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CASE REPORT

A bicaudatus sartorius muscle: a rare variant with potential clinical implications

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ABSTRACT

Background: Sartorius muscle (SM) belongs to the thigh anterior compartment musculature. It corresponds to the longest muscle of the human body, while its variations are described rarely. The current case reports aims to describe a distal bifurcation of the SM, forming the bicaudatus SM variant.

Materials and methods: An 84-year-old male cadaver was dissected for educational and research purposes at the Department of Anatomy, National and Kapodistrian University of Athens.

Results: On the left lower limb, the SM was typically originated from the anterior superior iliac spine. After 351.22 mm length, it was bifurcated into an anterior and posterior part. Both muscular parts were contributing to the pes anserinus morphology. Femoral nerve branches were providing innervation to the variant muscle, while the saphenous nerve and vein were coursed posteriorly to the variant muscle.

Conclusions: SM morphological variability is described quite rarely. The current case report corresponds to the bicaudatus SM variant. Accessory parts of SM could lead to

compression symptoms to the femoral nerve anterior branches, as well as to the saphenous nerve.

Keywords: sartorius muscle, bicaudatus, variation, dissection, accessory head

INTRODUCTION

The thigh anterior compartment is composed of the quadriceps femoris, and the sartorius muscles (SM). Typically, the SM is the longest muscle of the human body, originates from the anterior superior iliac spine (ASIS), and inserts into the medial side of the tibia. The SM is supplied by the femoral artery (FA) and is innervated by the femoral nerve (FN) [10]. Although the SM morphological alterations are rare, different variants have been described. According to *Bergman's Comprehensive Encyclopedia of Human Anatomic Variation*, the SM can be absent and duplicated partially (proximal or distal) or entirely [10]. Accessory muscles or heads are closely related to the presence of entrapment syndromes, while in the case of accessory SM, the FN and/or FA could be prone to compression. Nevertheless, the SM insertion into the tibia medial side contributed to pes anserinus morphology. Olewnik et al. [8] created an interesting and detailed classification of pes anserinus morphology, that included SM duplicated insertion. This knowledge is important due to the usage of pes anserinus for autologous graft harvesting [7, 8].

In the current cadaveric report, the occurrence of a distally bifurcated SM was identified. The embryological development, morphological variability, and clinical significance of SM are further described.

CASE REPORT

An 84-year-old donated male cadaver was dissected for educational and research purposes at the Dissection Hall of the Anatomy Department of the Medical School of the National and Kapodistrian University of Athens. Skin, subcutaneous fat, and deep fascia were dissected to expose the muscles and the neurovascular structure of both lower limbs. Each muscle proximal and distal attachment was carefully examined.

On the right lower limb, an uncommon SM was observed. It typically originated from the ASIS and retained its usual course and attachment into the tibia medial side (contributing to the pes anserinus). However, the distal third of the muscle was divided into anterior and posterior parts (351.22 mm distally to the ASIS), that

they were contributed to the pes anserinus morphology. The FN innervated the SM, and the FA branches supplied the variant muscle. The saphenous vein and nerve retained a course posterior to the variant muscle (deep location). On the left lower limb, the SM was presented as typical.

An electronic caliper (Mitutoyo Corporation, Kawasaki-shi, Kanagawa, Japan) was used for the measurements. Each measurement was repeated twice with an accuracy of up to 0.1 mm. The morphometric measurements are summarized in Table 1.

DISCUSSION

In the current case, an SM with a bifurcation of its inferior part was observed. It typically originated from the ASIS, and 351.22mm distally to the ASIS, it was bifurcated into two muscular parts, forming the *SM bicaudatus* variant.

Developmentally, muscles that belong to a specific group seem to differentiate from a common pre-muscular mass; however, this is not the case with the thigh anterior compartment. According to Bardeen [1], the SM develops from an anlage not directly fused with that of the quadriceps femoris. There is some fusion of the proximal ends between the SM, rectus femoris, and iliacus muscles [1]. As the embryonic period proceeds, the muscle becomes fully differentiated towards its iliac and tibial attachments [1]. SM morphological variations are rare, and this could be attributed to the developmental background of the muscle and the non-total fusion with the other thigh muscles. The FN branches extend into the SM muscular parenchyma [1]. In cases of SM variants, such as the bicaudatus SM, it is possible to identify FN branches penetrating the muscular heads [7, 11].

