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ORIGINAL ARTICLE

Variations in the compartmental location of the superficial fibular nerve: a cadaveric study with meta-analysis

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Abstract

Purpose To investigate variations in the course of the superficial fibular nerve (SFN) and its branches—the medial dorsal cutaneous nerve (MDCN) and intermediate dorsal cutaneous nerve (IDCN)—concerning the leg compartments by means of a meta-analysis supplemented with an original anatomical study.

Materials and methods A literature survey was conducted in the PubMed, Scopus, Web of Science, and Lilacs databases on October 14th, 2021, to obtain anatomical data, and the PRISMA statement was adopted as a methodological guideline. We used MetaXL software for data analysis. We classified the anatomical data into three location patterns: in Type 1, the SFN courses through the lateral compartment; in Type 2, the SFN courses through the anterior compartment; in Type 3, the MDCN courses through the anterior compartment and the IDCN courses in the lateral compartment.

Results Twelve studies ($n = 837$ lower limbs) comprised the current review. The SFN location was normal (Type 1 variation) in 77% (95% CI 72.9–78.9) of the cases, while Type 2 had a pooled prevalence of 14.3% (95% CI 11.1–15.9). Type 3 was the less common course, with a prevalence of 8.7% (95% CI 5.9–9.7). We found differences among the geographical subgroups analyzed.

Conclusions The SFN courses through the lateral compartment of the leg most times, and the prevalence of this pattern varies significantly between the different geographical subgroups evaluated. These results are of great clinical and surgical relevance.

Keywords Superficial fibular nerve · Anatomy · Anatomic variation · Meta-analysis

Introduction

The superficial fibular nerve (SFN) arises from the branching of the common fibular nerve [26] and is usually located in the lateral compartment of the lower leg [19]. The SFN provides motor stimuli to the peroneus longus and peroneus brevis muscles, which are located in the same compartment [13]. When the SFN emerges from the fascia and reaches the dorsum of the foot, it divides into the medial (MDCN) and intermediate dorsal cutaneous nerves (IDCN) [9].

The traditionally described anatomical description for the SFN defines that it courses through the lateral compartment of the leg. However, recent studies have reported variations in which the SFN courses through a non-lateral compartment of the leg. In 1991, Adkison et al. reported surprise to find this nerve in the anterior compartment during elective fasciotomy surgery [1]. Other researchers have reported the same [2, 4] and other findings [21, 27] since then.

Variations in the SFN location have considerable clinical and surgical importance. Adkison and collaborators [1] stress the relevance of widely knowing these variations to perform fasciotomies, make fasciocutaneous flaps, and evaluate traumatic or non-traumatic pain syndromes of the leg. Rosson and Dellon (2005) suggest that in patients with SFN entrapment or neuroma, the surgeon should examine the lateral and anterior compartments of the leg due to potential anatomical variations in the location of this nerve [23].

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Knowing the SFN course variations is of great clinical and surgical importance; hence, the purpose of the present research article is to provide a broad, systematic meta-analysis on the SFN location patterns in the compartments of the leg, supplemented with our own cadaver sample.

Materials and methods

Anatomical studies

Dissection method

A longitudinal incision was made along the anterior midline of the leg to expose the SFN course. This was performed using a No. 3 scalpel handle with a No. 15 surgical scalpel blade and Metzenbaum scissors to split the deep fascia from the skin. The data were collected and classified for further analysis, as well as stored through a photographic record.

Sample characteristics

We included fetuses aged from the fourth to the ninth month of conception without neural or non-neural deformities in their lower limbs. The fetuses were obtained from cadaver donation programs for anatomy research at our university. Sixty-three formalin-fixed Brazilian fetal cadaver specimens (33 males and 30 females) ($n = 126$ lower limbs) were used in the present anatomical study.

Ethical considerations

We state every effort was made to follow all local and international ethical guidelines and laws concerning the use of human cadaveric donors in anatomical research, as recommended by Iwanaga et al. [16]. Ethical approval from the local Human Research Ethics Committee is included at the end of the paper.

