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Factors Influencing Common Fibular Nerve Course Variability before Bifurcation into the Superficial Fibular Nerve and Deep Fibular Nerve: A Cadaveric Study

Dylon P. Collins BS[1], Nayeem M. Chowdhury MS[2], Anika Sedani BS[3], Claudia Henderson BS[4], Debra McNally MS[5], Nicholas Lutfi MD, MS, DPM[6]

[1-6] Nova Southeastern University, Dr. Kiran C. Patel College of Osteopathic Medicine

ABSTRACT

Background and Objectives: The common fibular nerve (CFN) has anatomical variance between individuals as it transitions from the posterior thigh to the anterior leg. The nerve's course around the fibular neck is of particular interest, where it becomes vulnerable to injury at the lateral knee. Therefore, we sought to compare factors that may predict distal CFN variability, such as height, age, sex, fibular length, and proximal sciatic variations, which individually or cumulatively play a role in predicting clinically significant locations where the CFN commonly transitions among certain populations.

Methods: In this cadaveric study, twenty anatomically-fixed specimens were analyzed, ten males and ten females. Data gathered included age, sex, height, CFN transition point measured from the proximal head of the fibular to the point 90 degrees off the midline of the fibula where the CFN courses around the fibular neck, fibular length, and proximal sciatic nerve variations characterized based on the Beaton and Anson classification system. Factors were compared and statistical values were generated.

Results: There was a statistically significant difference between CFN transition points compared to fibular lengths, heights, and between sexes. Sciatic nerve (SN) bifurcation levels and exits were bilaterally identical on all cadavers. All SN exits were Beaton and Anson type 1 (undivided nerve below and undivided piriformis), and bifurcation levels were 20% high, 25% middle, and 55% low.

Conclusions: This study highlights the importance of considering a person's height, fibular length, and sex when addressing injuries involving the CFN at the lateral leg.

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INTRODUCTION

The CFN, also known as the common peroneal nerve, is a SN division that runs along the posterolateral side of the knee. Classically, the CFN bifurcates from the SN proximal to the popliteal fossa and courses down the posterolateral part of the leg before going deep to the biceps femoris tendon. It then passes through the popliteal fossa and goes inferior and lateral to the proximal fibular head. As the CFN courses distally, it travels around the fibular head and the biceps femoris tendon at the anterolateral side of the leg **[1].** The CFN pierces the fibularis longus muscle and courses anteriorly around the fibular neck before dividing into the superficial fibular nerve (SFN) and deep fibular nerve (DFN).

The SFN runs anterolaterally along the lateral aspect of the extensor digitorum longus and the medial aspect of the fibularis longus. The SFN bifurcates distally in the lateral compartment proximal to the lateral malleolus. The DFN runs anteriorly alongside the anterior tibial artery, going between the medial aspects of the extensor digitorum longus and tibialis anterior in the anterior compartment. As the DFN continues distally down the anterior compartment, it travels between the tibialis anterior and the extensor hallucis longus **[2].**

With variants of the sciatic nerve documented in a multitude of research, its route is an important consideration when studying the CFN. The SN originates from the L4-S3 nerve roots in the pelvis. Typically, the SN exits through the

 Corresponding Author: Dylon P. Collins BS

greater sciatic foramen inferior to the piriformis muscle. The SN then divides into the CFN and the tibial nerve (TN), classically at the superior angle of the popliteal fossa. A common variation is a high division of the SN into the CFN and TN in the pelvis or thigh proximal to the popliteal fossa. It is suggested that the SN's pelvic exit variation stems from the SN branches' existence as separate nerves during the embryological period **[3].** Beaton and Anson first characterized SN variation relative to the piriformis muscle in 1937 based on six classifications **[4].** Most studies use a modified version of the original Beaton and Anson classification system, where the SN variations are categorized into two groups of variants. One group consists of variants where the SN enters the gluteal region as a common trunk, whereas the other group consists of variants where the SN enters the gluteal region bifurcated into the CFN and TN in relation to the piriformis. As it relates to the route of the CFN, variations in how the SN exits the pelvis and where it bifurcates into the CFN and TN may contribute to variations in the distal course of the CFN.