Morphological variability of the muscle is very narrow and rarely reported in the literature, with only a few case reports existing [3, 4, 7, 11]. Macalister [5] in his prestigious manuscript on *Muscular Anomalies in Human Anatomy*, reported several SM variants according to his findings and the literature review:

- The SM can be identified as duplicated with an accessory SM coexisting with the typical one, while the accessory head being inserted into the femur was also reported.
- One proximal accessory head was inserted into the typical one (proximal duplication), while the lower border split into two parts (distal duplication).
- Complete absence of the muscle.

- Other variants irrelevant to the muscular part were also identified, such as an SM of a more transversely course, and a central tendinous insertion.

Following Macalister [5], Testut [9] reported SM morphological variability. Testut [9] reported that muscle duplication was identified as extremely rare, with the following types: complete duplication with one head being inserted into the femur and the other one into the tibia, muscle duplication only on its inferior part, and muscle duplication only on its superior part. Testut [9] made a special reference to Brock's [3] case, an accessory proximal head of SM that originated from the iliopectineal line and coursed over femoral vessels and nerve. Brock's [3] case was not reported on Macalister's [5] nor on Testut's [9] findings. Mori [6] did not report a duplication of the muscle in any type.

In the recent literature, few cases of SM variants have been described. Kim and Lee [4] reported a very interesting case of an SM that originated from the ASIS and was bifurcated into medial and lateral heads. The lateral head was inserted into the patella via a thin tendon, and the medial head was fused with an accessory SM, that originated from the inguinal ligament. The complex (medial head and accessory SM) was inserted into the tibia contributing to the pes anserinus morphology [4]. Morphologically close to Kim and Lee's [4] finding, Natsis et al. [8] observed an SM that was bifurcated into a lateral and medial bundle. The medial bundle was fused with the accessory SM. Both heads were commonly inserted into the tibia, while only the complex (medial bundle-accessory SM) was contributing to the pes anserinus. Interestingly, they observed FN branches penetrating the SM heads [8], and they characterized this variant as "*biceps-bicaudatus SM*".

Closest to the current case, Zielinska et al. [11] reported an SM bifurcation, and further identified saphenous nerve branches penetrating the gap of the two muscular parts. A muscular connection existed between the two muscular parts both inserted into the tibia, contributing to pes anserinus. The current case, as well as the Zielinska et al. [11] case, can be termed as "*bicaudatus SM*" according to Bergman et al. [2]. A summary of the current literature regarding SM variants can be found in Table 2.

The SM insertion corresponds to the tibia medial side, contributing to the pes anserinus morphology. Due to its high clinical impact as a source of grafts, this morphology has been well studied. Olewnik et al. [8] in an up-to-date classification of

the pes anserinus morphology, observed 6 cases (5.8%), where the SM tendon was bifurcated at the pes anserinus (site of insertion).

Although SM variants are exceptionally rare, it is paramount to mention their clinical impact. The occurrence of accessory heads may be a cause of entrapment syndromes. For example, Natsis et al. [7] and Zielinska et al. [11] cases in FN and SN branches penetrating between typical and accessory heads could be a possible site for compression. Pain, numbness, and paresthesia of the anterior thigh (for FN branches) or medial knee joint, medial leg, and foot (for SN branches) [7, 11]. Moreover, the SM insertion into the pes anserinus is important as this structure is often used as an autologous graft harvesting in an anterior cruciate ligament (ACL) reconstruction surgery [7]. Variants at the insertion site may complicate the procedure or could place the SN into a more prone-to-injury position intraoperatively [7].

CONCLUSIONS

The current case report described another rare variation of the SM. Its morphological variability is quite narrow, with few case studies reporting its variants. Accessory parts of the muscle could potentially lead to compression symptoms, while variability into the insertion point could cause confusion intraoperatively.

Article information and declarations

Ethics statement

The cadaver belonged to the Department of Anatomy, Medical School, National and Kapodistrian University of Athens.

