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MORPHOLOGICAL AND METRIC STUDY OF THE PES ANSERINUS TENDONS IN HUMAN FETUSES

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ORIGINAL STUDY

RESUMO

Introdução: Os pes anserinus correspondem à inserção conjunta dos tendões dos músculos sartório, grácil e semitendíneo na face anteromedial da porção proximal da tíbia. Esses tendões são amplamente utilizados como enxertos autólogos em procedimentos de reconstrução do ligamento cruzado anterior (LCA). No entanto, variações anatômicas e o conhecimento insuficiente dessa região podem contribuir para complicações cirúrgicas e falhas na retirada do enxerto. **Objetivo:** Fornecer conhecimento detalhado dessa região medial do joelho em fetos e das possíveis variações anatômicas dos tendões, a fim de auxiliar na redução de complicações cirúrgicas. **Metodologia:** Foram dissecados 40 membros inferiores de 20 cadáveres humanos fetais (20 membros direitos e 20 membros esquerdos), com idade gestacional média de 27,94 semanas. Foram obtidas medidas morfométricas dos ventres musculares e dos tendões que formam os pes anserinus. **Resultados:** A mensuração dos músculos que formam os pes anserinus revelou que o músculo sartório apresentou o maior valor médio para o ventre muscular (66,10 mm), enquanto o tendão do músculo semitendíneo demonstrou o maior comprimento médio (31,70 mm). Em 5% dos casos (n=2), observou-se uma inserção tendínea comum para os músculos grácil e semitendíneo. Além disso, foram encontradas inserções tendíneas acessórias em 52,5% (n=21) dos casos, restritas aos músculos grácil e semitendíneo. **Conclusão:** Os dados anatômicos e morfométricos detalhados fornecidos por este estudo contribuem para uma melhor compreensão do desenvolvimento fetal dos pes anserinus e podem ajudar a reduzir falhas técnicas durante a retirada de enxertos autólogos em procedimentos de reconstrução ligamentar.

Palavras-chave: Pes anserinus; Tendão do grácil; Tendão do semitendinoso; Bandas acessórias;

Variação anatômica; Transplantes; Procedimentos cirúrgicos reconstrutivos; Ortopedia.

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ABSTRACT

Introduction: The pes anserinus corresponds to the conjoined insertion of the sartorius, gracilis, and semitendinosus muscle tendons on the anteromedial aspect of the proximal tibia. These tendons are widely used as autologous grafts in anterior cruciate ligament (ACL) reconstruction procedures. However, anatomical variations and insufficient knowledge of this region may contribute to surgical complications and graft harvesting failures. **Objective:** To provide detailed knowledge of this medial knee region in fetuses and the possible anatomical variations of the tendons to assist in reducing surgical complications. **Methodology**: Forty lower limbs from 20 human fetal cadavers (20 right limbs and 20 left limbs), with an average gestational age of 27.94 weeks, were dissected. Morphometric measurements of the muscle bellies and tendons forming the pes anserinus were obtained. **Results:** Measurement of the muscles forming the pes anserinus revealed that the sartorius muscle presented the largest mean value for the muscle belly (66.10 mm), while the semitendinosus muscle tendon demonstrated the greatest mean length (31.70 mm). In 5% of cases (n=2), a common tendinous attachment for the gracilis and semitendinosus muscles was observed. Additionally, accessory tendinous attachments were found in 52.5% (n=21) of cases, restricted to the gracilis and semitendinosus muscles. **Conclusion:** The detailed anatomical and morphometric data provided by this study contributes to a better understanding of the fetal development of the pes anserinus and may help reduce technical failures during the harvesting of autologous grafts in ligament reconstruction procedures.

Keywords: Pes anserinus; Gracilis tendon; Semitendinosus tendon; Accessory bands; Anatomical variation; Transplants; Reconstructive surgical procedures; Orthopedics.

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INTRODUCTION

The pes anserinus is an anatomical region corresponding to the conjoined insertion of the sartorius, gracilis, and semitendinosus muscle tendons with the crural fascia. It is composed of superficial and deep layers, both inserting on the superomedial aspect of the tibial tuberosity. The superficial layer is formed by the sartorius tendon, while the deep layer consists of the gracilis and semitendinosus tendons (Olewnik et al., 2019).

The gracilis and semitendinosus tendons are widely used as primary sources of autologous grafts in anterior cruciate ligament (ACL) reconstruction procedures (Oliveira et al., 2006), a common injury particularly associated with amateur and professional sports activities (Astur et al., 2016). Compared with patellar tendon autografts, reconstruction using gracilis and semitendinosus tendons follows a similar surgical technique, with the additional benefit of being less prone to anterior knee pain (Tuman et al., 2007).

