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

Authors: Krystian Maślanka, Nicol Zielinska, Friedrich Paulsen, Małgorzata Niemiec, Łukasz Olewnik

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

Krystian Maślanka et al., Plantaris muscle

Krystian Maślanka¹, Nicol Zielińska¹, Friedrich Paulsen², Małgorzata Niemiec³, Łukasz Olewnik¹

¹Department of Anatomical Dissection and Donation, Medical University of Lodz, Poland
²Institute of Functional and Clinical Anatomy, Friedrich Alexander University Erlangen-Nürnberg, Erlangen, Germany
³Medical University of Silesia, Poland

Address for correspondence: Łukasz Olewnik, MD, PhD, Department of Anatomical Dissection and Donation, Chair of Anatomy and Histology, Medical University of Lodz, ul. Żeligowskiego 7/9, 90–410 Łódź, Poland, e-mail: lukasz.olewnik@umed.lodz.pl

ABSTRACT

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 fibers), and consider what clinical implications it may have.

Keywords: plantaris muscle, rudimentary muscle, development muscle, Kaplan fibers, 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) [19, 21]. 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 [19, 21, 23]. 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, 17, 23].

The proximal and distal attachments of plantaris muscle show high variability [17, 19]. It is a muscle that is not always present [26]. Some authors suggest that bilateral loss of PM is more common than unilateral [13, 17]. In addition to its absence, there are also cases of doubled muscle and muscle with multiple bellies [13, 20, 22]. 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 [8, 11, 23, 32].

The PM is practically negligible for the functions of the knee and ankle joints due to its small physiological cross-section [27]. Its importance lies rather in its action on the anterior tibial vessels, to which adventititia the fascia of the muscle is connected via the connective tissue of the popliteal fossa [23]. During flexion in the knee joint, the PM prevents kinking and 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 [24, 26, 28].

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 fibers, the other two bellies (second and third) were attached to the lateral head of GM.

CASE REPORT

A 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 [16].

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 PM was fused at its origin point with the
distal Kaplan fibers and additionally, some of its fibers attach 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 fibers.

After careful dissection, the next stage of the procedure involved detailed morphometric measurements and photographic documentation. Their measurements were taken twice with up to 0.1 mm accuracy 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 this rudimentary muscle, is certainly its unstable occurrence in the population. Recent studies report that its incidence is ranges between 90.1% and 100% [17, 18, 21, 28], with two researchers reporting no absence of PM [1, 28]. Waśniewska et al. [30] in their study conducted on human fetuses describe 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 [23]. 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 [8, 11, 31]. 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. [20]. Interestingly one, PM with the bicipital origin which attaches to the lateral condyle of the femur and lateral supracondylar line without any fibers to GM, was described by Upasna and Kumar [29]. There are also cases of double PM, unilateral as well as bilateral [13, 22].

As we mentioned above, the three-headed PM was already described [20]. In this case [20], the highest head originated on the medial side of the lateral femoral condyle and posterior femoral surface, while the first head in our case originated on the lateral femoral condyle and distal Kaplan fibers. The second head – successively from the lateral head of the GM and lateral femoral condyle, and in the described by us – from the lateral head of the GM. 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. [20] was formed 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 point.

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 in the opposite, that the heads were formed to relieve the neurovascular bundle in several places by contraction.

According to the latest proposed classification for PM origin proposed by Olewnik et al. [17] (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 [18]. The distal attachment was characterized by insertion at the calcaneal bone and constituted Type III in the classification proposed by Olewnik et al. [18]

However, the most important aspect of this case is its fusion with distal Kaplan fibers (DKF). Kaplan fibers connect the iliotibial band with the distal part of the femur and was divided into two distinct structures – proximal (PKF) and distal Kaplan fibers (DKF) [25]. 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 [9]. The function of the Kaplan fibers 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 [10, 14]. Authors believe that DKP rupture can be contribute to anterolateral rotatory instability [4, 12]. It is speculated that their function can be also to support the ACL [10, 12, 14].

We speculate that combination in this case may be the reason for the disruption of the proprioceptive function of the DFK due to the possible tensioning of them during PM contraction or stretch (maximum extension of the knee and ankle joint pronation) and in this way may contribute to the anterolateral and rotatory 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, 15]. Batty et al. states in his study that imaging in the sagittal plane had the highest rate of identification of the Kaplan fibers [2]. He 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. Among other, 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.

DECLARATIONS

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

Consent to publish: Not applicable

Availability of data and materials: Please contact authors for data requests (Łukasz Olewnik PhD - email address: lukasz.olewnik@umed.lodz.pl).

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Authors’ contribution: 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.
Table 1. Morphometric measurements of the three-headed plantaris muscle

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

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

<table>
<thead>
<tr>
<th>FH length</th>
<th>SH length</th>
<th>TH length</th>
<th>Common tendon</th>
<th>FH point of insertion</th>
<th>SH point of insertion</th>
<th>TH point of insertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our case report</td>
<td>73.8</td>
<td>49.39</td>
<td>40.43</td>
<td>320.55</td>
<td>DKF and PFS</td>
<td>LFC and LHGM</td>
</tr>
<tr>
<td>The case described by Olewnik et al. [20]</td>
<td>39.1</td>
<td>58.72</td>
<td>53.32</td>
<td>311.23</td>
<td>DKF and LFC</td>
<td>LHGM</td>
</tr>
</tbody>
</table>


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

The points of the origin
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>the lateral head of GM, lateral femoral condyle, and the knee joint capsule</td>
</tr>
<tr>
<td>IB</td>
<td>lateral head of the GM, lateral femoral condyle, knee joint capsule, the popliteal surface of the femur</td>
</tr>
<tr>
<td>II</td>
<td>lateral femoral condyle, lateral head of GM</td>
</tr>
<tr>
<td>III</td>
<td>lateral femoral condyle, knee joint capsule</td>
</tr>
<tr>
<td>IV</td>
<td>lateral femoral condyle, knee joint capsule, iliotibial band</td>
</tr>
<tr>
<td>V</td>
<td>lateral condyle of the femur</td>
</tr>
<tr>
<td>VI</td>
<td>rare cases (not classified)</td>
</tr>
</tbody>
</table>

**REFERENCES**