In a study exploring the branching patterns and localization of the CFN by Watt et al., they found significant relationships between patient traits and the anatomy of the CFN. A significant correlation was found between a cadaver's height and the length of the exposed sub-cutaneous CFN, defined as the length between the CFN emergence from the biceps femoris to the CFN submergence under the fibularis longus **[5].** There was also a significant relationship between the cadaver's fibular length and where the DFN and anterior tibial recurrent nerve (ATRN) both branch from the CFN. In another study by Hildebrand et al., they wanted to identify the anatomical relationship between the CFN and the fibular head. Using the distance between the fibular head and the center of the CFN as it exits under the biceps femoris, a moderate correlation was found between this measurement and the heights of the cadavers **[6].**

With variations of the CFN having implications on CFN neuropathies and surgical interventions in the proximal lower leg, we sought to explore if certain patient traits act as factors to predict CFN variations. We aim to focus on patient age, height, sex, CFN transition point from posterior thigh to the anterior leg, fibular length, and SN route variability. Given the encouraging findings from the Watt and Hildebrand investigations, we hope to find significant relationships between these factors and CFN course variability.

MATERIAL AND METHODS

This was an Institutional Review Board (IRB) exempt cadaveric study with no funding provided. Twenty anatomically-fixed, full-body, cadaveric specimens with an average age of 81.2 years (68.8-93.6 years) consisting of ten males and ten females were analyzed. Data gathered included age, sex, height, CFN transition point, fibular length, and SN route observations.

With the specimens supine, height was assessed with a standard measuring tape post-craniotomy via re-articulating of the skull cap. Measurements were taken from the highest prominence of the skull down to the right inferior and distal aspect of the calcaneus. Fibular lengths were measured from the most proximal aspect at the fibular head to the most distal aspect at the lateral malleolus. The CFN branches were exposed proximally and distally. The CFN transition points were measured from the most proximal aspect of the fibula to the point where the CFN went from the posterior thigh to the anterior leg with digital calipers capable of measuring to 0.001mm **[Figure 1].** The transition point was standardized as 90 degrees lateral from the midline of the fibula. CFN transition points and fibular lengths were measured bilaterally and averaged.

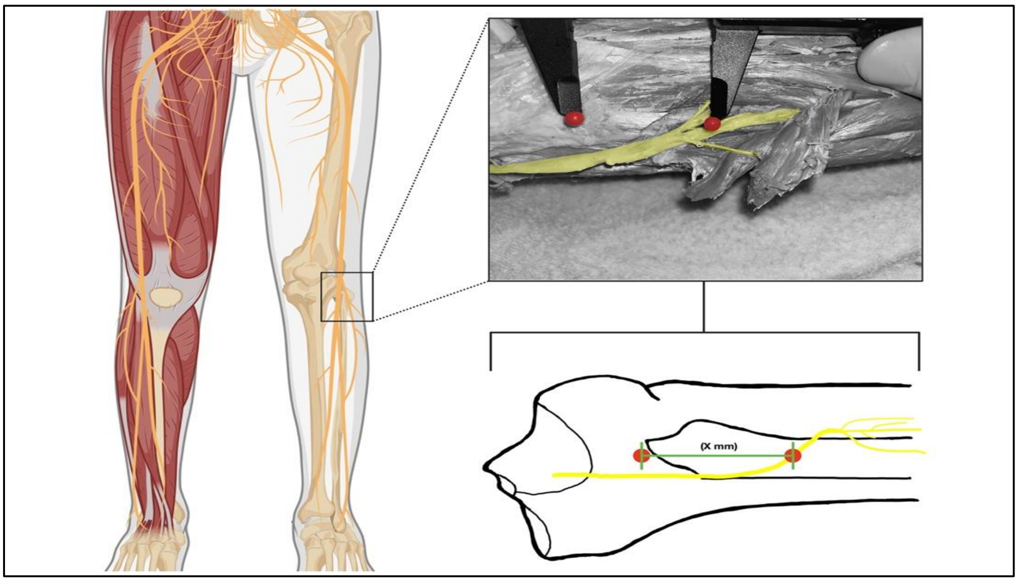

Figure 1: CFN transition point. Created with BioRender.com

The specimens were then turned prone to analyze proximal variations. SN exit in relation to the piriformis was based on the Beaton and Anson classification system, types 1 through 6. Three categories were established for SN bifurcation: high, middle, and low. High was within the gluteal region superior to the distal border of the gluteus maximus, middle was between the distal border of the gluteus maximus and superior border of the popliteal fossa, and low was distal to the superior border of the popliteal fossa. SN observations were gathered bilaterally.