Meta-analysis

Register and guidelines

This study was reported as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [20] and the methods for systematic review and meta-analysis of anatomical studies proposed by the International Evidence-Based Anatomy Working Group (iEBA-WG) [14]. The International Prospective Register of Systematic Reviews (PROSPERO) approved our review protocol (registry code CRD42020207050).

Search strategy

Anatomical data were acquired by means of a literature survey conducted in PubMed, Scopus, Web of Science, and Lilacs databases on October 14, 2021. The search strategy adopted was (superficial peroneal nerve OR superficial fibular nerve) AND (anatomy OR anatomic variation). No restrictions pertaining to year of publication, language, and study design were applied. Reference lists of relevant articles were also searched.

Eligibility assessment

Three review authors screened the retrieved records from the searched databases for evaluation of eligibility. Studies on the anatomy of the SFN with no distinction of design or method of anatomical evaluation (e.g., magnetic resonance imaging, ultrasound, intraoperative, and dissection) were considered eligible for inclusion. In addition, the studies were not restricted with regard to the sex of the subjects. Case reports, case series, reviews, book chapters, conference abstracts, and papers outside the scope of this review (i.e., without anatomical data on the SFN course) were excluded after reading abstracts and full texts.

Data extraction

Three independent review authors (A.C., J.V., and B.R.) extracted the following data from the included articles: first author's surname, location where the study was carried out, publication year, sample size, and amount of variations found in the study. The review authors reached a consensus among each other to solve disagreements at this stage.

The SFN courses were classified into three location patterns: Type 1—the SFN courses through the lateral compartment of leg as a single nerve trunk; in Type 2—the SFN courses through the anterior compartment of leg as a single nerve trunk; in Type 3—the MDCN courses through the anterior compartment and IDCN courses through the lateral compartment.

Figure 1 displays the internal anatomy of leg, its compartments and septa, and the SFN location patterns.

Statistical analysis

A proportions meta-analysis was performed to estimate the multicategory pooled prevalence of the SFN location patterns using MetaXL version 5.3 software (Wilston, Queensland, Australia) [3]. The random-effects model was used in all analyses, with a 95% confidence interval (95% CI) and a Freeman–Tukey double arcsine transformation [12, 17].

To measure heterogeneity among the included studies, Cochran's Q test and Higgins' I^2 statistic were used. The

