



A three-headed plantaris muscle with a bipartite insertion of its two accessory heads

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Abstract

The plantaris muscle consists of a small muscular and a long tendinous part and is located at the superficial compartment of the posterior leg. The purpose of the current cadaveric report is to describe a rare variant of the plantaris muscle. During a routine dissection, a three-headed plantaris with two accessory heads was identified with a variant insertion of the two accessory heads. All heads originated from the femur popliteal surface, independently the one from the other. The first head contributed to the long and thin calcaneal tendon, and the two accessory heads were mainly inserted via their musculoaponeurotic expansion into the medial femoral condyle. The plantaris muscle morphological variability has been extensively studied lately. The incidence of the two-headed muscle has been estimated at 1.6%, while the three-headed muscle corresponds to an even rarer variation. This is the third case reported in the English literature, while the insertion of the two accessory heads has never been described before.

Keywords Plantaris muscle · Variation · Accessory head · Dissection · Morphology

Introduction

The superficial muscle compartment of the posterior leg is composed of the gastrocnemius muscle (GM), the soleus muscle (SM), and the plantaris muscle (PM), which control the foot and ankle plantar flexion. The PM has the most insignificant influence (0.7% of plantar flexor power) (Silver et al. 1985). The PM seems to have a valuable contribution to hand tendon reconstruction and Achilles tendinopathy (Gonera et al. 2021). Typically, the PM has a short and slim belly with a long and thin tendon, which originates from the popliteal surface of the femur and the knee joint capsule, and inserts into the calcaneal tuberosity (Gonera et al. 2021). Both muscular and tendinous parts demonstrate

high morphological variability (Olewnik et al. 2018, 2020a). Rarer PM variants occasionally described were not included in the classifications (Olewnik et al. 2020b; Maślanka et al. 2023; Gonera et al. 2020; Zielinska et al. 2024).

The current cadaveric report describes a three-headed PM, with two accessory heads and an uncommon bipartite insertion of the accessory heads. The morphological variability, as well as possible clinical implications, is further discussed.

Case description

A bilateral lower limb dissection for education and research purposes under a pre-established protocol (Maślanka et al. 2023) was performed on an 84-year-old male cadaver, derived from a body donation at the Department of Anatomical Dissection and Donation of the Medical University of Lodz. Skin and subcutaneous fat from the popliteal fossa and posterior leg compartment were dissected to expose the related muscles and neurovascular bundle. The GM lateral and medial heads were carefully identified and then dissected, to expose the SM and PM. On the left limb, an uncommon three-headed PM variant with two accessory heads was identified. The three

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heads originated independently from the femur popliteal surface. The one head (typical) contributed to the PM's long and thin tendon and was typically inserted into the calcaneal tuberosity. The other two (accessory) heads with their short and thin tendon (per head) had a bipartite insertion into the PM's first head (lateral typical attachment) and the medial femoral condyle (MFC) via their musculoaponeurotic complex expansion (medial variant attachment) (Figs. 1, 2). The muscle received its innervating branches from the tibial nerve that was typically identified from the sciatic nerve; the nerves, as well as the vessels of the popliteal fossa were dissected to better depict the muscular variant. The contralateral PM was identified as typical. A morphometric analysis of the PM variant was also performed.

Morphometric measurements were obtained using an electric caliper (*Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan*) and are summarized in Table 1. The cadaver belonged to the Anatomical Dissection and Donation Department of the Medical University of Lodz. The authors hereby confirm that every effort was made to comply with all local and international ethical guidelines and laws concerning the use of cadaveric donors in anatomy education and research.

