



# Morphological variability of the gastrocnemius muscle's third head: cadaveric dissection findings

Konstantinos Natsis<sup>1</sup>, George Konstantinidis<sup>1</sup>, Maria Piagkou<sup>2</sup>, George Triantafyllou<sup>3</sup>, Alexandros Samolis<sup>3</sup>, Trifon Totlis<sup>1</sup>, George Tsakotos<sup>4</sup>, Dimitrios Chytas<sup>5,6</sup>, Juergen Koebke<sup>7</sup>

<sup>1</sup> Faculty of Health Sciences, Aristotle University of Thessaloniki, Greece, Thessaloniki, Greece

<sup>2</sup> Faculty of Medicine, National and Kapodistrian University of Athens, Athens, Greece

<sup>3</sup> Department of Anatomy, School of Medicine, National and Kapodistrian University of Athens, Athens, Greece

<sup>4</sup> School of Medicine, National and Kapodistrian University of Athens, Athens, Greece

<sup>5</sup> University of the Peloponnese, Sparta, Greece

<sup>6</sup> European University Cyprus, Nicosia, Cyprus

<sup>7</sup> Department of Anatomy, University of Cologne, Cologne, Germany

**Corresponding author:** Maria Piagkou, Faculty of Medicine, National and Kapodistrian University of Athens, Athens, Greece; Email: mapian@med.uoa.gr

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## Abstract

**Aim:** The gastrocnemius tertius (GT) represents the presence of a third head (TH) of the gastrocnemius muscle (GM), the most common morphological variant of the GM. This cadaveric dissection series aimed to determine the frequency, morphological characteristics, and anatomical relationship of the GT with the popliteal neurovascular structures (PNVS).

**Materials and methods:** Forty formalin-embalmed cadaveric lower limbs from the Department of Anatomy and Surgical Anatomy, Aristotle University of Thessaloniki, were examined. All specimens were donated to the Department after obtaining informed consent prior to death, in accordance with institutional and national ethical regulations.

**Results:** The GT was identified in six of forty specimens (15%). In four cases (10%), the third head originated from the posterior distal surface of the femur, medial to the lateral head (LH), and fused with it. The popliteal vessels were located medially to the TH. In one case (2.5%), the TH arose from the LH and fused with the medial head (MH), with the popliteal vessels coursing between the TH and MH. In another case (2.5%), the TH did not fuse with the LH but instead formed a distinct tendon inserting into the calcaneal tendon.

**Conclusion:** The GT was observed in 15% of Greek cadavers, representing the highest prevalence reported to date. Specific morphological configurations may predispose to PNVS compression, potentially affecting one or more components of the neurovascular bundle. Awareness of such GM variants, supported by thorough clinical assessment and targeted imaging, is essential for accurate diagnosis and effective management of popliteal fossa pathologies.

## Keywords

gastrocnemius muscle, variation, gastrocnemius tertius, third head, entrapment.

## Introduction

The superficial muscles of the posterior compartment of the leg include gastrocnemius, soleus, and plantaris (GM, SM, and PM, respectively). Together, they form the calcaneal tendon (CT), the thickest tendon in the human body, which attaches to the posterior surface of the calcaneus.<sup>[1]</sup> The GM typically consists of two heads: a lateral head (LH) and a medial head (MH), which originate from the lateral and medial femoral condyles, respectively. Acting in conjunction with the SM, the GM primarily facilitates plantar flexion and supination of the foot and also contributes to knee flexion.<sup>[1]</sup>

A well-recognized morphological variation of the GM is the presence of a third head (TH), referred to as the gastrocnemius tertius (GT), first described by Kelch in 1813.<sup>[2]</sup> GT is the most prevalent variation of the GM, with reported prevalence rates varying considerably among different populations.<sup>[3]</sup> Triantafyllou et al.<sup>[4]</sup> performed a cadaveric study and meta-analysis, reporting a pooled prevalence of 4.34%. This finding highlights the remarkable morphological diversity and clinical relevance of this muscular variant. The additional head may arise from the popliteal surface of the femur, the lateral condyle, the knee joint capsule, or, less frequently, from the long head of the biceps femoris.<sup>[3]</sup> Typically, the GT fuses with the MH of the GM.<sup>[3]</sup>

Frey<sup>[5]</sup> proposed a classification system comprising twelve morphological types of GT based on their origin and insertion patterns. Clinically, GT is important because specific variants traverse the popliteal neurovascular structures (PNVS), potentially leading to entrapment syndromes.<sup>[3,5]</sup>

## Aim

The present cadaveric case series investigates the frequency and morphological variability of the GM, particularly concerning the GT's origin and insertion, as well as its anatomical relationship with the PNVS. It also discusses the developmental and comparative anatomical context, population-based prevalence, and clinical implications of this muscular variation.