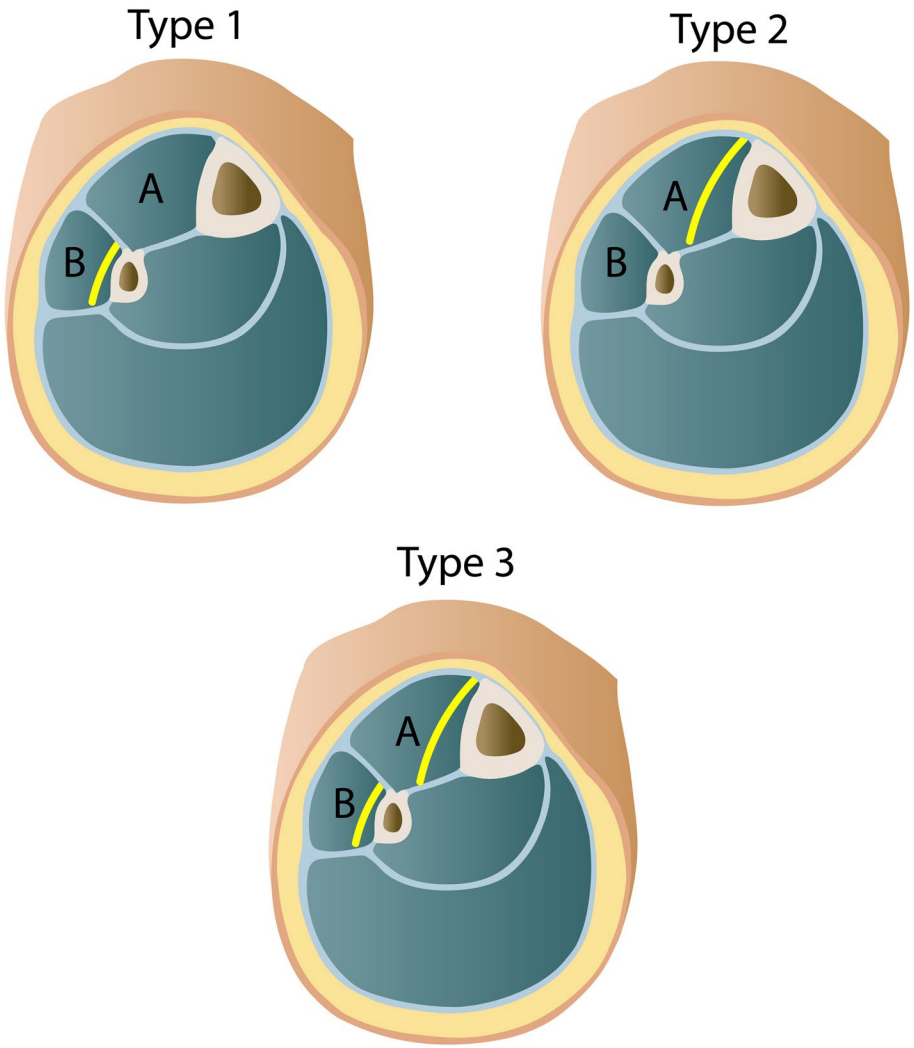

Fig. 1 Variations of the SFN, compartments, and septa of the right leg. A, Anterior compartment; B, lateral compartment

reference values for these two tests followed the recommendations of previous studies [3, 14]. Results of this step have been displayed in forest plots.

We also performed geographical subgroup analyses, based on the locations where studies were conducted, to assess whether there is a geographical influence on the SFN course. We did not perform subgroup analyses by age category (e.g., adults and fetuses) because the variations remain stable since embryonic life. The proportions were analyzed using the Chi^2 test, deeming p-values lower than < 0.05 as significant.

Results

Results of the current anatomical study

Table 1 shows the cadaveric dissection results of the present anatomical study. We found no statistically significant differences regarding gender ($p = 0.110$) and side ($p = 0.762$). The dissection results of the current study were pooled into the meta-analysis.

Study identification

Eight hundred and twenty-seven records were retrieved from the database searching. A manual search found one record. After the removal of duplicates, 720 records were analyzed, of which 57 were considered potentially eligible

Table 1 Results of cadaver dissection in the present study

	Compartmental location patterns of the SFN			
	Side		Sex	
	Right (%)	Left (%)	Male (%)	Female (%)
Type 1	92.1	93.6	94.0	91.7
Type 2	6.3	1.6	3.0	5.0
Type 3	1.6	4.8	3.0	3.3

