ORIGINAL ARTICLE

Cadaveric variation in the morphology of the gastrocnemius muscle in a Nigerian population

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Abstract

Background: The morphology of the gastrocnemius is typically described as bipennate, with its robustness being a key feature of human locomotion. *Aim and Objectives:* Although a three-headed variant of the gastrocnemius has been frequently reported, there is limited information on the morphological variability of this muscle in the Nigerian population. *Material and Methods:* Variations in the heads of origin of the gastrocnemius muscle were examined in 31 lower limbs during routine dissection of the popliteal fossa at the anatomical museum of Delta State University. *Results:* The most common finding was two heads of origin, present in 80.6% of cases, while 12.9% exhibited a gastrocnemius tertius, and 6.5% had four heads. The plantaris muscle was present in 93.5% of the cadavers, with an absence rate of 6.5%. *Conclusion:* Awareness of a multi-headed gastrocnemius muscle is crucial when performing myocutaneous flaps around the knee or during limb-sparing surgeries.

Keywords: Cadaver, Morphology, Bipennate, Gastrocnemius, Variation

Introduction

The conspicuous 'belly' of the calf originates from the gastrocnemius muscle, which has two components termed the caput mediale and caput laterale [1]. The medial head, being the bigger of the two, arises from a robust tendon [2]. It begins in the hollow found at the upper and back section of the medial condyle, just behind the adductor tubercle, a raised area on the femoral popliteal surface above the medial condyle, as well as the underlying areas of the articular capsule and the front surface of the aponeurosis that covers the head [2]. The lateral head originates from an indentation on the upper and posterior aspect of the lateral surface of the lateral femoral condyle, the lower portion of the lateral supracondylar line of the femur, and the anterior surface of the aponeurosis covering the head [3]. Williams *et al*. suggest that the gastrocnemius originates from two heads, as previously described by various researchers, with each head attaching independently to the femoral condyles through robust tendons [4]. The structure of the gastrocnemius plays a crucial role in comprehending the evolution of bipedalism and is vital for surgical as well as radiological evaluations of the popliteal area.[5]. Variations in anatomical structures are common [6-9], and they are often encountered during routine cadaver dissections. While many variations are benign, some result from developmental abnormalities or the persistence of embryonic conditions [10]. These variations can occasionally affect the muscular, vascular, nervous, skeletal, or organ systems [11]. One of the most frequently reported variations in gastrocnemius anatomy is the presence of a third head of origin,

known as caput tertius [11-14]. Singh *et al*. [15] described a structural variant in which the medial and lateral heads of the gastrocnemius remained fleshy throughout their length and inserted directly into the calcaneus without forming the Achilles tendon. Another variation, in which an abnormal gastrocnemius muscle mass originated from the semimembranosus and biceps femoris muscles and inserted into the tendocalcaneus tendon, was reported by Somayaji *et al*. [16]. A study led by Ashaolu in 2014 on morphological variations of the gastrocnemius muscle reported occurrences of two-headed, three-headed, and four-headed gastrocnemius muscles [5].

Conducting research on cadavers is essential for advancing medical and scientific knowledge, as it provides critical insights into human anatomy, disease progression, and the effects of various medical treatments. This research is instrumental in improving surgical techniques, understanding human physiology, and enhancing educational training for future healthcare professionals. The motivation for this study surfaced from the critical need to address the declining trend in cadaveric research in Nigeria, a trend that has important implications for medical education, clinical practice, and the advancement of anatomical knowledge. The scarcity of cadaveric studies limits opportunities for hands-on learning, accurate anatomical understanding, and the development of new surgical techniques, ultimately impacting healthcare delivery. This decline can be attributed to several factors, one of which is the limited availability of cadaveric specimens in medical schools. It is estimated that around two-thirds of human bodies are used for educational purposes, while one-third are used for research [17].

The cadavers used by medical students and researchers are primarily to study the normal structure of the human body. However, unclaimed or donated bodies are often not suitable for the curriculum's objectives [18]. The Anatomy Act governs the use of deceased bodies for medical purposes, ensuring the supply of unclaimed bodies to hospitals and educational institutions for anatomical examination and dissection [19]. Unclaimed bodies refer to those of individuals who die in hospitals or nursing homes and are not claimed by relatives, or those of homeless or indigent people found on the streets [20]. Despite their availability in government mortuaries, unclaimed bodies are rarely used for anatomical study today, as they are often deemed unsuitable [18]. Factors that may make an unclaimed body unsuitable include postmortem examination, infectious diseases, organ damage from chronic illnesses, and improper storage or preservation after death [18]. Enes Kara highlighted that cultural and religious factors are key contributors to the decrease in body donations for anatomical studies in Africa, Asia, and the Middle East [21]. Anatomy teaching and research primarily rely on cadaver dissection. This research seeks to explore and reinstate the value of cadaveric studies as a foundational aspect of medical training and scientific inquiry. Furthermore, the necessity of this research emerged from the scarcity of literature on the identification of the four-headed gastrocnemius muscle.