However, anatomical variations in this region, particularly the presence of accessory bands, are frequently encountered during graft harvesting. Failure to properly identify these bands can lead to surgical failures, as these accessory bands may deviate the course of tendon separation, resulting in a short and inadequate graft (Pagnani et al., 1993; Candal-Couto et al., 2003; Tuncay et al., 2007). These accessory bands, formed during embryological development, typically arise from the distal third of the tendon and consist of additional fibers attaching to adjacent structures, such as the tibial collateral ligament, superficial and deep crural fascia, gastrocnemius fascia, sartorius muscle fascia, popliteal fascia, and tibial periosteum (Candal-Couto et al., 2003; Reina et al., 2013; Dziedzic et al., 2020). Other potential complications may arise from extraction, including injury to the tibial collateral ligament, inadvertent harvesting of the sartorius muscle tendon, and damage to the infrapatellar branch of the saphenous nerve, even when minimally invasive incisions are employed (Kartus et al., 1999; Dziedzic et al., 2014).

Considering that the muscles comprising the pes anserinus exhibit, in both adults and fetuses, quite similar morphology and metric proportion. Detailed investigation at this stage may contribute to a better understanding of their morphological organization and variation patterns. Therefore, the present study aims to provide a comprehensive morphological and morphometric analysis of this medial knee region in fetuses and of the possible anatomical variations of the tendons of these muscles, with the goal of assisting in the reduction of surgical complications.

METHODOLOGY

Forty lower limbs from 20 human fetal cadavers were dissected. The mean gestational age was 27.94 weeks and was estimated based on foot length measurements according to the method described by Goldstein et al. (1988).

The fetuses were fixed and preserved in a 10% formaldehyde solution. The cadavers belonged to the Anatomy Laboratory of the Morphology Department at the Federal University of Sergipe. The use of the material complied with Brazilian Federal Law No. 8,501 of November 30, 1992, which addresses the use of unclaimed cadavers for study or scientific research purposes.

Cadavers exhibiting macroscopically detectable pathological alterations in the lower limbs were excluded from the study.

Dissection procedure

All dissections were performed using standard anatomical techniques. The lower limbs were positioned in the supine position, with the knee in full extension and the hip in neutral rotation to ensure measurement standardization. A longitudinal medial incision was made along the distal third of the thigh and proximal third of the leg, followed by careful removal of the skin and subcutaneous tissue to expose the sartorius, gracilis, and semitendinosus muscles and their tendons.

The crural fascia was carefully dissected to identify the superficial and deep layers of the pes anserinus and to detect accessory tendinous bands. Attention was paid to the distal third of the gracilis and semitendinosus tendons, where accessory expansions are most frequently observed.

Morphometric analysis

Morphometric measurements were obtained using a digital caliper with 0.01 mm precision. All measurements were performed with the limb maintained in full extension and aligned in the anatomical position.

The following parameters were recorded:

- Length of the muscle;

- Tendon length;

- Width of the tendons at their distal insertion.

All measurements were performed twice by the same observer at two different time points, with an interval of one week between measurements, to minimize recall bias. The mean of the two measurements was used for analysis. Intra-observer reliability was assessed using the intraclass correlation coefficient (ICC).

Documentation and statistical analysis

The anatomical findings were documented through high-resolution digital photography. Descriptive statistical analysis was performed, including mean, standard deviation, and percentage frequency for categorical variables.

RESULTS

Morphometric Analysis

Among the muscles forming the pes anserinus, the sartorius exhibited the greatest mean muscle belly length (right: 66.4 mm; left: 65.8 mm; mean 66.10mm) whereas the semitendinosus demonstrated the longest tendon length (right 31.8 mm; left 31.6 mm; mean 31.70mm). Minor side-to-side differences were observed.

The semitendinosus muscle tendon was, on average, 0.2 mm longer on the right side, while its muscle belly was on average 0.9 mm longer on the right compared to the left. The sartorius muscle tendon was 0.5 mm longer on the left, whereas its muscle belly was, on average, 0.6 mm longer on the right. Conversely, when analyzing the difference between the limbs regarding the gracilis muscle tendon data, the mean values were more like each other, with the left side presenting an average superiority of 0.2 mm compared to the contralateral limb.

Despite these small variations when comparing the muscles comprising the pes anserinus, no statistically significant side-to-side differences were identified ($p > 0.05$) considering a sample space of 40 dissected limbs. This indicates an absence of morphometric asymmetry within the sample studied.

Detailed morphometric data are presented in **Table** 1, and proportional relationships between muscle bellies and tendons are shown in **Table** 2.