Author contributions

George Tsakotos — project development, data collection and management, data analysis, and manuscript writing. **Łukasz Olewnik** — data analysis, and manuscript writing. **George Triantafyllou** — data collection, and manuscript writing. **Georgi Georgiev** — data analysis, and manuscript editing. **Nicol Zielinska** — data analysis, and manuscript editing. **Maria Piagkou** — supervision, data collection, data analysis and manuscript editing.

All authors have read and approved the manuscript.

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Table 1. The morphometric measurements of the variant sartorius muscle (SM)

Morphometric measurements	**Length**	**Width**
Typical Muscle	516.80	PA: 28.23 DA: 22.20
Bifurcation level	351.22	26.64
Anterior part	165.58	28.08

Posterior part	146.22	15.07

All values were expressed in mm; PA — proximal attachment, DA — distal attachment.

Table 2. A brief summary of sartorius muscle (SM) variants with description and proposed terminology based on the current literature

SM variations	**Description**	**Proposed terminology**	**Reference**
Complete duplication	Doubled SM with two morphological similar heads	*Accessory SM*	Macalister (1875), Testut (1884), Bergman (1988)
Proximal duplication	Two muscular heads that fuse to form a single SM that it is typically inserted	*Biceps SM*	Macalister (1875), Testut (1884), Bergman (1988)
Distal duplication	SM that splits into two muscular parts	*Bicaudatus SM*	Macalister (1875), Testut (1884), Bergman (1988), Zielinska et al. (2024), Current case (2024)
Special case	SM that splits into two muscular parts, while the one of them fuses with an accessory SM	*Biceps-Bicaudatus SM*	Kim and Lee (2019), Natsis et al. (2024)

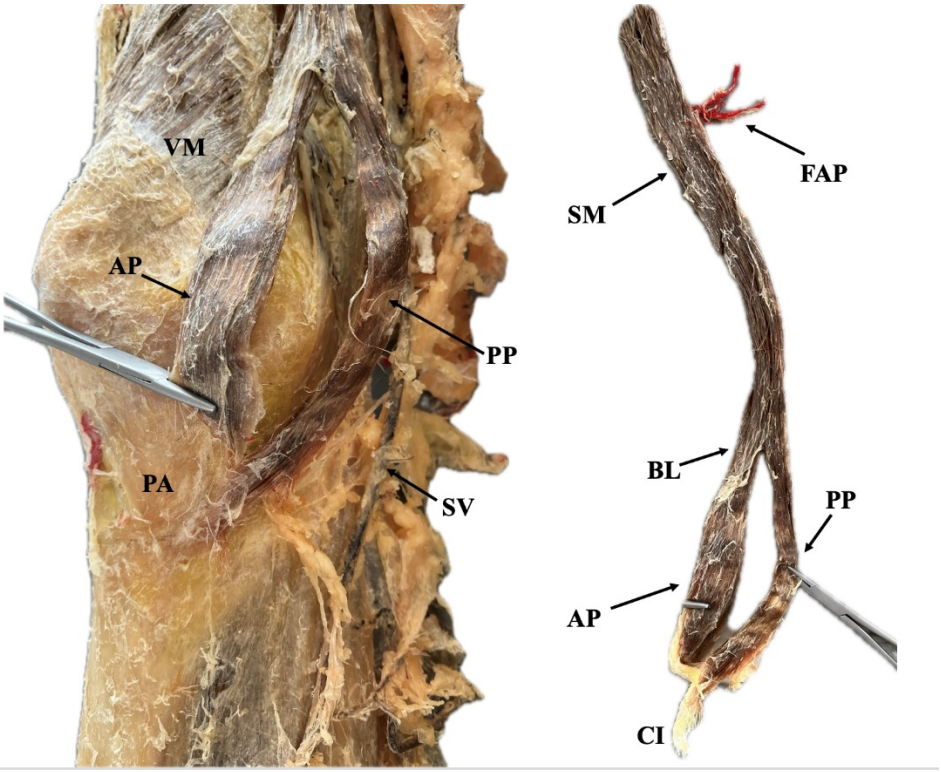

Figure 1. Left. The right lower limb sartorius muscle (SM) variant. AP — anterior part, PP — posterior part, SV — saphenous vein, PA — pes anserinus, VM — vastus medialialis; **Right.** The SM variant dissected. BL — bifurcation level, AP — anterior part, PP — posterior part, CI — common insertion, FAP — femoral artery perforators.