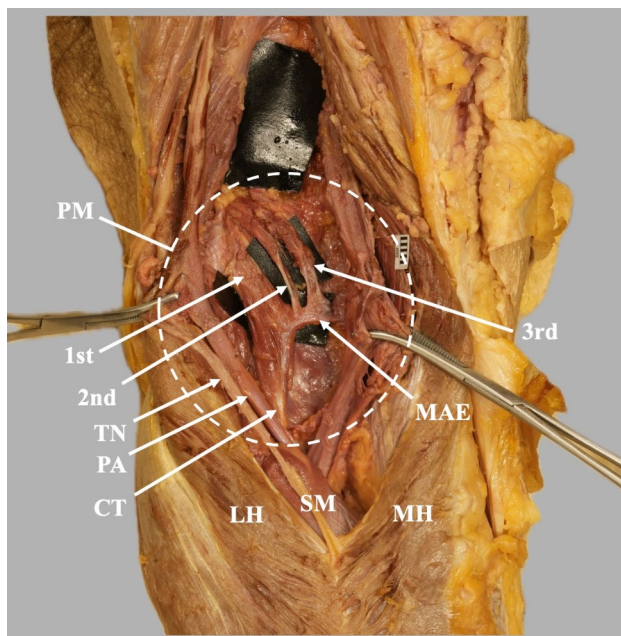


Fig. 1 The three-headed plantaris muscle (PM, dotted cycle area) with the 1st (typical) 2nd, and 3rd (accessory) heads. The 2nd and 3rd heads are inserted partially into the common tendon (CT) formed by all heads, and via their musculoaponeurotic expansion (MAE) to the medial femoral condyle. LH-lateral head of the gastrocnemius muscle, MH-medial head of the gastrocnemius muscle, SM- soleus muscle, TN- tibial nerve, PA- popliteal artery

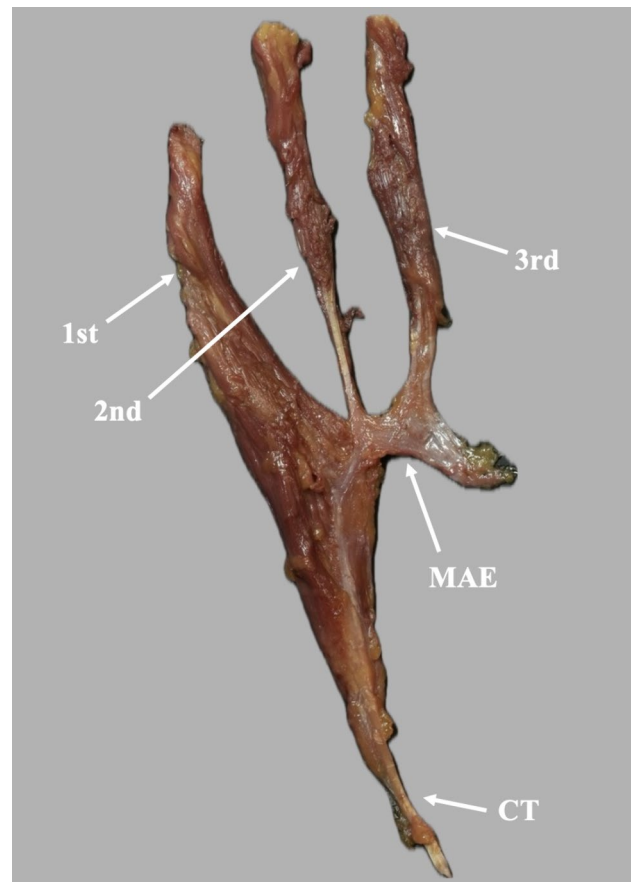


Fig. 2 The 1st, 2nd, and 3rd head of the plantaris muscle after their dissection. MAE- musculoaponeurotic expansion, CT- common tendon

Discussion

The current report describes an uncommon three-headed PM with two accessory heads and a bipartite insertion. In the current literature, only two case reports of a three-headed PM have been described, while the identified insertions were not similar to the present case.