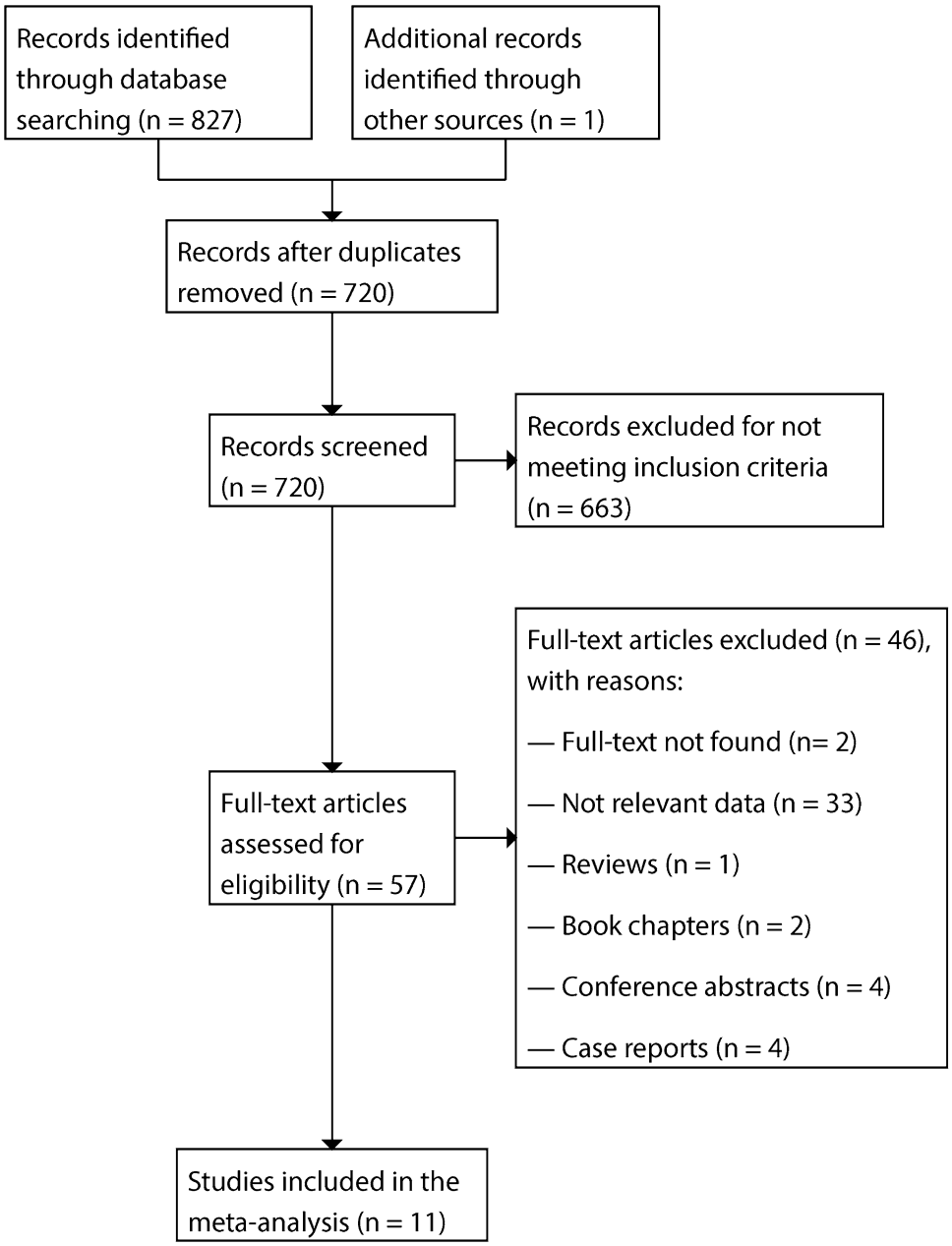

Fig. 2 Flowchart of literature screening in compliance with the PRISMA statement

after reading the titles. Forty-six studies were excluded according to the exclusion criteria. For a list of exclusions, please see Fig. 2.

Characteristics of included articles

After the eligibility assessment process, a total of 11 articles [1, 2, 4, 5, 8, 10, 11, 15, 22–24] were included. Considering the current anatomical study, 12 studies ($n = 837$ lower limbs) comprised this meta-analysis. The characteristics of the included articles are summarized in Table 2.