Material and Methods

The study was evidence based, comprising of 15 male cadaveric embalmed [2], specimens (30 lower extremities) and that of one lower limb of unknown gender. It was conducted at the Anatomy Museum, Delta State University, Abraka. The limited number

of cadavers was due to shortages in the region where the study was conducted. Although the exact ages of the cadavers were not retrievable, they were presumed to be adults. Dissection steps of the dorsal compartment of the leg was done with the aid of a Cunningham's manual for anatomical dissection [22]. An incision was made starting from the middle of the back of the thigh, on the dorsal side of the popliteal area, and extending to the posterior part of the calcaneus. The skin flaps that were covering the incised regions were then reflected anteriorly to allow for an appropriate dissection of the studied muscle [5]. The attached site of each head of the gastrocnemius were noted, highlighting variants in fiber orientation and the presence of thin intermuscular fascia separating them, extending to the muscle's deep surface. The proximal bellies of the gastrocnemius were also analyzed for the number and manner of attachment, with the results documented. The gastrocnemius was classified as having two, three, or four heads, and its bony insertions were noted. The plantaris muscle was also taken into consideration. Photographs were taken for permanent record-keeping. Statistical analysis was conducted using Statistical Package for the Social Sciences software version 21. Ethical clearance for this study was granted by the University Ethics Committee of the Faculty of Basic Medical Sciences, Delta State University, Abraka, in accordance with the guidelines set by the National Health Research Ethics Committee of Nigeria (DELSU/CHS/ANA/68/25).

Results

Every subject analyzed had the muscle being studied, although the pattern of orientation differed. There were no occurrences of a single-headed gastrocnemius. Of the gastrocnemius muscles studied, 80.6% had two heads, 12.9% had three heads, and 6.5% had four heads. Each gastrocnemius muscle was bilaterally symmetrical, externally lined by a thin layer of perimysium, and attached proximally to the corresponding femoral condyles. Among the cadavers, examined, 80.6% demonstrated dominance of the medial head while 19.4% displayed dominance of the lateral head (Table 1 & Figure 1).

Figure 2 illustrates a two-headed left gastrocnemius muscle (with medial and lateral heads labeled 1 and 2, respectively) dissected from the posterior leg compartment. Inspection and palpation revealed that the lateral head was larger and more robust than the medial head.

In three-headed gastrocnemius muscles, the heads were categorized as medial, lateral, in addition to middle (Figure 3). That of the middle is commonly known as the caput tertium or the third head of the gastrocnemius [5]. The middle head was the smallest and least bulky. The muscle fibers of the lateral heads extended further downward than those of the medial heads. All three heads remained separate for a variable distance before merging to form the Achilles tendon.

In four-headed gastrocnemius muscles, the heads were classified as medial, lateral, intermediomedial, and intermedio-lateral [5]. That of the lateral was the largest and most robust of the four and extended further downward than the other heads (Figure 4).

The plantaris muscle maintained its status as having the longest tendon in the human body, as confirmed in this study. The plantaris had a prevalence rate of 93.5% in the studied cadaver population, with an absence rate of 6.5%.

Table 1: Frequency of occurrence of various heads of gastrocnemius origin

Number of heads of origin	Frequency (Percentage)
0	0 (0%)
1	0 (0%)
2	25 (80.6%)
3	4 (12.9%)
4	2 (6.5%)
> 4	0 (0%)
Total	31 (100%)

