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CASE REPORT

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A three-headed plantaris muscle fused with Kaplan fibres: potential clinical significance

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The plantaris is a short, small muscle that usually originates at the popliteal surface of the femur and has a long, thin tendon that typically inserts into the calcaneal tuberosity. Its role and degree of development have been objects of debate for years. Some authors consider it a vestigial muscle while others believe it is a process of its development. The clinical significance of plantaris muscle is usually related to its morphological variation, which is common and well described in the literature. These variations are often a risk factor for many ailments and disorders. We would like to present another, very rare case of three-headed plantaris muscle (fused with distal Kaplan fibres), and consider what clinical implications it may have. (Folia Morphol 2024; 83, 2: 466–471)

Keywords: plantaris muscle, rudimentary muscle, development muscle, Kaplan fibres, knee stability, three headed plantaris

INTRODUCTION

The plantaris muscle (PM) is usually characterized by a short spindle-shaped muscle belly and a long, thin tendon that runs posteriorly to the popliteal muscle, between the soleus (SM) and gastrocnemius muscle (GM) [18, 20]. Typically, the PM arises proximal or distal to the lateral head of GM at the lateral condyle of the femur and at the knee joint capsule [18, 20, 22]. Its short, lean muscle belly merges in the lower region of the popliteal fossa into a long tendon that crosses obliquely medially and extends distally between GM and SM, where it attaches to the medial border of the Achilles tendon in the lower third of the lower leg and radiates with it into the bone of the calcaneal tuberosity [5, 16, 22].

The proximal and distal attachments of plantaris muscle show high variability [16, 18]. It is a muscle that is not always present [25]. Some authors suggest that bilateral loss of PM is more common than unilateral [12, 16]. In addition to its absence, there are also cases of doubled muscle and muscle with multiple bellies [12, 19, 21]. In the available literature, we can find reports about PM originating at the ligamentum posticum, or with accessory bundles at the femur, fibula, at the collateral fibular ligament, or the knee joint capsule, or even flexor hallucis longus [7, 10, 22, 31].

The PM is practically negligible for the functions of the knee and ankle joints due to its small physiological cross-section [26]. Its importance lies rather in its action on the anterior tibial vessels, to which adventitia the fascia of the muscle is connected via the connective tissue of the popliteal fossa [22]. During flexion in the knee joint, the PM prevents kinking and

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Table 1. Morphometric measurements of the three-headed plantaris muscle

	First belly [mm]	Second belly [mm]	Third bell [mm]	Myotendinous junction (MJ) [mm]
Width in origin point / MJ	13.47	10.85	6.4	4.58
Thickness in origin point / MJ	1.77	1.18	1.58	1.25
Length of the belly / MJ	73.8	49.38	40.43	–

compression of the vessels by its contraction. Because of this, its functional significance is minimal, and its long tendon can readily be harvested for reconstruction with minimal function deficit [23, 25, 27].

This case report describes a very rare variant of plantaris muscle. The PM had three bellies with different proximal attachments. The first belly was inserted into the distal Kaplan fibres, the other two bellies (second and third) were attached to the lateral head of GM.

CASE REPORT

An 82-year-old body donor (height 182 cm) was subjected to anatomical dissection for teaching and research purposes at the Department of Anatomical Dissection and Donation, Medical University of Lodz, Poland. Traditional dissection was carried out on the right lower limb, using techniques according to a strictly specified protocol [15].

We started the dissection by removing the skin from the popliteal and shin area up to the gastrocnemius muscle. The lateral and medial heads of the GM were carefully separated, afterwards, the medial head was gradually removed, while the lateral head was cut at the myotendinous junction point and deflected. These procedures made it possible to expose and carefully clean the PM. We discovered a hitherto undescribed, unique origin variant of the three-headed plantaris muscle. The first belly of the PM was fused at its origin point with the distal Kaplan fibres and additionally, some of its fibres attached to the lateral femoral condyle. The other two bellies were attached to the lateral femoral condyle and the knee joint capsule by numerous thin muscle fibres.

After careful dissection, the next stage of the procedure involved detailed morphometric measurements and photographic documentation. Measurements were taken twice to the nearest 0.1 mm using an electric caliper (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan) and summarized in Table 1.

DISCUSSION

There are numerous functional theories due to inconstancy, peculiar location, and variability. The first studies, which appeared two centuries ago, suggested that PM is a vestigial muscle and plays a small role in gait biomechanics [6]. The evolution towards a bipedal posture has resulted in a migration of its distal attachment from plantar aponeurosis towards the calcaneus [7]. An unquestionable argument for the fact that it is a rudimentary muscle is certainly its unstable occurrence in the population. Recent studies have reported that its incidence ranges between 90.1% and 100% [16, 17, 20, 27], with two researchers reporting absence of PM [1, 27]. Waśniewska et al. [29] in their study conducted on human fetuses described an incidence of 78.26%.

In the available literature, we can find reports about PM originating at the fibula or with accessory bundles at the femur, at the collateral fibular ligament, or from the knee joint capsule [22]. The presence of additional heads is often associated with a non-standard origin such as fascia of popliteus, ligamentum posticum, fibula or even flexor hallucis longus [7, 10, 30]. Of course, this is not the only case of multi-headed PM in literature. The three-headed plantaris muscle was already described by Olewnik et al. [19]. Interestingly, PM with the bicipital origin which attached to the lateral condyle of the femur and lateral supracondylar line without any fibres to GM, was described by Upasna and Kumar [28]. There are also cases of double PM, unilateral as well as bilateral [12, 21].