Table 1: Pes anserinus muscles morphometry (mm)

	Dimidium	
Average lenght (mm)	**Left**	**Right**
Tendon of sartorius	11.4	10.9
Tendon of gracilis	24.9	25.1
Tendon of semitendinosus	31.6	31.8
Muscular belly of sartorius	65.8	66.4
Muscular belly of gracilis	49.3	49.5
Muscular belly of semitendinosus	43.8	44.8

Table 2: Morphometry of pes anserinus muscles, muscle bellies, and tendons

	Dimidium	
Relation	**Left**	**Right**
Muscle/Tendon of sartorius	5.77	6.09
Muscle/Tendon of gracilis	1.98	1.97
Muscle/Tendon of semitendinosus	1.39	1.40
Muscle/Belly of sartorius	1.17	1.16
Muscle/Belly of gracilis	1.51	1.51
Muscle/Belly of semitendinosus	1.72	1.71
Tendon /Belly of sartorius	6.77	7.09
Tendon /Belly of gracilis	2.98	2.97
Tendon /Belly of semitendinosus	2.39	2.41

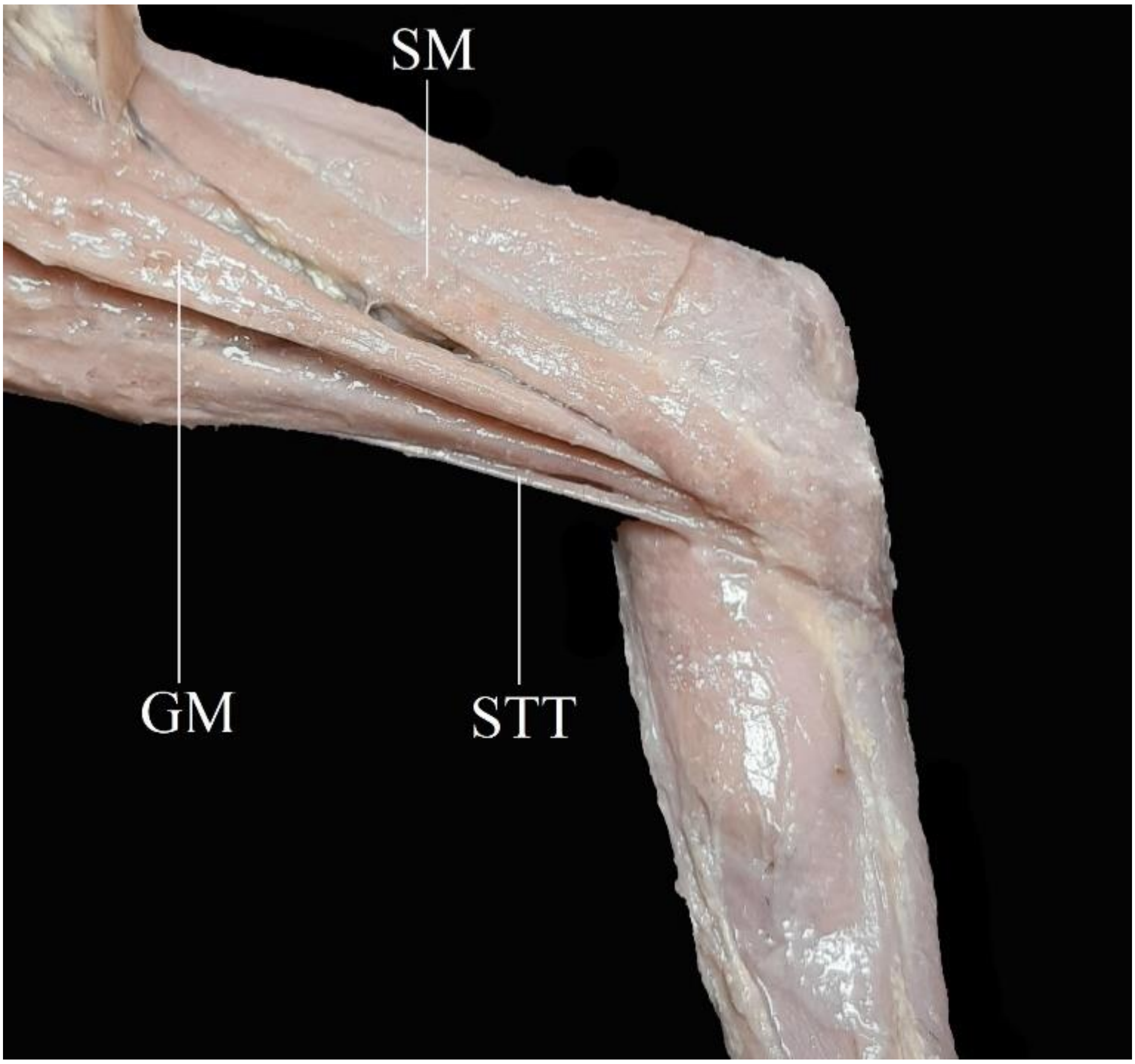
Morphological Analysis

Muscular portions. Regarding the morphological analyses of the sartorius, gracilis, and semitendinosus muscles, no anatomical variations were evidenced in the muscular portion. All specimens demonstrated the classical anatomical pattern, commonly reported in classic literature, in which sartorius muscle courses obliquely through the anterior compartment towards the medial compartment of the thigh for its distal insertion, the gracilis muscle remains within the adductor compartment throughout its trajectory, and the semitendinosus muscle, with apparent origin in the posterior compartment, reaching the medial region through its tendinous portion (**Figure** 1).