SFN location patterns concerning the leg compartments

Eleven studies ($n = 711$ lower limbs) analyzed variations in SFN location patterns regarding the compartments of leg. In the overall analysis, Type 1 variation had a pooled prevalence of 77% (95% CI 72.9–78.9; $I^2 = 78\%$; $p < 0.001$), and Type 2 had a pooled prevalence of 14.3% (95% CI 11.1–15.9; $I^2 = 86\%$; $p < 0.001$). The pooled prevalence of Type 3 variation was 8.7% (95% CI 5.9–9.7; $I^2 = 88\%$; $p < 0.001$) (Fig. 3). Subgroup analysis based on

Table 2 Characteristics of the studies included in this review

Study	Year	Geographical subgroup	Sample (lower limbs)	Study type
Adkison et a.l [1]	1991	North America	85	C
Apaydin et al. [2]	2008	Asia	38	C
Barrett et al. [4]	2006	North America	75	C
Bas et al. [5]	2012	Asia	40	C
Canella et al [8]	2009	Europe	65	C and U
Correia et al. (current study)	2022	South America	126	C
Domagała et al. [10]	2003	Europe	53	C
Ducic et al. [11]	2006	North America	111	C and S
Herron et al. [15]	1993	Europe	20	C
Prakash et al. [22]	2010	Asia	60	C
Rosson and Dellon [23]	2005	North America	35	S
Solomon et al. [24]	2001	Oceania	68	C

C, cadaver; S, surgery; U, ultrasound

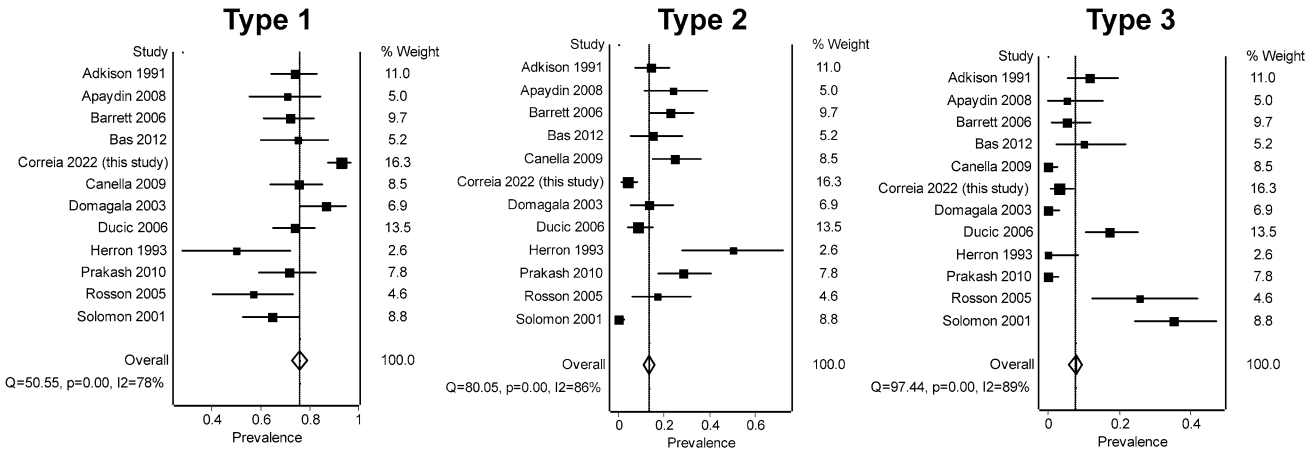

Fig. 3 Forest plots for analysis of prevalence of each SFN location pattern

Table 3 Geographical subgroup analyses of the SFN location patterns

Geographical location	Type 1	Type 2	Type 3
Asia	72.3 (64.4–79.3)	23.7 (16.6–30.8)	3.7 (0.9–7.3)
Europe	76.4 (69.1–83.3)	23.6 (16.7–30.9)	0 (0–0)
North America	71.6 (66.2–76.5)	14.8 (10.9–18.9)	13.5 (9.8–17.5)
Oceania	64.5 (52.9–75.7)	0 (0–0)	35.5 (24.3–47.1)
South America	92.9 (87.6–96.8)	4 (1.1–8.2)	3.1 (0.7–7.1)

geographical locations where studies were carried out was performed (Table 3), and differences were found between the different geographical subgroups ($p < 0.001$).