A two-sided independent-sample t-test, assuming equal variance, was used to compare cadaveric heights, ages, CFN transition points, and fibular lengths. A paired t-test, assuming equal variance, was used to compare CFN transition points between sexes. An analysis of variance (ANOVA), assuming equal variance, was used to compare sciatic nerve bifurcation levels to age, CFN transition points, and fibular lengths. A Chi-Squared test was used to compare sciatic nerve bifurcation levels between sexes. Statistical significance was defined as a p-value less than 0.05.

RESULTS

A total of twenty cadavers were analyzed, totaling forty lower extremities. There was a statistically significant difference between heights compared to CFN transition points, at 166.2 cm (153.2-179.1 cm) and 43.4 mm (35.5-51.3 mm) (r=0.69, 95% CI: 0.36,0.86, p<0.001) **[Figure 2]** and heights compared to fibular lengths, at 166.2 cm (153.2-179.1 cm) and 37.9cm (34.4-41.4 cm) (r=0.93, 95% CI: 0.83,0.97, p<0.001) **[Figure 3].** There was a statistically significant difference between CFN transition points at 43.4 mm (35.5-51.3 mm) and fibular lengths at 37.9 cm (34.4-41.4 cm) (r=0.78, 95% CI: 0.52, 0.91, p<0.001) **[Figure 4].** There was a statistically significant difference between CFN transition points compared between sexes with males at 48.5 mm and females at 38.55 mm (p<0.007) **[Figure 5].**

SN bifurcation levels and exits were the same bilaterally on all cadavers. SN bifurcation levels were 20% high, 25% middle, and 55% low. All SN exits were undivided and below the piriformis, Beaton and Anson type 1. SN bifurcation levels were compared to height, CFN transition points, fibular lengths, and between sexes, but no significance was found among comparisons.

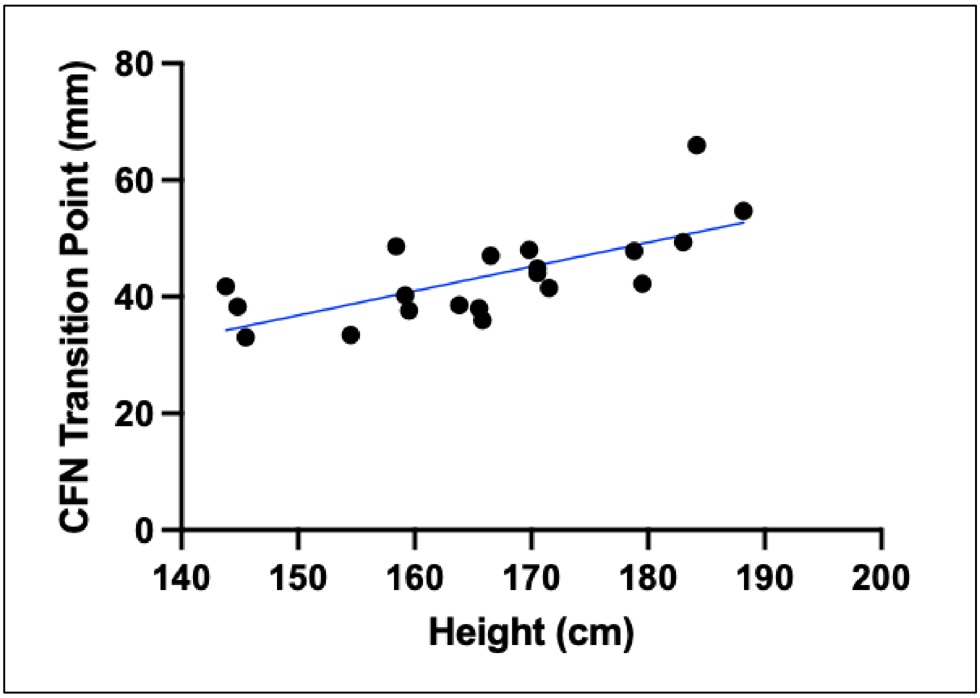

Figure 2: Height compared to CFN transition point (r=0.69, p<0.001)