As we mentioned above, the three-headed PM was already described [19]. In this case [19], the highest head originated on the medial side of the lateral femoral condyle and posterior femoral surface, while in our case, the first head originated on the lateral femoral condyle and distal Kaplan fibres. The second head – successively from the lateral head of the GM and lateral femoral condyle, and in the case described by us — from the lateral head of the GM — Figure 1. However, the third head in both cases had its origin in the lateral head of the GM. The difference was also that our case had one common tendon for all heads, while the PM common tendon in the case described by Olewnik et al. [19] was formed

Figure 1. A rare case of the three-headed plantaris. 1 — first head of the plantaris muscle; 2 — second head of the plantaris muscle; 3 — third head of the plantaris muscle; lhGM — lateral head of the gastrocnemius muscle; mhGM — medial head of the gastrocnemius muscle; CT — common tendon; KP — distal Kaplan fibres.

Table 2. The comparison of the three-headed plantaris muscle described so far

	FH length	SH length	TH length	Common tendon	FH point of insertion	SH point of insertion	TH point of insertion
Our case report	73.8	49.39	40.43	320.55	DKF and PFS	LFC and LHGM	LHGM
The case described by Olewnik et al. [20]	39.1	58.72	53.32	311.23	DKF and LFC	LHGM	LHGM

FH — first head; SH — second head; TH — third head; DKF — distal Kaplan fibres; LFC — lateral femoral condyle; LHGM — lateral head of gastrocnemius muscle; PFS — posterior femoral surface

by two tendons — a common tendon for the first and second heads and a separate one for the third head. Table 2 shows a comparison of their measurements and origin points.

Both cases potentially could increase the risk of neurovascular entrapment due to the greater number of potential places of confinement between the additional heads, especially considering the first head we described extends across the entire posterolateral area of the knee. However, we could also speculate on the opposite mechanism, that the heads were formed to relieve the neurovascular bundle in several places by contraction.

According to the latest classification for PM origin proposed by Olewnik et al. [16] (Table 3), our case seems to fit perfectly into Type VI, which includes the farthest types of plantaris muscle origin. The course of the tendon was a classic one, classified as Type A [17]. The distal attachment was characterized by insertion at the calcaneal bone and constituted Type III in the classification proposed by Olewnik et al. [17].

Table 3. The classification of the origin points of PM proposed by Olewnik et al. [17]

	The points of the origin
Type IA	The lateral head of GM, lateral femoral condyle, and the knee joint capsule
Type IB	Lateral head of the GM, lateral femoral condyle, knee joint capsule, the popliteal surface of the femur
Type II	Lateral femoral condyle, lateral head of GM
Type III	Lateral femoral condyle, knee joint capsule
Type IV	Lateral femoral condyle, knee joint capsule, iliotibial band
Type V	Lateral condyle of the femur
Type VI	Rare cases (not classified)

However, the most important aspect of this case is its fusion with distal Kaplan fibres (DKF) — Figure 2. Kaplan fibres connect the iliotibial band with the distal part of the femur and was divided into two distinct structures — proximal (PKF) and distal Kaplan fibres

Figure 2. A rare case of the three-headed plantaris. 1 — first head of the plantaris muscle; 2 — second head of the plantaris muscle; 3 — third head of the plantaris muscle; KP — distal Kaplan fibres; mhGM — medial head of the gastrocnemius muscle.

[24]. The iliotibial tract cooperates with associated muscles in adduction, extending and laterally rotating the hip, and bracing and stabilization of the knee in the upright position [8]. The function of the Kaplan fibres is not precisely understood; they are thought to play a significant role in the control of knee stability (anterolateral and rotatory stability) through proprioception and mechanical stabilization [9, 13]. Authors believe that DKP rupture can contribute to anterolateral rotatory instability [4, 11]. It is speculated that their function can also to support the ACL [9, 11, 13].

We speculate that this anatomical variant may be the cause of proprioceptive dysfunction of the DFKs due to their possible tightening during PM contraction or extension (maximum knee extension and ankle pronation) and thus may contribute to anterolateral and rotational instability in the knee. This could be more relevant for patients with a torn ACL ligament, and could also be potentially associated with a worse prognosis for patients after ACL reconstruction.

Furthermore, we conjecture that this type of PM may disrupt DKF imaging, and the possibility of such a fusion should be considered during the medical imaging related to DKF. DKFs and PKFs are most often evaluated during the diagnosis of ACL rupture [3], and may be visualized on routine MRI of the knee [2, 14]. Batty et al. found in their study that imaging in the sagittal plane had the highest rate of identification of the Kaplan fibres [2]. They also described that there is a consistent relationship between DKFs and the lateral gastrocnemius tendon, lateral joint line, and superior lateral geniculate artery in MRI images [2]. We speculate that this variation of PM can also make it difficult to recognize DKF during the examination (like the structures mentioned above) and we should remember about this variant during this procedure. Clinicians planning surgery on the lateral knee complex should also be mindful of the possibility of its occurrence because it can make the procedure more difficult to perform. This case shows that anatomical parameters are characterized by high variability; therefore, it is impossible to develop standard recommendations for surgical procedures without prior imaging diagnostics.

CONCLUSIONS

Although its variability is well described in the literature, more variants of PM are still being reported. Variations in the musculoskeletal system may be clinically relevant; it is important to know the anatomical variants that we may encounter in everyday clinical practice. Moreover, they can pose quite a challenge for clinicians, especially during diagnosis.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

The cadavers belonged to the Department of Anatomical Dissection and Donation, Medical University of Lodz.

Authors contributions

Krystian Maślanka (student): project development, data collection and management, data analysis and manuscript writing; Nicol Zielinska (student): data collection, data analysis and manuscript editing; Friedrich Paulsen (MD, PhD, Professor): data collection, data analysis and manuscript editing; Małgorzata Niemiec: data analysis and manuscript editing; Łukasz

Olewnik (MD, PhD, Professor): data analysis and manuscript editing. All authors have read and approved the manuscript.

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