Discussion

The current paper aimed to investigate the SFN location patterns in the compartments of the leg in a sample of Brazilian fetuses, complemented with a meta-analysis. Our results have shown high variability in the SFN course, which is significantly different among different geographical subgroups. We identified a previous narrative review on this topic [25] with smaller sample size and no meta-analysis.

We found differences in geographic distribution of SFN location variations: Type 1 was more prevalent in populations from South America (specimens dissected in this study), Type 2 was more prevalent in Asian subjects, and Type 3 was more common in populations from Oceania. The anatomic variability among different geographical

subgroups is relevant for decision-making regarding leg and foot surgeries. This unequal distribution shows the need for further anatomical studies that address these variables, especially in additional geographical subgroups and ethnicities.

Incidental SFN injury is a major complication that may arise from leg surgeries (e.g., fascial release) and can happen when unexpected SFN variations are overlooked. One way to identify the SFN compartmental location is through Tinel's sign, which can indicate the SFN location and possible variations, such as SFN branches in other compartments [25, 27]. This sign may show the need for caution by the surgeon during invasive procedures.

Symptomatic SFN entrapment may occur in the fibular tunnel—which is located in the lateral compartment of the leg—and each anatomic pattern variation is associated with a specific entrapment point and decompression site [18]. Therefore, the surgeon should know that the SFN may not be found in the lateral compartment of the leg, but rather in the anterior compartment [25] or even with branches in both compartments. This highlights the need not presume the nerve location to avoid inadvertent nerve injury.

The anterior compartment of the leg is most commonly involved in chronic exertional compartment syndrome [6]. According to Apaydin et al. (2008), the wide SFN variability is an important risk factor for direct injury in subcutaneous fasciotomies during blind dissections of the lower limbs. Injury to the SFN is a problematic complication incidentally observed after anterior or lateral compartment fasciotomy. As a result, persistent pain, paresthesia, and reduced skin sensitivity may occur on the dorsum of the foot [7].

Recently, de Bruijn et al. described a technique that did not injure the SFN during anterior compartment fasciotomy [7]. This technique involves safely placing the fasciotome in a 2-cm skin incision located 2–3 cm lateral to the tibial crest, offering optimal visibility of the course of the SFN. However, avoiding injury to all small and clinically less relevant proximal sensory branches may not be possible, as highlighted in this study.

Variations in the SFN compartmental location are also important during minimally invasive fasciotomies. When the SFN courses through the anterior compartment, it can be injured during a fascial release surgery [2]. Because of possible additional branches of the SFN, the surgeon should be aware when performing fasciotomies for compartment syndrome to avoid creating a neuroma of the SFN [23].

Knowing the SFN variations reported in this study is valuable to analyze magnetic resonance imaging (MRI) findings related to non-traumatic fibular nerve palsy and to evaluate the usefulness of MRI in these patients, as previously stated by Apaydin et al. [2].

The absence of detailed descriptions regarding subjects' ethnicities in the original primary studies limited the present meta-analysis; thus, we were limited to a geographic subgroup analysis, which is not as clinically or surgically important as an analysis based on ethnicity. Furthermore, the studies also did not provide detailed descriptions concerning sex and side, which also limited our analyses.

Conclusion

The SFN travels through the lateral compartment of the leg as a single nerve entity in almost 8 of 10 cases. However, the course of this nerve may vary, either coursing entirely through the anterior compartment or dividing early and giving terminal nerve branches that traverse the anterior and lateral compartments of the leg. We observed variations among the different geographical subgroups, which may show the need for caution by surgeons and physicians when evaluating patients of different nationalities.

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Availability of data and materials Not applicable.

Declarations

Conflict of interest The authors state no conflict of interests.

Ethical approval This study was approved by the Human Research Ethics Committee of the Federal University of Sergipe (No. 79260417.0.0000.5546).

Consent for publication Not applicable.

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