## Materials and methods

Forty formalin-embalmed lower limbs were dissected to identify the presence and morphological variations of the GT. The specimens were obtained from the donated cadaveric collection of the Department of Anatomy and Surgical Anatomy at the Aristotle University of Thessaloniki, Medical School. Dissection began at the leg with the removal of the skin and superficial fascia to expose the GM. A detailed examination of the popliteal fossa (PF) was then performed. The following morphological features of the GM were systematically evaluated: the presence of a TH,

its origin, course, and insertion, as well as its anatomical relationship with the PNVS.

All cadavers were donated to the Department for educational and research purposes, with informed consent obtained before death, in accordance with Greek legislation. The study was conducted in compliance with the Declaration of Helsinki and the institutional ethical guidelines for anatomical research.

## Results

The GT was identified in 6 (15%) out of 40 dissected lower limbs.

*Type I* variant (4/40; 10%): In four specimens, the TH originated from the posterior distal femoral surface, close to the midline, medial to the LH, and fused with it. In these cases, the popliteal vessels (PVs) were located medial to the TH (**Fig. 1**).

*Type II* variant (1/40; 2.5%): In one specimen, the TH originated from the LH and fused with the MH. The PVs traversed between the TH and MH, indicating potential for neurovascular entrapment (**Fig. 2**).

*Type III* variant (1/40; 2.5%): In another case, the TH did not fuse with the LH but instead formed an independent tendon, which inserted directly into the CT. This independent configuration highlights a unique anatomical course with clinical implications for the posterior leg compartment (**Fig. 3**).

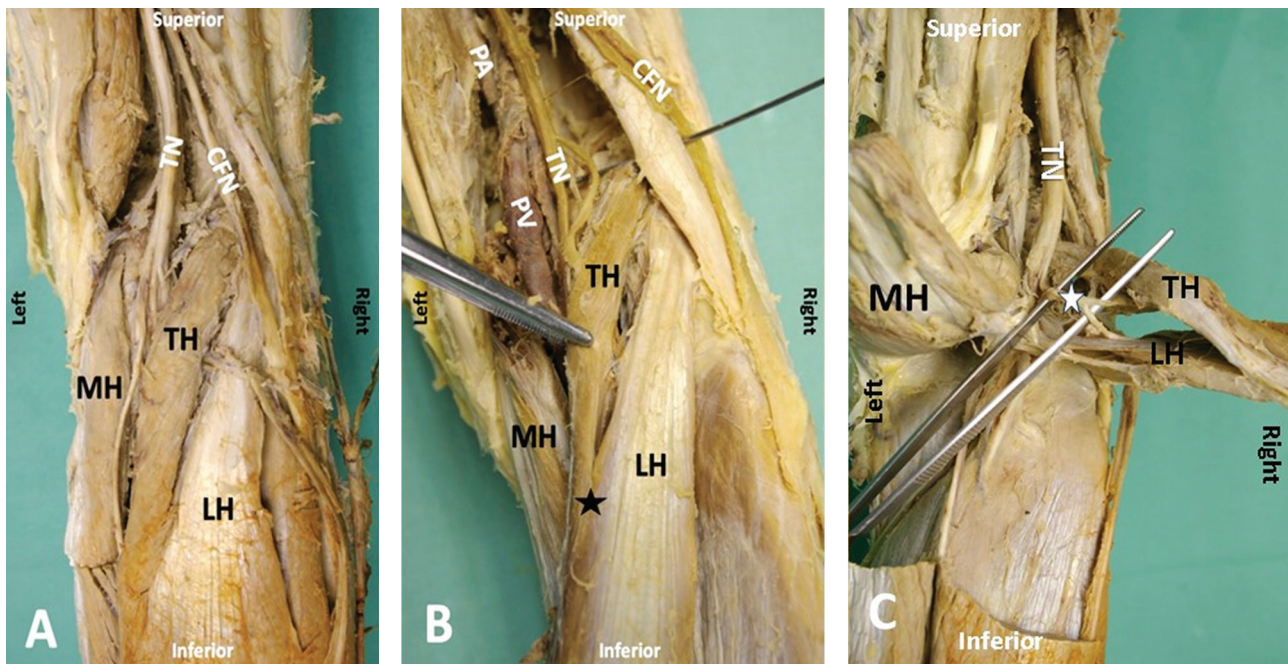
Overall, the majority of GTs fused with the gastrocnemius heads, while a minority demonstrated independent insertion into the CT.

