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Morphometric description of the subfascial intermuscular adipose tissue of anterior compartment of the leg

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Abstract

Objectives: To describe the morphological characteristics of subfascial intermuscular adipose tissue (IMATS) in the anterior compartment of the leg, considering its developmental and functional relationship with the crural fascia.

Methods: In twenty formalin-fixed cadaveric legs (13 males, 7 females), after removal of the skin and crural fascia, the IMATS was exposed and classified into four types according to its shape. Leg length was divided into eight regions. The length, width at the widest point, closest distances of the upper and lower ends to the intermalleolar line and the anterior margin of the tibia, as well as the thickness of the skin-subcutaneous tissue complex, limb and leg lengths were measured for IMATS.

Results: The most common type of IMATS was the short-large type. The largest point of IMATS was located in zone 3 or 4, and this point was located in the two zones closest to the lower end of IMATS in 75% of cases. In all cases, one to three connecting vessels piercing the crural fascia (80% were in zones 2, 3 or 4) connected to the IMATS in a slightly lateral to medial oblique course of the IMATS from top to bottom. The IMATS was superficially located in the tendinous and muscular parts of the extensor digitorum longus and/or tibialis anterior muscles, loosely attached to the muscles and crural fascia, but not between the muscle fibers. Although the largest point ($p=0.041$) and the distance from the distal end to the anterior margin of the tibia were found to be greater in males ($p=0.049$), the gender difference disappeared when normalized for limb length.

Conclusion: No data on IMATS morphometry could be found in the literature. A remarkable finding of the study, which is open to interpretation in terms of the function of the IMATS, is that the location of the IMATS overlaps with the crural fascia region, which is reported to be biomechanically stiffer in the transverse direction. Our data that a connecting vessel is always connected to the IMATS by a fixed spatial relationship strengthens the argument that the developmental history of both structures may intersect.

Keywords: anterior compartment of leg; crural fascia; extensor digitorum longus; fat pad; intermuscular adipose tissue; tibialis anterior muscle

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Introduction

Adipose tissue serves as an energy storage, a metabolic lipid source, thermal insulation and mechanical shock absorber, and adapts to the changing shape and volume of the components during movement.[1] These tissues, which can produce inflammatory mediators and growth factors, are considered an endocrine organ with sensory and immune functions.[2] Intermuscular fat masses are typically deposits of lipids in adipocytes beneath the deep fascia of the muscle, and can be found intramuscular or intermuscular.[3] Intramuscular ones are the result of ectopic lipid accumulation in myocytes, while intermuscular adipose tissues (IMAT) are described as visible muscle fat deposits resulting from the infiltration of fatty tissue between muscle fibers.[4] The prevailing view regarding the formation of IMAT suggests that depending on the conditions, satellite cells around the myofibrils, differentiate into adipocytes and become fat depots instead of muscle precursor cells.[5,6]

Under normal conditions, adipogenic formation or differentiation of muscle satellite cells is negligible in healthy muscles; however, the adipogenic potential changes with age, and factors such as increased insulin resistance, decreased oxygen supply, and alterations in metabolic conditions may induce muscle satellite cells to undergo the alternative mesenchymal lineage differentiation pathway, ultimately increasing IMAT accumulation by increasing their transformation of satellite into mature adipocytes.[5]

The function of IMAT, found in certain amounts in normal individuals, is not yet clearly understood. It has been suggested that decreased physical activity in healthy individuals causes significant (15–20%) increases in IMAT levels without changes in subcutaneous adipose tissue.[7] Excess IMAT is associated with lower levels of muscle strength, impaired mobility, older age and higher risk of disability.[3,7–12] It is acknowledged that adipose tissues not only serve as energy storage but also have a direct mechanical function, providing protection for sensitive organs and buffering body parts exposed to high levels of mechanical stress.[13,14]

Kager's fat pad is an example of a deep-seated fat pad, i.e. IMAT, that can assume biomechanical roles. It is suggested that during ankle plantar flexion, this fat pad helps lubricate the subtendinous region of the Achilles tendon as it moves towards the bursal space, increasing the efficiency of the system.[15–17] Similarly, it is accepted that the infrapatellar fat pad acts as a biomechanical support and stabilizing role, absorbs a portion of the load reaching the joint. It provides the distribution and dampening of mechanical stresses during joint activity, and distributes the tensile stress around it homogeneously to neighboring biological structures through its cushioning role in the knee joint.[13,18–20]