Tendon insertions. Concerning the morphology of the tendons, specifically the mode of insertion on the superomedial aspect of the tibia, the independent distal insertion of the sartorius, gracilis, and semitendinosus muscles, from their respective tendons to the attachment region, was found in 95% (38) of the observed limbs (**Figure**

1).

Figure 1. Medial view of the left inferior limb shows the muscle bellies of the sartorius and gracilis muscles, as well as the semitendinosus muscle tendon. Note, in the pes anserinus region, that the tendons insert independently.

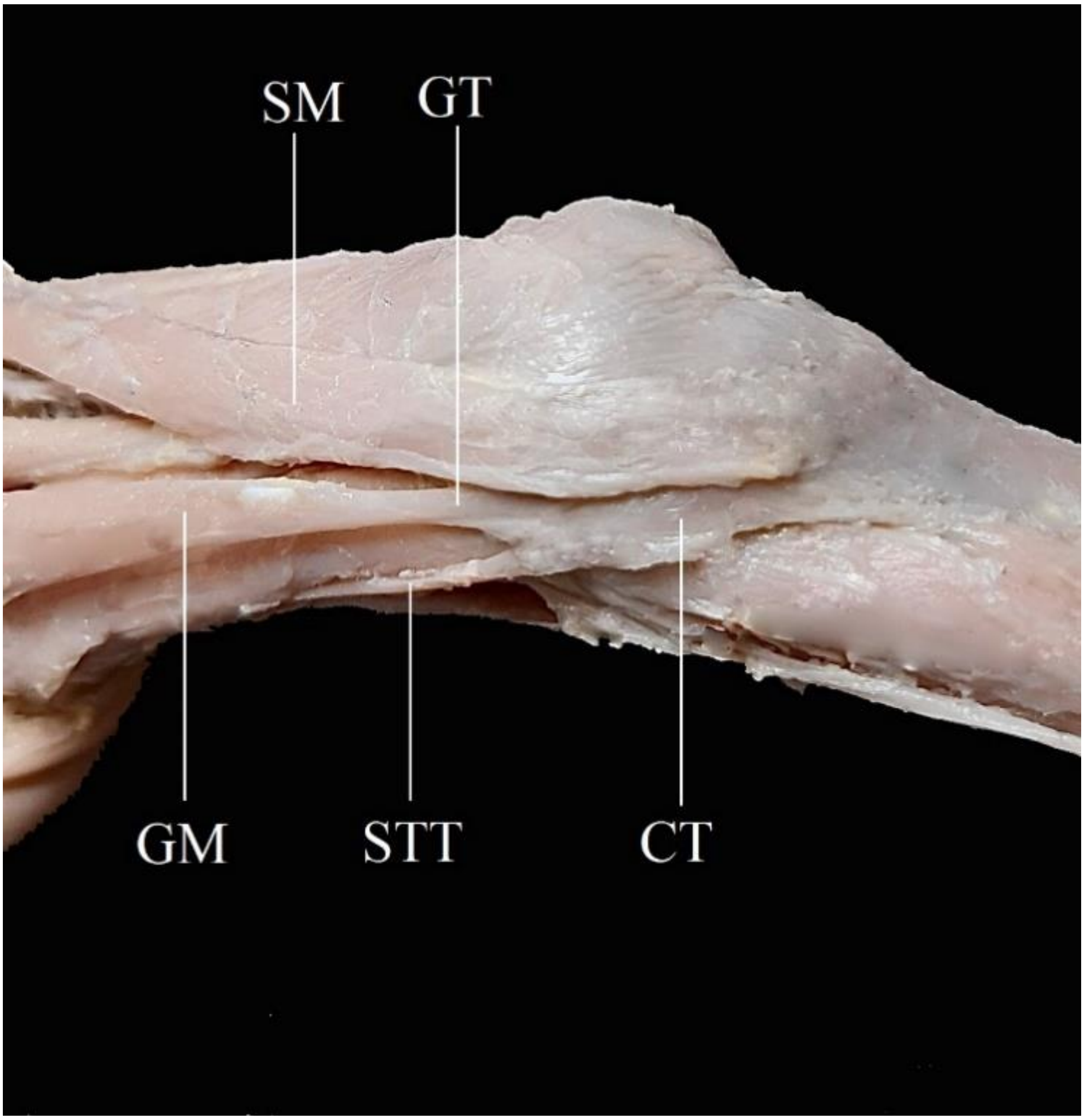


Legend

SM: Sartorius muscle; **GM:** Gracilis muscle; **STT:** Semitendinosus tendon.