## Discussion

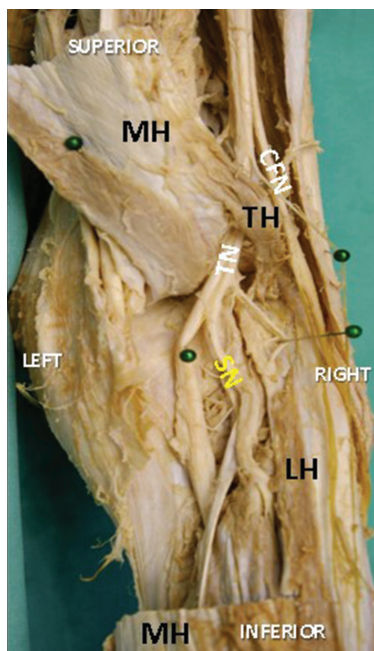
### Embryological perspective

The GM and SM originate from the lateral portion of the leg's flexor plate. The GM develops superficially, with its two partially separated heads identifiable by the 11-mm embryonic stage, positioned above the TN.<sup>[6]</sup> By the 14-mm stage, the GM connects to the calcaneal blastema. By 20 mm, the GM-SM complex extends over the TN, with the calcaneal tendon (CT) forming and the LH attaching above the lateral femoral condyle. The MH completes its development later in the second developmental month, coinciding with the proliferation of the GM heads.<sup>[6]</sup>

Comparative anatomy highlights the developmental plasticity of this muscle group. In amphibians, reptiles, and lower mammals, the MH and LH remain distinct; however, in humans, both derive embryologically from the fibular aspect of the leg.<sup>[7,8]</sup> Variations, such as the GT, may thus represent a developmental remnant arising from the incomplete differentiation of the GM-SM plate.



**Figure 1.** Dissection of the popliteal fossa showing morphological variants of the gastrocnemius tertius (GT, third head, TH) and its relation to the popliteal neurovascular structures. (A) *Right lower limb*: The TH arises from the posterior femoral surface, medial to the lateral head (LH), and fuses with it. The medial head (MH) is shown for reference. The tibial nerve (TN) and common fibular nerve (CFN) course superficially in the popliteal fossa. The sural nerve is the thin neural filament between the MH and the TH; (B) *Right lower limb*: The TH arises from the LH and fuses with the MH. The popliteal vessels (PV: popliteal vein; PA: popliteal artery) are interposed between the TH and MH. A star indicates the plane of fusion; (C) *Right lower limb*: The TH arises from the posterior femoral surface and forms a distinct tendon joining the calcaneal tendon, without fusing with either GM head. The TN lies adjacent. A white star highlights the tendon's contribution to the calcaneal tendon. Abbreviations: TH: third head (gastrocnemius tertius); LH: lateral head of gastrocnemius; MH: medial head of gastrocnemius; TN: tibial nerve; CFN: common fibular nerve; PA: popliteal artery; PV: popliteal vein.



**Figure 2.** Dissection of the right popliteal fossa showing the third head of the gastrocnemius (TH). The TH arises from the lateral head (LH) and fuses with the medial head (MH). The popliteal neurovascular structures pass between the TH and MH. The tibial nerve (TN), common fibular nerve (CFN), and sural nerve (SN) are identified.