 Corresponding Author: Dylon P. Collins BS

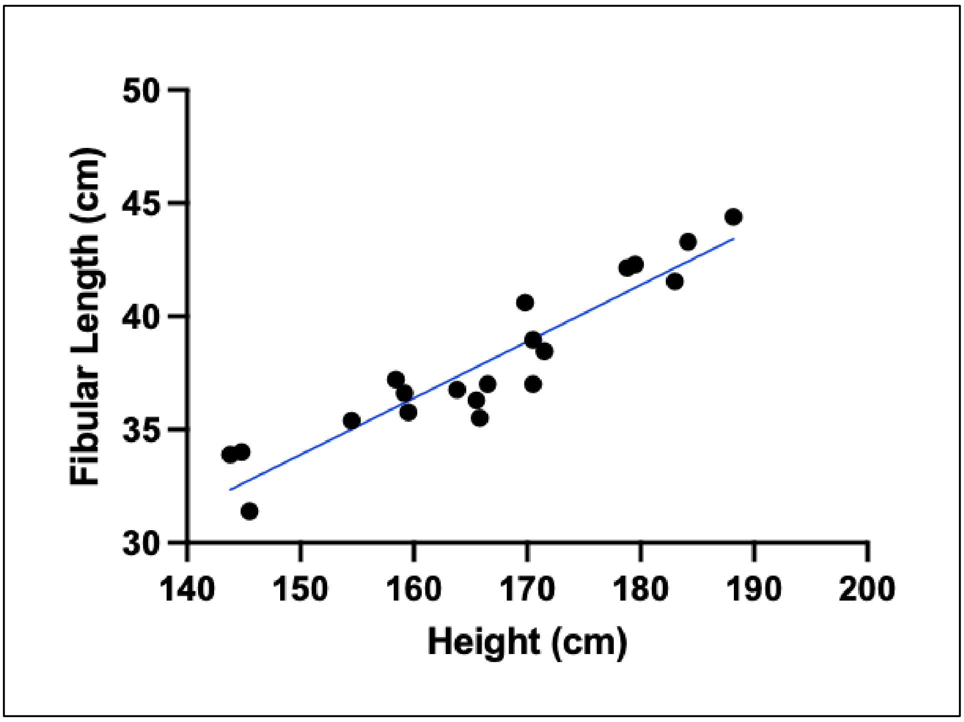

Figure 3: Height compared to fibular length (r=0.93, p<0.001)