In the remaining 5% of cases (n=2), both observed in left limbs, a common tendinous attachment occurred for the gracilis and semitendinosus muscles. That is, the tendons of these muscles united in their final third, forming a common tendon and, thereby, a bitendinous insertion of the pes anserinus muscles, composed of the sartorius muscle tendon and the single tendon formed by the fusion of the gracilis and semitendinosus muscles (**Figure** 2).

Figure 2. Medial view of the left inferior limb showing the sartorius tendon and the common tendon formed by the gracilis and semitendinosus. It is noted that in the pes anserinus region, the tendons exhibit a variant attachment pattern.



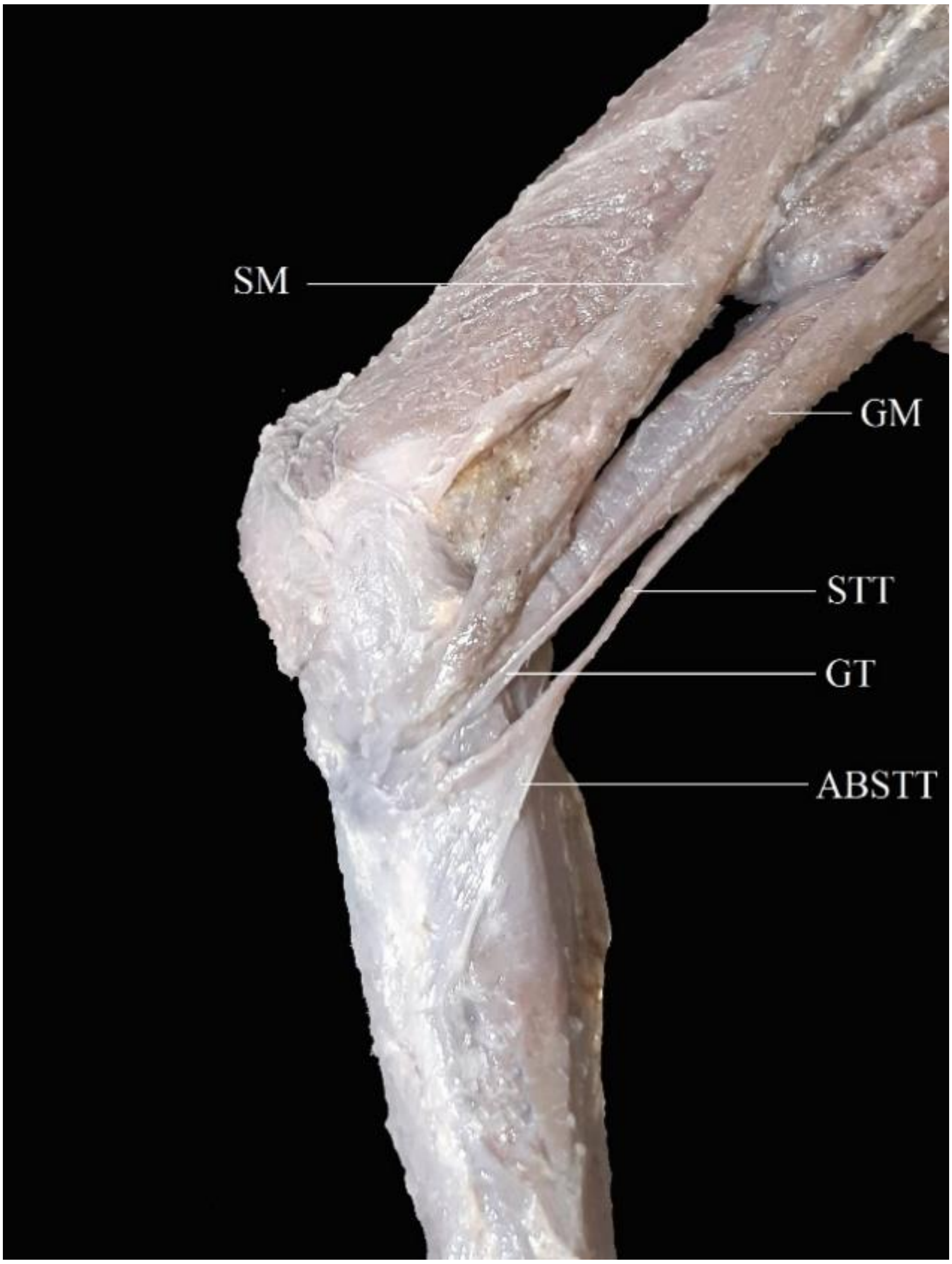
Legend

SM: Sartorius Muscle; **GM:** Gracilis Muscle; **STT:** Semitendinosus Tendon; **GT:** Gracilis Tendon; **CT:** Common Tendon formed by the Gracilis and Sartorius tendons.