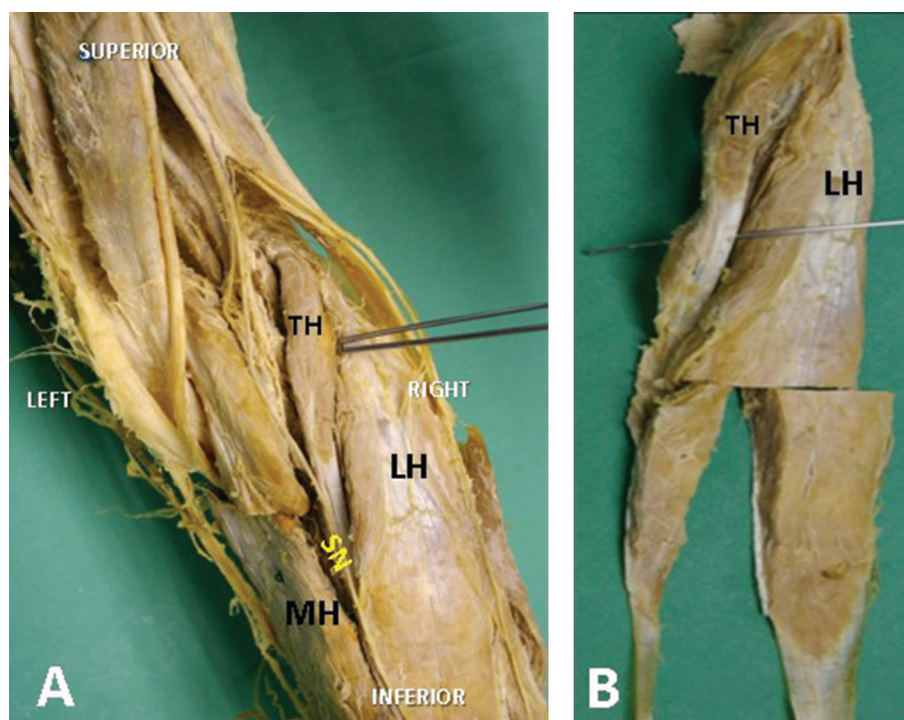
## Prevalence in different populations

In the present Greek cadaveric series, the GT was identified in 15% of lower limbs (6/40), representing the highest prevalence reported to date. Previous studies have documented GT in 2–13.3% of cases<sup>[9,10]</sup>, suggesting notable inter-population variability. Ashaolu et al.<sup>[9]</sup> reported a prevalence of 13.3% in Nigerian cadavers, whereas Argentinian dissections revealed a frequency of 7.5%.<sup>[10]</sup> Among European populations, German series documented substantially lower rates, ranging from 2.9% to 3.4%.<sup>[5]</sup> Radiological investigations have similarly demonstrated the relative rarity of this variation. Koplak et al.<sup>[8]</sup> identified GT in only 2% of 1,039 magnetic resonance imaging (MRI) scans. Bilateral GT has been described only sporadically.<sup>[11–13]</sup> Tsakotos et al.<sup>[13]</sup> reported a bilateral GT, with the tendon of the TH attaching to the LH, coexisting with a unilateral two-headed PM.

The comparatively high prevalence observed in the current Greek sample may reflect both methodological factors – specifically, the use of cadaveric dissection versus imaging techniques – and genuine population-based anatomical variation.

## Morphological variability

Three distinct morphological types of GT were identified in the present series:



**Figure 3.** Dissection of the right lower limb demonstrating a third head of the gastrocnemius (TH) contributing to the calcaneal tendon. (A) The TH originates from the posterior femoral surface, medial to the lateral head (LH). Unlike the other cases, the TH does not fuse with the GM heads but forms a distinct tendon. The medial head (MH) is also visible; (B) Isolated specimen of LH and TH, showing their parallel course before the TH tendon joins the calcaneal tendon. Abbreviations: TH: third head (gastrocnemius tertius); LH: lateral head of gastrocnemius; MH: medial head of gastrocnemius, SN: sural nerve.

1. GT arising from the posterior femoral surface and fusing with the LH (10%).
2. GT originating from LH and fusing with MH (2.5%).
3. GT arising from the posterior femoral surface and inserting into the CT via a distinct tendon (2.5%).

The most frequent configuration observed in this series – fusion with the LH (66.7%) – corresponds with the findings of Koplak et al.<sup>[8]</sup> In contrast, Bergman et al.<sup>[14]</sup> reported that fusion with the MH is more common. Frey<sup>[5]</sup> established the first detailed classification system, describing twelve morphological variants of GT based on its origin, insertion, and relationship with the TN and PNVS.