Anatomical studies evaluating IMAT in crural compartments are quite limited in the literature. Takumi et al.[21] suggested that adipose tissue located deep within the crural fascia (CF) in the posterior compartment of the leg may reduce frictional and compressive stress, and present data suggesting that pain complaints associated with medial tibial stress syndrome may be a result of inflammation of this fat pad. Ortiz-Miguel et al.[22] mentioned a fat pad located between the extensor digitorum longus muscle (EDL) and tibialis anterior muscle (TA) in the anterior compartment in their study on CF and related anatomical structures but did not mention the morphological features of the fat pad. In Stecco's book "Functional Atlas of the Human Fascial System", in which he discusses fascia in a comprehensive and detailed manner, the fat pad can be clearly distinguished in cadaveric images of the anterior compartment of the leg, but no specific definition or name is given to this structure.[23]

This study aims to identify the subfascial intermuscular adipose tissue (IMATS), which is located as a fat pad deep to the CF superficial to the EDL and/or TA in the anterior compartment of the leg, and to evaluate its anatomical features in relation with its possible developmental history and biomechanical role.

Materials and Methods

Twenty formalin-fixed cadaver legs (13 males, 7 females, 9 bilateral sides) from the inventory of the Anatomy Laboratory of Mersin University were included in the study. There was no significant difference in mean age between male (66.35±9.72) and female (67.74±1.55) cadavers.

After the skin-subcutaneous tissue complex (SSTt) of the anterior leg was dissected, two transverse incisions were made in the CF, passing through the head of the fibula above and the intermalleolar line below. With a longitudinal incision following the medial side of the anterior intermuscular septum, the CF of the anterior compartment was incised from the lateral edge, and then it was released from the deep muscles and IMATS with a gentle blunt dissection technique and deviated medially (**Figure 1**). Along the medial edge of the CF, the anterior compartment was divided into four equal parts throughout its length as: first quarter (Q1), second quarter (Q2), third quarter (Q3) and fourth quarter (Q4). Then the Q2, Q3 and Q4 parts where IMATS could be located were divided into two on the photographs and six regions were determined that would allow the relative settlement relationships of the structures to be analyzed (**Figure 2a**). IMATS was revealed and classified into four types according to its shape (**Figure 2**).

IMATS was distinguished with a near-longitudinal oblique course deep to the CF of all legs, mostly in the lower half of the anterior compartment. To describe the location and dimensions of the IMATS, its length, width at the largest point, the distance of its distal end to the anterior margin of the tibia and to the intermalleolar line were measured. The zones of the upper end, lower end, largest point of the IMATS and, if present, the connecting vein connecting to the IMATS by piercing the CF were noted (**Figure 2a**). The thickness of the SSTt of the same region was measured at the level of the IMATS. A digital caliper with 0.01 mm precision (MARCAL 16 ER, Mahr, Gottingen, Germany) was used for these measurements. In addition, the length of lower extremity (distance from the anterior superior iliac spine to the lowest point of the heel) and leg length (distance between the two transvers lines mentioned above) were measured with a tape measure.

