations in CSA of the sciatic nerve comparing 3 different positions of the leg including a neutral position, leg supported in the roll, and the position forming the figure of four. The position B and E may be useful for the protection of the neural system and should be adopted in patients with sciatica. The increase of the CSA of the sciatic nerve with the knee flexion or lumbar neutral position may be related to the entrapment of the surrounding muscles.

The piriformis muscle, the hamstrings, the sacroiliac joint, and several other sites may also contribute to a double compression and the symptoms of sciatica.[35-38] Although piriformis syndrome is a controversial diagnosis,[39] sciatica caused by the compression of the sciatic nerve by the piriformis muscle was found in 67.8% of sciatica patients who had surgical failures.[37] Furthermore, the hamstrings were previously associated with the sciatic injury.[38] The role of increased local muscle tone restricting peripheral nerve stretching has already been demonstrated.[40] On the other hand, the preload of the sciatic nerve with the ankle dorsiflexion movement during the SLR test induced an increase of the muscle activation of the distal and proximal muscles.[40] The enhancement of muscle activation may be a protective response to the neural tension.

Our results demonstrated a decrease between 18% and 19% in the CSA of the sciatic nerve in the addition of ankle dorsiflexion in both the flexed lumbar position with extended knee and ankle dorsiflexion (final position F) and the neutral lumbar position with extended knee and ankle dorsiflexion (initial position C), demonstrating the potential increase of the neural tension when compared with the position of the neutral lumbar, flexed knee, and neutral ankle (initial position B). The addition of the ankle dorsiflexion enhanced the neural sensitization during the extended leg elevation test,[41] corroborating our findings. Besides, a cadaveric study demonstrated a significant difference in neural tension with the addition of ankle dorsiflexion.[42] The decrease of the CSA of the sciatic nerve with the addition of ankle dorsiflexion should be considered in planning the use of FDT in patients with sciatica.

Limitations

Our participants were healthy individuals, which may have influenced the study findings. Future studies should investigate patients with low back pain and related disorders to establish a more comprehensive knowledge about the sciatic nerve and the FDT. Besides, we considered the decrease of the CSA of the sciatic nerve as an increase of the sciatic nerve tension as previously reported,[23,26] although the increase of the CSA of the nerve has been considered a sign of neural pathology owing to the intraneural inflammatory process.[43] Frade et al[44] also showed increased CSA of the fibular nerve in leprosy neuropathy, and increased CSA of the median nerve in the wrist is a marker of carpal tunnel syndrome.[45] In diabetic neuropathy, Boyd et al[43] showed a significant increase in CSA of the tibial nerve in the ankle of patients with diabetes when compared with healthy controls. Also, the increase in CSA of the tibial nerve was related to the reduction of the nerve excursion in patients with diabetes.

Some factors may influence the acquisition of ultrasound imaging. The sharpness of the generated image is dependent on the quality of the equipment, the transducer type, the skill of the examiner, as well as adjustments, position, and pressure of the transducer on the skin and possible anatomical variations of each participant. A reliability study of the measurements was carried out, and the results were satisfactory for inter- and intraexaminer reliability in the determination of CSA of the sciatic nerve through the ultrasound exam. In the literature, we found excellent intraexaminer reliability for CSA of the sciatic nerve in the evaluation of ultrasound imaging[46,47] but low for a transverse excursion in anteroposterior movement.[29] Ultimately, the images of the ultrasound were performed in static positions in the FDT and could obtain different results if performed after a period of flexion-distraction operation and with another associated positioning, such as flexed head and stretched and fixed limbs. In future research, it is necessary to consider the effect of sciatic nerve tension under a treatment protocol in FDT, with frequency, time, and predetermined exposure time, comparing symptomatic and asymptomatic groups.

Conclusion

The CSA of the sciatic nerve varied with the adoption of different FDT positions. The combination of knee extension and ankle dorsiflexion decreased the CSA, whereas knee flexion and neutral position of the ankle increased the CSA of the sciatic nerve. Therefore, this positioning should be adopted for the treatment of patients with symptoms related to the sciatic nerve.

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No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): M.A.M.P., F.R., L.A.C.N.
Design (planned the methods to generate the results): M.A.M.P., L.A.C.N.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): M.A.M.P., L.A.C.N.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): M.A.M.P., L.A.C., L.A.C.N.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): M.A.M.P., R.S.A., N.A.M.-F., S.M., L.A.C.N.
Literature search (performed the literature search): M.A.M.P., N.A.M.-F., S.M., L.A.C.N.
Writing (responsible for writing a substantive part of the manuscript): M.A.M.P., S.M., L.A.C.N.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): M.A.M.P., L.A.C., R.S.A., N.A.M.-F., S.M., F.R., L.A.C.N.

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Practical Applications

- The knee extension with ankle dorsiflexion decreased the CSA of the sciatic nerve.
- The knee flexion with neutral position of the ankle increased the CSA of the nerve.
- Clinicians should be mindful of the effect of the knee and ankle on the sciatic nerve.

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