Notably, one specimen in the present study displayed a lateral trajectory to the PNVS before inserting into the MH, a configuration associated with a high risk of neurovascular compression.<sup>[15]</sup> No sexual dimorphism was detected in the current series, consistent with previous reports in the literature.<sup>[9-14]</sup>

### Contribution to the calcaneal tendon (CT)

The CT demonstrates variable contributions from the GM and SM fibers. Szaro et al.<sup>[16]</sup> reported that in 90% of specimens, the posterior layer of the CT was predominantly composed of GM fibers. In comparison, the anterior layer was LH-dominant in 57.5% of cases. Cummins et al.<sup>[17]</sup> classified CT morphology into three distinct types based on

the proportional contributions of GM and SM fibers. In the present series, only one GT contributed to CT formation, attaching via a separate tendon—a rare but clinically meaningful variant. This independent contribution underscores the anatomical diversity of the posterior leg compartment and its potential relevance in surgical and imaging contexts.

### Clinical implications

Variants of the GT have been associated with entrapment of the PNVS. Neural compression may involve:

- **TN and sciatic nerve**, leading to neuropathy and GM atrophy.<sup>[8]</sup>
- **Sural nerve (SN)**, resulting in sensory loss over the lateral aspect of the leg and ankle, and, in some cases, motor deficits due to mixed fiber involvement.
- **Common Peroneal Nerve (CPN)**, which may occasionally produce peroneal neuropathy.

Vascular compression may affect:

- **Popliteal vein (PV)**, resulting in true or pseudo-thrombophlebitis.
- **Popliteal artery (PA)**, causing intermittent ischemia and claudication.<sup>[15,18]</sup>

The severity of symptoms typically correlates with the size and course of the GT head.<sup>[19]</sup> Diagnostic evaluation should include a thorough clinical examination supplemented by imaging modalities such as ultrasonography<sup>[20]</sup>, magnetic resonance imaging, and, in selected cases, elec-

tromyography. These tools aid in differentiating GT-related entrapment syndromes from other causes of posterior leg pain and vascular compromise.

## Strengths and limitations

### Strengths

This study offers valuable anatomical insights into the morphological variability of the GT within a Greek population, representing one of the few cadaveric investigations on this topic in Southeastern Europe. The systematic dissection of forty formalin-embalmed lower limbs allowed precise morphological characterization and reliable documentation of the GT's relationship to the PNVS. In addition, the detailed classification of GT variants, supported by photographic documentation, enhances the clinical and educational relevance of the findings. The study also integrates embryological, comparative, and population-based perspectives, offering a comprehensive understanding of GT morphology and its potential clinical implications.

### Limitations

The present study is limited by its relatively small sample size, which restricts the evaluation of less common GT variants. The use of unpaired limbs precluded assessment of bilateral occurrence. Furthermore, the absence of clinical data prevented correlation of GT morphology with potential symptoms or associated comorbidities.

### Conclusions

This cadaveric dissection series identified the GT in 15% of Greek specimens, representing the highest prevalence reported to date. Three distinct morphological configurations were observed: fusion with the LH, fusion with the MH, and independent insertion into the CT. In most cases, the tertius head fused with the LH; however, one specimen demonstrated a lateral trajectory associated with potential compression of the PNVS. Clinically, recognition of GT variants is essential, as they may contribute to neurovascular entrapment syndromes within the popliteal fossa. A thorough understanding of GT morphology, supported by targeted imaging, facilitates accurate diagnosis, prevents misinterpretation during radiological or surgical procedures, and aids in comprehensive preoperative planning.

### Ethical considerations

The research was conducted ethically following the Code of Ethics of the World Medical Association (Declaration of Helsinki). The corpses belonged to the Anatomy and Sur-

gical Anatomy Department (Aristotle University of Thessaloniki) through the Body Donation Program.

### Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that they obtained a written informed consent from the donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalized human and animal cell lines were used in the present study.

### Conflict of interest

The authors have declared that no competing interests exist.

### Funding

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### Use of AI

No use of AI was reported.

### Data availability

All data used are referenced or included in the article.

### Author contributions

Conceptualization: KN, JK, and MP; data collection: KN, GK, GTr, and TT; data analysis: GTs, AS, TT, and DC; writing—original draft: GTr and MP; writing—review: KN, GK, GTs, TT, and DC; supervision: MP; Approval: All authors.

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