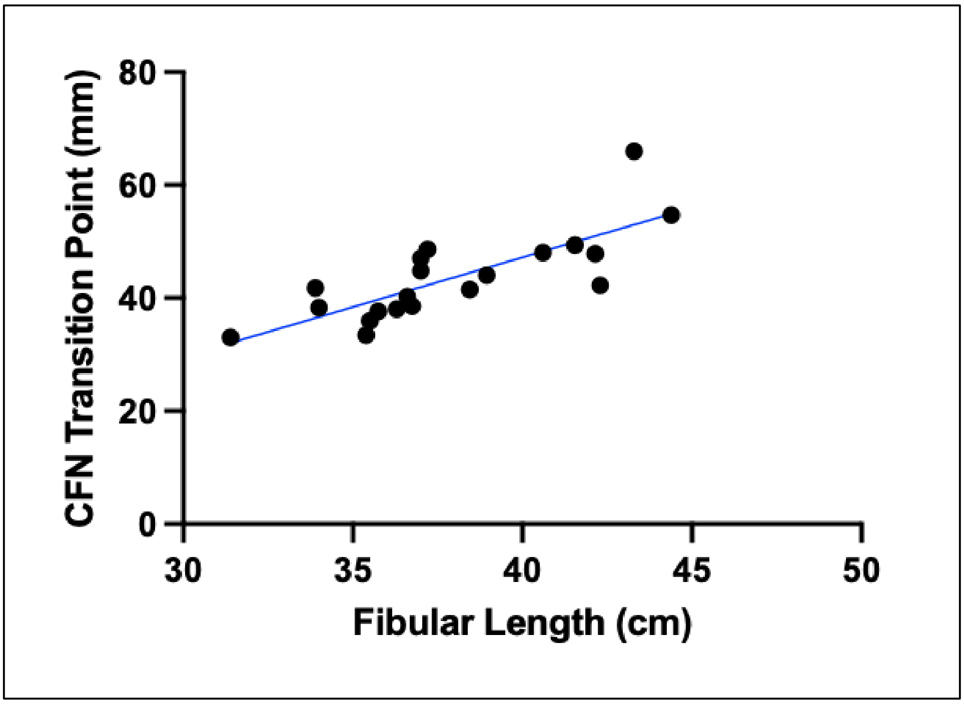

Figure 4: Fibular length compared to CFN transition point (r=0.78, p<0.001)

 Corresponding Author: Dylon P. Collins BS

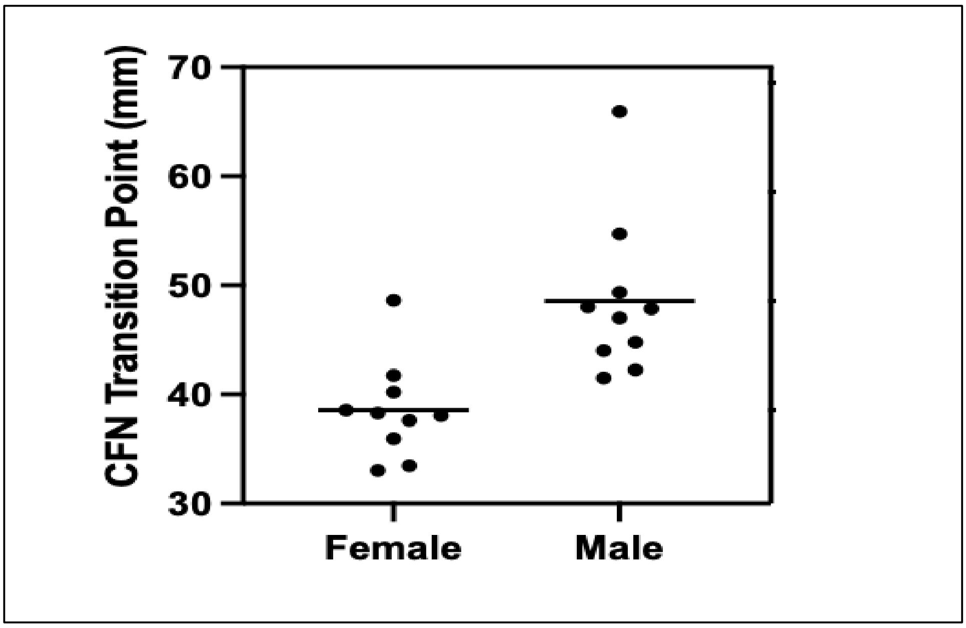

Figure 5: CFN transition point compared between males (n=10) and females (n=10) (p<0.007)

DISCUSSION

In this study, height, sex, and fibular length should be considered as clinically significant factors to determine the location of the CFN transition point.

Some of the early investigations into CFN variations occurred in 1999. The first study by Deutsch et al. sought to clarify the CFN anatomy at the knee's lateral joint line and its implications in arthroscopically assisted lateral meniscus repair procedures**.** They were prompted to explore the anatomy of the CFN after reviewing case reports of iatrogenic injuries that occurred during arthroscopic inside-out repair of meniscus tears. The first part of the study focused on the location of the CFN relative to the lateral joint line of the knee and the branching pattern of the CFN into the DFN and SFN. The results on 70 lower extremities from 35 preserved adult cadavers showed that in 7 of the lower extremities (10%), the CFN divided into its deep and superficial branches proximal to the knee joint **[7].** On average, this pattern of CFN division was 7.5 mm proximal to the knee joint and was found on bilateral extremities in 3 cadavers **[7].** In 6 of the lower extremities (8.6%), the division occurred 33 mm distal to the knee joint but proximal to the fibular neck, on average **[7].** The presence of variations in CFN branching at the lateral joint line introduces the risk of iatrogenic nerve injury sustained during arthroscopically assisted lateral meniscus repair. This study was significant because it exhibits injurious implications in applying the previously accepted assumption of the CFN classically branching distally to the knee joint at the fibular neck in all patients, especially when performing arthroscopic knee repair procedures.