Accessory tendinous bands. A classical tendon configuration without accessory attachments was observed in 42.5% of limbs (n = 17). Accessory tendon attachments were found in 52.5% (n = 21) of the cases, exclusively involving gracilis and semitendinosus muscles, with semitendinosus being the majority (n = 18).

Semitendinosus variations. In 35% (n = 14) of the analyzed limbs, the semitendinosus muscle tendon presented an accessory band extending toward the fascia of the medial head of the gastrocnemius muscle (**Figure** 3).

Figure 3. Medial view of the right inferior limb showing the semitendinosus tendon with its accessory band continuous with the fascia covering the medial head of the gastrocnemius muscle.



Legend

SM: Sartorius muscle; **GM:** Gracilis muscle; **STT:** Semitendinosus tendon; **GT:** Gracilis tendon;

ABSTT: Accessory band of the semitendinosus tendon.

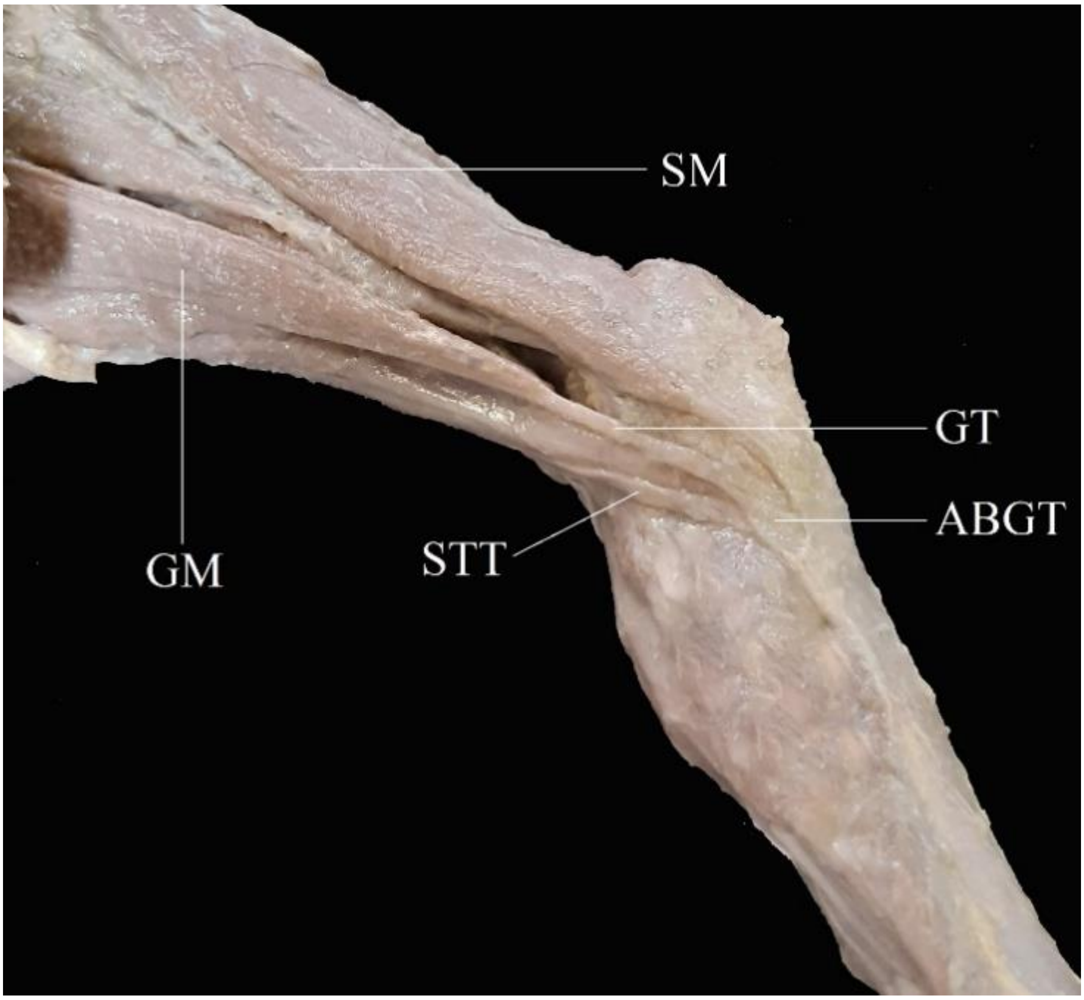
In 10% (n = 4) of the cases, the tendon exhibited a "fan-shaped" morphology, characterized by distal widening of its terminal third.