From a developmental point of view, the three muscles of the superficial compartment of the posterior leg are derivatives of a common pre-muscular mass. The PM's anlage is located anteriorly to the SM and is partially covered by the GM. In a 12 mm embryo, the PM mass is not differentiated only from GM. Lastly, in a 17 mm embryo, the PM is differentiated from the GM, and differentiation alterations could lead to variant muscle formation, such as the two or even three-headed PM (Diogo et al. 2019). These interesting developmental relationships between PM and GM created a debate: should the PM be considered as a "GM tertius" (GM third head) or derivate of deep posterior crural muscles anlage? (Olewnik et al. 2020a).

Table 1 The three-headed plantaris muscle (PM) with two accessory heads (2nd and 3rd) morphometric measurements, expressed in mm

Morphometric parameters	Plantaris muscle (PM) morphology			
	1st head	2nd head	3rd head	Common tendon
Length (craniocaudal diameter)	74.24	55.65	50.46	236.62
Width (maximum laterolateral diameter)	7.40	3.70	2.66	–

This question still remains unclear, while the most recent studies (Diogo et al. 2019) proved that the PM derives from the GM lateral part and, theoretically, it can be considered “GM tertius”. Further embryological research will enhance our knowledge about the developmental of these muscles.

The PM muscular origin has been systematically investigated by Olewnik et al. (2020a), and classified into the following six different origin patterns:

- PM of type I corresponded to a typical origin from the lateral femoral condyle (LFC), the GM lateral head, and the knee joint capsule, in 48.4%.
- PM of type II corresponded to an origin from the knee joint capsule and the GM lateral head, identified in 25%.
- PM of type III is characterized by an origin from the LFC, and the knee joint capsule (10.15%).
- PM of type IV includes an origin from the LFC, the knee joint capsule, and the iliotibial band (6.25%).
- PM of type V includes an origin from the LFC (8.6%).
- PM of type VI (2 cases only, 1.6%) is composed of rare PM variants. One variant (0.8%) corresponded to a double PM (two muscular parts and two distinct tendons), and the other variant (0.8%) was characterized as “bifurcated PM” (two muscular parts that fused into a single tendon).

Hence, the three-headed PM identified in the current report was not observed in the PM systematic morphological study by Olewnik et al. (2020a). Based on this classification system, Waśniewska et al. (2022) studied the PM in human fetuses and concluded the lack of a bipartite PM, i.e., a duplicated PM (distinct double origins) or bifurcated PM (distinct double insertions). Hence, the duplicated or bifurcated PM corresponds to a rare variant, while the three-headed variant is even rarer. The imaging study by Herzog (2011) is a unique study referring to the accessory PM, based on a review of 1000 magnetic resonance imaging (MRI). The authors identified the PM accessory form in 6.3% (63 cases), reporting a prevalence higher than the cadaveric studies (1.6%). However, it is unclear if the PM muscular part, as well as PM variant forms can be easily visualized via imaging.

The existence of PM accessory heads, such as the one described in the present case, has been published before. Olewnik et al. (2020a) identified a “double PM” and a

“bifurcated PM” in 0.8% of their sample, per each form. During a forensic autopsy, Smędra et al. (2021) observed a PM with two muscular heads that fused to a common tendon, which corresponds to Olewnik et al. (2020a) “bifurcated PM”. Futa et al. (2023) observed another morphological variant similar to Smędra et al. (2021). Contrariwise, Kurtys et al. (2021) and Heo et al. (2021) identified during dissection an accessory PM that corresponded to the Olewnik et al. (2020a) “double PM”. The two rare cases observed by Olewnik et al. (2020a) have also been described as case reports by the aforementioned studies. Nevertheless, Tsakotos et al. (2024) identified the coexistence of two-headed PM with the bilateral appearance of GM accessory (third) head.