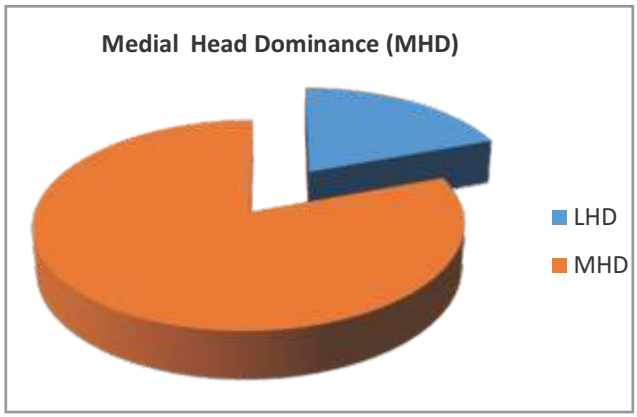

Figure 1: Symmetrical head dominance was observed, with Medial Head Dominance (MHD) present in 80.6% of cases and Lateral Head Dominance (LHD) in 19.4% of the examined cadaveric legs

Figure 2: Dissection of the posterior leg compartment showing a two-headed left gastrocnemius muscle (medial and lateral heads, numbered 1 and 2 respectively)

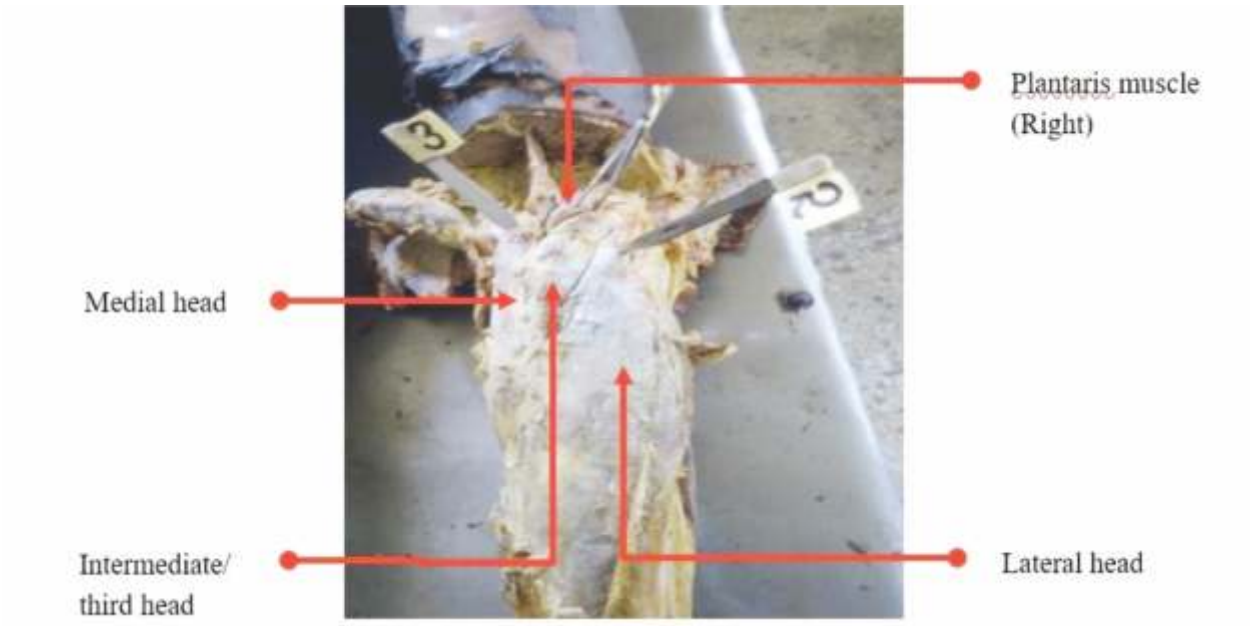

Figure 3: Dissection of the dorsal compartment of the right leg showing a three-headed gastrocnemius muscle