Gracilis variation. In 7.5% of limbs (n = 3), the gracilis muscle tendon presented an accessory band crossing superficially over the semitendinosus tendon (**Figure** 4).

Spatial relationship between tendons. It is important to highlight that the sartorius muscle tendon covered the gracilis and semitendinosus muscle tendons in the distal third in 95% of the analyzed limbs, with the gracilis and semitendinosus tendons running in parallel beneath it.

In the remaining 5% (n = 2) of cases, the sartorius muscle did not completely overlap the proximal third of the gracilis muscle tendon, resulting in greater spatial separation between the tendons.

Figure 4. Medial view of the left inferior limb showing the gracilis tendon in the distal part with an accessory band.



Legend

SM: Sartorius muscle; **GM:** Gracilis muscle; **STT:** Semitendinosus tendon; **GT:** Gracilis tendon; **ABGT:** Accessory band of the gracilis tendon.

DISCUSSION

Bilateral Symmetry and Developmental Considerations. The present study did not demonstrate statistically significant bilateral asymmetry in the morphometric parameters of the pes anserinus muscles or their tendons. Although minor side-to-side numerical differences were observed, these variations were not statistically supported, suggesting proportional bilateral development at the analyzed gestational ages.

This finding contrasts with the study by Kędzia et al. (2011), who reported significant asymmetry in the sartorius muscle in fetuses between 14 and 28 weeks of gestation. In their sample of 71 fetuses, the mean sartorius muscle belly length was 43.3 mm on the right and 42.3 mm on the left. In the present study (23–33 weeks, n = 20 fetuses), the corresponding values were 66.4 mm (right) and 65.8 mm (left). The greater absolute measurements observed in our sample are likely attributable to the higher mean gestational age. These findings suggest that, although early developmental asymmetries may occur, proportional growth may become more balanced in later gestational stages.

From a translational perspective, the absence of significant asymmetry reinforces the expectation of bilateral morphometric predictability, which may be relevant when extrapolating anatomical knowledge to surgical planning.

Morphometric Parameters and Gestational Progression. Few studies have quantitatively evaluated the morphometry of the muscles that comprise the pes anserinus during fetal development, limiting broader comparisons. In the present study, the semitendinosus muscle exhibited a mean muscle belly length of 44.35 mm and a mean tendon length of 30.95 mm, with a tendon-to-muscle belly ratio of 0.70. For the gracilis muscle, the mean muscle belly length was 49.40 mm and tendon length was 25.05 mm, with a ratio of 0.51.

These values were higher than those from other studies conducted in fetuses with a lower gestational average, such as that by Dziedzic et al., (2020), who conducted an anatomical study with younger fetuses (12 to 21 weeks) and described a mean semitendinosus muscle belly length of 26.25mm, 19.70mm for the tendon, and 0.75mm for the tendon/muscle belly ratio. Similarly, Dziedzic et al., (2018) reported a gracilis muscle belly length of 30.1 mm and tendon length of 15.5 mm, with a ratio of 0.51 in 10 fetuses between 15 and 21 weeks.

The progressive increase in absolute dimensions observed in our study is consistent with advancing gestational age. Importantly, the relative tendon-to-muscle proportions appear to remain relatively stable, suggesting coordinated longitudinal development of muscle and tendon components. This proportional growth may have implications for understanding the ontogenetic basis of tendon length and graft potential in postnatal life.

Layered Anatomy of the Pes Anserinus and Surgical Correlation. In all analyzed fetuses, it was possible to confirm that the semitendinosus muscle tendon is located more deeply in the pes anserinus, being directly overlapped by the gracilis muscle tendon, and both are enveloped by the sartorius muscle tendon, which is, therefore, in the most superficial layer of the leg fascia. Thus, the classical layered anatomical arrangement of the pes anserinus was confirmed This configuration aligns with descriptions by Mochizuki et al. (2004), LaPrade et al. (2007), and Lee et al. (2014).

From a surgical standpoint, this layered organization is critical during tendon harvesting for ACL reconstruction. Proper identification of the sartorial fascia and sequential exposure of the gracilis and semitendinosus tendons minimizes the risk of incomplete release or iatrogenic injury. The consistent pattern observed in fetal specimens suggests that this anatomical layering is established early in development and persists into postnatal life.

Accessory Bands: Developmental Origin and Surgical Risk. Accessory bands were identified exclusively in the gracilis and semitendinosus tendons. No accessory bands were observed in the sartorius tendon in our sample, despite suggestions in the literature that all pes anserinus tendons may exhibit accessory expansions (Olewnik et al., 2019).