Even when considering just the classical course of the CFN, it has been implicated in peripheral neuropathies, typically due to injuries at the level of the fibular head. This is due to the fibular head's bony prominence, the CFN's superficial positioning, and the CFN often being tethered by the fibularis longus tendon within the fibular tunnel **[8].** CFN neuropathies can result from various etiologies of injury and external compression in the area of the fibular head, such as bracing devices, blunt injuries to the popliteal fossa or lateral knee, knee dislocations, traction injuries, and fibula fractures. Understanding the route of the CFN and its course relative to other anatomical locations has clinical implications, such as foot drop and surgical approaches. When we consider the relatively significant prevalence of CFN variation and the injuries that can occur along the route of the CFN, it highlights the importance of characterizing variations in the CFN and finding predictable factors.

Foot drop is a common manifestation of CFN neuropathy, which is the inability to lift the forefoot due to weakness in the dorsiflexor muscles of the foot **[9].** The primary dorsiflexors of the foot are the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and fibularis tertius, all of which are innervated by the DFN **[10].** Because of this, compression or injury at the level of the fibular head are common causes of CFN palsy that leads to foot drop. Interestingly, patients with a high division of the SN may be more prone to compressions of the CFN within the gluteal region due to piriformis relation based on the Beaton and Anson type **[11].** This is commonly due to piriformis hypertrophy or scarring. In addition, prior to the inability to dorsiflex the foot due to entrapment of the CFN, a patient can experience numbness, tingling, burning, or decreased sensation anywhere from the lower lateral leg to the dorsal aspect of the foot.

Injuries at the posterolateral corner of the leg are typically associated with lateral collateral ligament (LCL) injuries, where a high-energy force with hyperextension and varus components are applied to the medial or anteromedial aspect of the knee **[12].** These injuries commonly occur while pivoting, jumping, and landing, putting certain individuals involved in high-intensity sports or activities at an increased risk of injury **[13,14].** In addition, the proximity of the CFN to the posterolateral corner of the knee in relation to the LCL leads to combined ligamentous and nerve injuries. Significantly, 35% of posterolateral corner injuries of the knee result in CFN palsy, which may result in mild parathesis or, more severely, foot drop **[15].**

Surgical interventions require appropriate preoperative planning because injuries of the CFN at the lateral knee must be avoided. In a study by Rausch et al., they sought to accurately describe the location of the CFN at the fibular head using 3D imaging to help reduce CFN injuries as a complication of operative treatment of the proximal lower leg. These treatments include corrective osteotomies, lengthening procedures, and fracture fixation. The results showed more variances in the distance of the CFN branches relative to the tip of the fibula than previously described **[16].** More significantly, previously described safe zones for surgery were shown to be unreliable because of the increased variability of the CFN course and its branches **[16].** Their results concluded that the posterolateral part of the proximal fibula should be avoided when treating fractures in that area **[16].** In addition, they suggest that pins or screws should only be inserted in the anterior or lateral proximal 27 mm of the fibula, given the course of the CFN and its branches **[16].**

The results of this current study will further aid clinicians in many clinical situations that arise at the lateral leg involving the CFN and lead to improved patient outcomes.

CONCLUSION

When addressing impacts to the CFN at the fibular neck, it is essential to consider individual patient factors. Clinical implications include, but are not limited to, fibular neck fractures, knee dislocations, external compression devices, and surgical preoperative planning approaches. Further examinations of these factors with larger sample sizes are needed to strengthen the significance of these results and examine additional predictors of distal CFN variability.

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