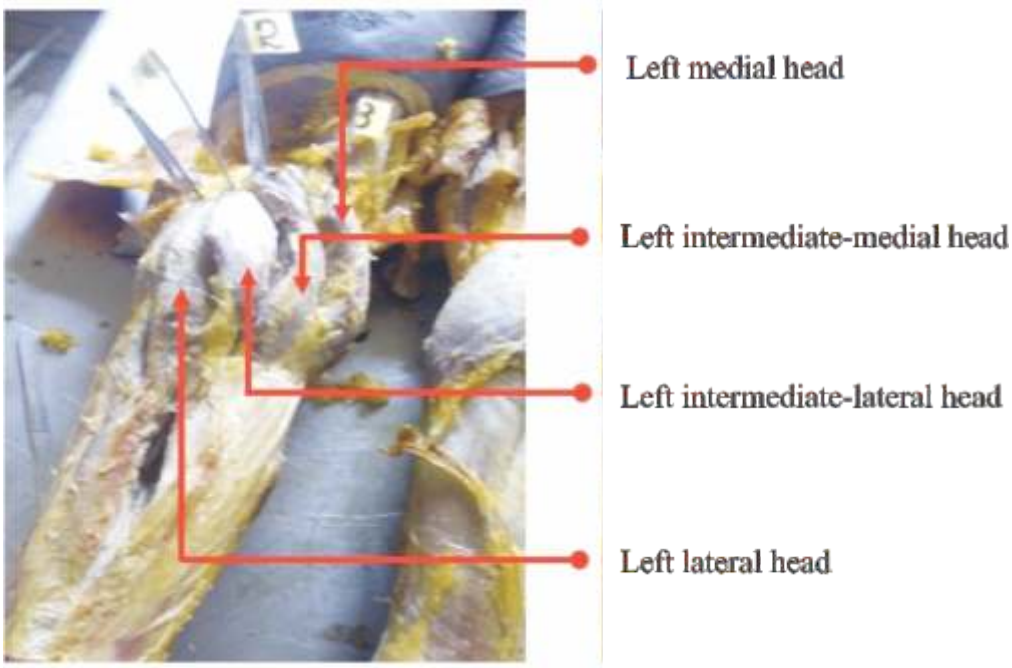

Figure 4: Dissection of the superficial posterior leg compartment showing a four-headed left gastrocnemuis muscle (medial, intermediate-medial, intermediate-lateral and lateral heads)

Discussion

The gastrocnemius muscle, during embryological development, originates from the calcaneum blastomere and ascends towards the lower femoral epiphysis before splitting into medial and lateral bellies. Variations in its migration and attachment during this process can lead to differences in the number of muscle bellies and attachment points [5]. It has earlier being noted that multi-headed gastrocnemius variants may be associated to its embryological origin [23].

Findings of this study align with that of global anatomical literature, confirming that the gastrocnemius is typically a bipennate, multi-headed muscle [5, 11-14, 16]. The two-headed variant, with its origins at the medial and lateral femoral condyles, was the most common. This result is consistent with previous reports by Williams *et al.* [4]. In a study of 40 cadaveric lower limbs, Arce *et al*. observed a 92.5% prevalence of the two-headed variant among Argentine cadavers [24]. Koplas *et al*. reported a 98.1% prevalence of the same variant in a U.S. sample, while Shalini *et al.* recorded 80% in the Indian population [25-26]. However, Ashaolu *et al*. found only 35% prevalence in their study [5].

The three-headed gastrocnemius, or caput tertium, is the most frequently observed variant according to several scholars [11, 13]. Bergman, using CT imaging, documented a prevalence rate of 2.9% to 5.5% for this variant [13]. Koplas *et al*. found a 1.9% prevalence among 1,039 CT-scanned knees in the United States, while Arce *et al*. and Shalini *et al*. noted prevalence rates of 7.5% in an Argentine population and 20% in an Indian population, respectively [25, 24, 26]. The present study observed a 12.9% prevalence of the three-headed gastrocnemius.

Ashaolu *et al*. found that the four-headed gastrocnemius was the most common variant in their study [5], with a prevalence of 51.7%, higher than the current study's 6.5%. Ashaolu *et al*. also reported a 90% coexisting occurrence of the plantaris muscle with multi-headed gastrocnemius variants [5], supporting his view, that the extra heads are not derived from the plantaris, which maintains its function and dominance.

In contrast, the current study found a 93.5% of the plantaris muscle and a 6.5% absence rate, closely reflecting Ashaolu *et al*.'s findings [5]. The additional gastrocnemius heads may be prone to injury during rapid dynamism [23]. It has been proposed that intermediate heads might play roles beyond propulsion, contributing to balance or proprioception at the knee joint due to dissimilarities in fiber orientation [23].

Despite these findings, the potential link between multi-headed gastrocnemius variants and popliteal vessel entrapment should not be overlooked. Anomalous muscle-artery relationships in the popliteal fossa can lead to arterial compression [28]. While, surgical removal of extra heads has proven effective in treating popliteal entrapment syndrome, care must be taken to avoid damaging neurovascular structures, as branches of the popliteal neurovascular complex often run between the gastrocnemius heads [5].

Conclusion

This descriptive study reinforces the presence of the caput tertius gastrocnemius and its four-headed morphological variants, with varying frequency rates. Understanding the existence of these anatomical variations should be a key consideration when planning medical or surgical treatments for conditions involving abnormal gastrocnemius anatomy, particularly in the popliteal region.

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