The overall frequency and number of accessory bands in our fetal sample were lower than those reported in adult studies. For example, Yasin et al. (2010), Reina et al. (2013), and Candal-Couto et al. (2003) described accessory bands in nearly all analyzed adult specimens, frequently with multiple bands per tendon. In contrast, we identified a single accessory band in the gracilis tendon in 7.5% of limbs and an accessory band of the semitendinosus tendon in 35%, most commonly directed toward the gastrocnemius fascia (**Table** 3).

Table 3. Accessory Bands of the Gracilis and Semitendinosus Tendons: Comparative Evidence from Fetal and Adult Studies

Study	**Sample**	**Population**	**Tendon analyzed**	**Presence of accessory bands (%)**	**Number of bands**	**Most common insertion / morphology**
Candal-Couto et al., 2003	10 knees	Adults	GM	100%	Mostly 2	Tibial collateral ligament, fascia
Candal-Couto et al., 2003	10 knees	Adults	STM	100%	Mostly 3	Gastrocnemius fascia
Yasin et al., 2010	25 knees	Adults	GM	96%	1–3 (16% with 1)	Variable
Yasin et al., 2010	25 knees	Adults	STM	100%	Mostly 3 (4% with 1)	Gastrocnemius fascia
Reina et al., 2013	30 knees	Adults	GM	73.3%	1 band in 53.3%	Variable
Reina et al., 2013	30 knees	Adults	STM	100%	≥1	Variable
Tanpowpong et al., 2019	Not specified	Adults	GM	39%	Mostly 1 (56%)	Gastrocnemius fascia
Lee et al., 2014	Korean population	Adults	STM	34%	1 (31%), 2 (3%)	Variable
Olewnik et al., 2019	Adults	Adults	GM	19.6%	Not specified	Fan-shaped tendon
Olewnik et al., 2020	Adults	Adults	STM	80.4%	Not specified	Fan-shaped tendon
Present study	40 limbs	Fetuses	GM	7.5%	1 only	Crossing over semitendinosus tendon

Present study	40 limbs	Fetuses	STM	35%	1	Gastrocnemius fascia
Present study	40 limbs	Fetuses	STM	10%	—	Fan-shaped tendon

Legend

GM: Gracilis Muscle; **STM:** Semitendinosus Muscle.

The reduced frequency and complexity observed in fetuses may reflect developmental maturation of fascial expansions occurring later in gestation or postnatally. Alternatively, the fine caliber of fetal accessory bands may hinder macroscopic identification.

Clinically, accessory bands are highly relevant because failure to recognize and release them during graft harvesting may result in premature tendon amputation, shortened graft length, and surgical failure. Understanding their developmental basis may contribute to improved anatomical anticipation during surgical procedures.

Tendon Fusion Patterns and Harvesting Implications. A common tendon attachment for the gracilis and semitendinosus muscles was observed in 5% of the limbs. This contrasts markedly with the 56% fusion rate reported by Oliveira et al. (2006) in adult specimens.

The lower incidence in fetuses suggests that some tendon fusion patterns described in adults may develop later or become more evident with growth and mechanical loading. From a surgical perspective, tendon fusion can complicate independent harvesting and may alter graft preparation strategies. Preoperative awareness of possible fusion patterns is therefore essential.

Study Limitations. This study presents some limitations. The sample size, although comparable to other fetal anatomical studies, remains relatively limited. The gestational age range was restricted to the late second and third trimesters, precluding assessment of earlier developmental stages. Additionally, the small caliber of fetal tendons and fascial expansions may have limited identification of extremely delicate accessory bands. Finally, no biomechanical or imaging correlation was performed.

Clinical and Translational Implications. This study contributes to the understanding of the ontogenetic development of the pes anserinus and its anatomical variations. The early establishment of the classical layered arrangement and the presence, albeit less frequent, of accessory bands indicate that the structural framework relevant for ACL graft harvesting is developmentally determined.

Although direct extrapolation from fetal anatomy to adult surgical practice must be done cautiously, recognizing that accessory bands and fusion patterns have a developmental basis may help explain interindividual variability encountered intraoperatively. These findings reinforce the importance of meticulous dissection during tendon harvesting and may support future correlations with imaging modalities or surgical outcomes.

CONCLUSION

No statistically significant bilateral differences were identified in the morphometric parameters of the pes anserinus tendons or muscle bellies. Nevertheless, the present study consistently demonstrated the presence of clinically relevant morphological variations, particularly involving the gracilis and semitendinosus tendons. A detailed understanding of the distribution, frequency, and anatomical relationships of these variants provides important anatomical support for optimizing surgical strategies during autologous tendon harvesting in ligament reconstruction procedures. The high degree of morphological and morphometric similarity observed between fetal and adult specimens reinforces the concept that the anatomical arrangement of the pes anserinus is established early in development and persists into postnatal life, supporting its translational relevance to clinical practice.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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