In the published data literature, only two reports described the occurrence of a three-headed PM (Olewnik et al. 2020b; Maślanka et al. 2023). Olewnik et al. (2020b) identified this rare variant in a female cadaver during dissection. The first head originated from the posterior femoral surface, the 2nd head from the LFC, and the GM lateral head, and the 3rd head originated exclusively from the GM lateral head. In this case, all head tendons created a common tendon (2020b). Maślanka et al. (2023) identified a slightly different three-headed PM that fused into a common tendon, with a 1st head originating from the LFC and fused with Kaplan fibers (another variant consisting of connections between the iliotibial band and the distal femur). The other two heads originated from the knee joint capsule and the LFC (Maślanka et al. 2023). The three-headed PM is a very uncommon variant (only two reports), while the identified bipartite insertion has not been reported. Olewnik et al. (2020b) and Maślanka et al. (2023) reports concerning the three-headed PM concluded a common tendon of the variant muscle, while in the current case, the two accessory heads had a bipartite insertion (lateral and medial attachments) via a short and distinct tendon into the calcaneal tendon and via a musculoaponeurotic expansion into the MFC. Thus, the present case report corresponds to the third case in the current English literature, while the presented insertion is different from the two previous case reports.

Zielinska et al. (2024) first reported the occurrence of a four-headed PM, a variant with four independent muscular heads that fuse into a common tendon.

Interestingly, in the current literature, there have been theories for a possible relationship between the PM and palmaris longus muscle (PLM). Some studies supported that the two muscles were homologous and equivalent

(Diogo and Molnar 2014); however, other studies cited in Gonera et al. (2021) review, pointed out many differences between them. Diogo and Molnar's (2014) theory could be disputed from the embryological background of the muscles. The upper limb muscle development precedes the lower limb muscles; specifically, the PM is fully developed and differentiated in a 14 mm embryo length, while the PM is not fully differentiated until a 17 mm embryo length (Diogo et al. 2019). Therefore, Diogo et al. (2019) highlighted that these two structures appear in different ontogenetic order and are derived from different primordia. Further studies investigating the embryology, comparative anatomy, function, and possible relationship with the PLM are adequate to extend our knowledge of this enigmatic muscle.

Presence of accessory heads, such as the three-headed PM, could lead to neurovascular compression. In the current case, accessory heads of PM could cause compression of the tibial nerve and sciatica-like symptoms (Zielinska et al. 2024) or popliteal artery entrapment (Olewnik et al. 2020a). Accessory heads of muscles could decrease the available space in the popliteal fossa and lead to vascular or nerve compression (Tsakotos et al. 2024). The PM clinical significance mainly corresponds to its tendon, and it has been proven that be involved in the mid-portion Achilles tendinopathy (Gonera et al. 2021). Different morphological types of this tendon can exist, and Gonera et al. (2021) have proposed a classification system with 10 types, while they highlighted that some types are more prevalent to cause Achilles tendinopathy (Gonera et al. 2021). Except for pathologic conditions, the PM tendon is a very good candidate for potential donor graft due to its unique morphology (long and thin tendon). The following clinical situations concerning this tendon could potentially help surgeons, such as the replacement of the lateral ankle ligaments, hand tendon reconstruction, and reinforcement of ruptured Achilles tendon (Kurtys et al. 2020; Gonera et al. 2021).

Conclusion

The current report described a rare variant of a three-headed PM with two accessory heads having a bipartite insertion, into the calcaneal tuberosity and the MFC through their musculoaponeurotic expansion. Clinicians, especially orthopedics, should be aware of PM variants due to their involvement in Achilles tendinopathy.

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Authors' contribution George Triantafyllou – student – project development, data collection and management, data analysis and manuscript writing. Nicol Zielinska – student – data collection, data analysis, and manuscript editing. Maria Piagkou (DDS, MD, PhD, MSc) – professor – data analysis and manuscript editing. Krzysztof Koptas – student – data collection and manuscript editing. Łukasz Olewnik (D.P.T., PhD) – assistant professor – supervision, data analysis and manuscript editing. All authors have read and approved the manuscript.

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Data availability For data request, please contact the corresponding author (George Triantafyllou-email:georgerose406@gmail.com).

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethical approval and consent to participate The cadaver belonged to the Department of Anatomical Dissection and Donation, Medical University of Lodz.

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