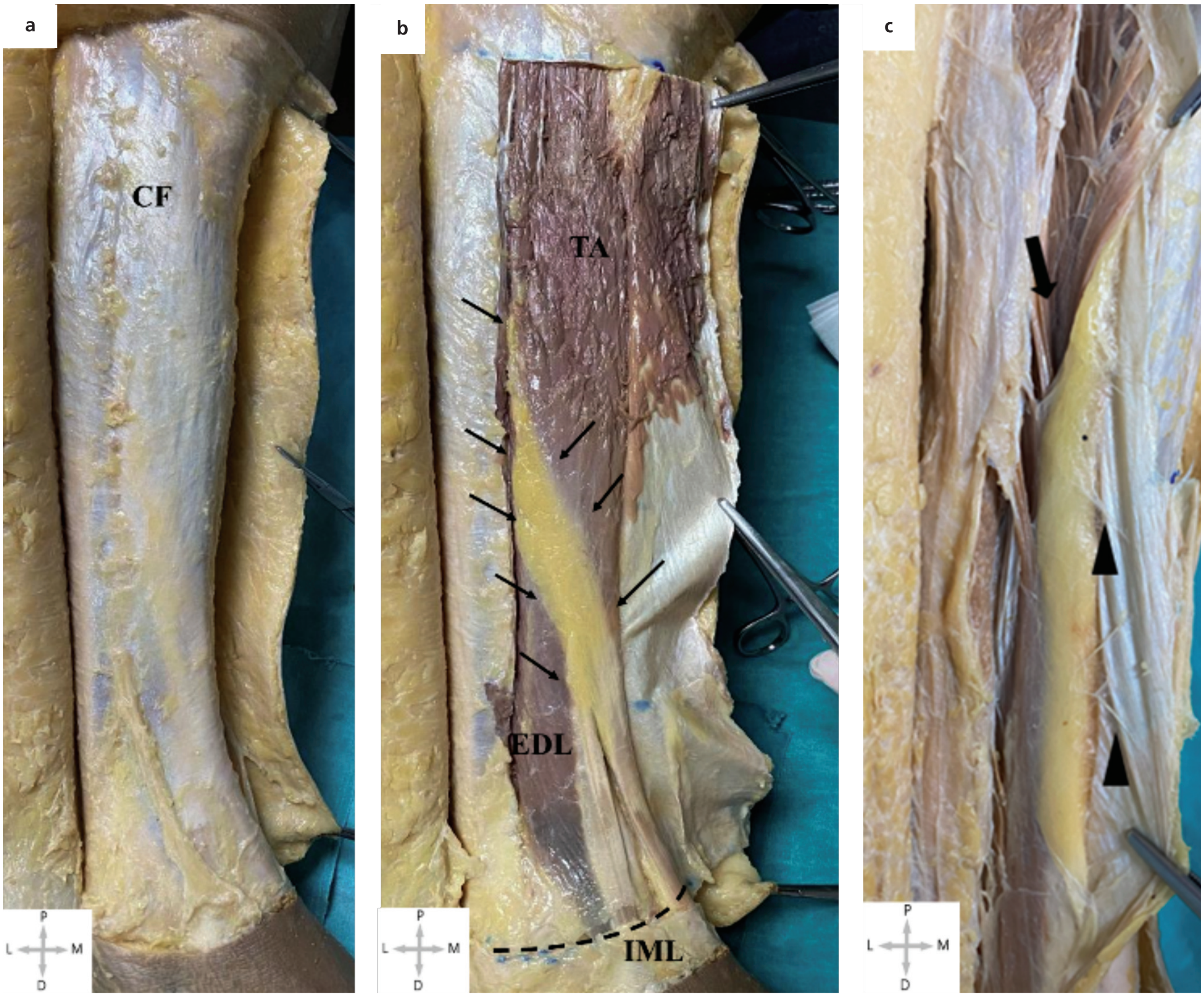

Figure 1. (**a**) Crural fascia after dissection of the skin. (**b**) A complete view of IMATS (**arrows**). (**c**) Fibrous fibers between the CF and IMATS (**arrow heads**), there is no fat tissue between the muscle fibers (**bold arrow**). **CF:** crural fascia; **EDL:** extensor digitorum longus muscle; **IML:** intermalleolar line; **SFN:** superficial fibular nerve; **TA:** tibialis anterior muscle.

The conformity of the variables to normal distribution was examined by Shapiro-Wilk and Skewness-Kurtosis. Descriptive statistics were presented using mean and standard deviation (**Table 1**). Since the metric data were found to be normally distributed, comparisons according to sex were evaluated with independent samples t-test, comparisons according to side were evaluated with paired samples t-test (only for bilateral cases), and correlation analysis was evaluated with Pearson's correlation coefficient. Significance level was taken as $p<0.05$.

Relations of the upper end, lower end with the largest point and the level of connecting vein attachment to the IMATS were evaluated with the Spearman's correlation test. Descriptive statistics for these parameters were given as ratio and percentage.

Results

IMATS was distinguished in all legs, extending obliquely from top to bottom and from lateral to medial, with the majority of its in the lower half of the anterior compartment. It was connected to the fascia by loose connective tissue that could be easily dissected even with a gentle blunt dissection. A few slightly resistant tight connective tissue strands extending from the IMATS to the fascia were rarely present (**Figure 1c**). In all cases, one to three connecting veins attached to the IMATS were detected by

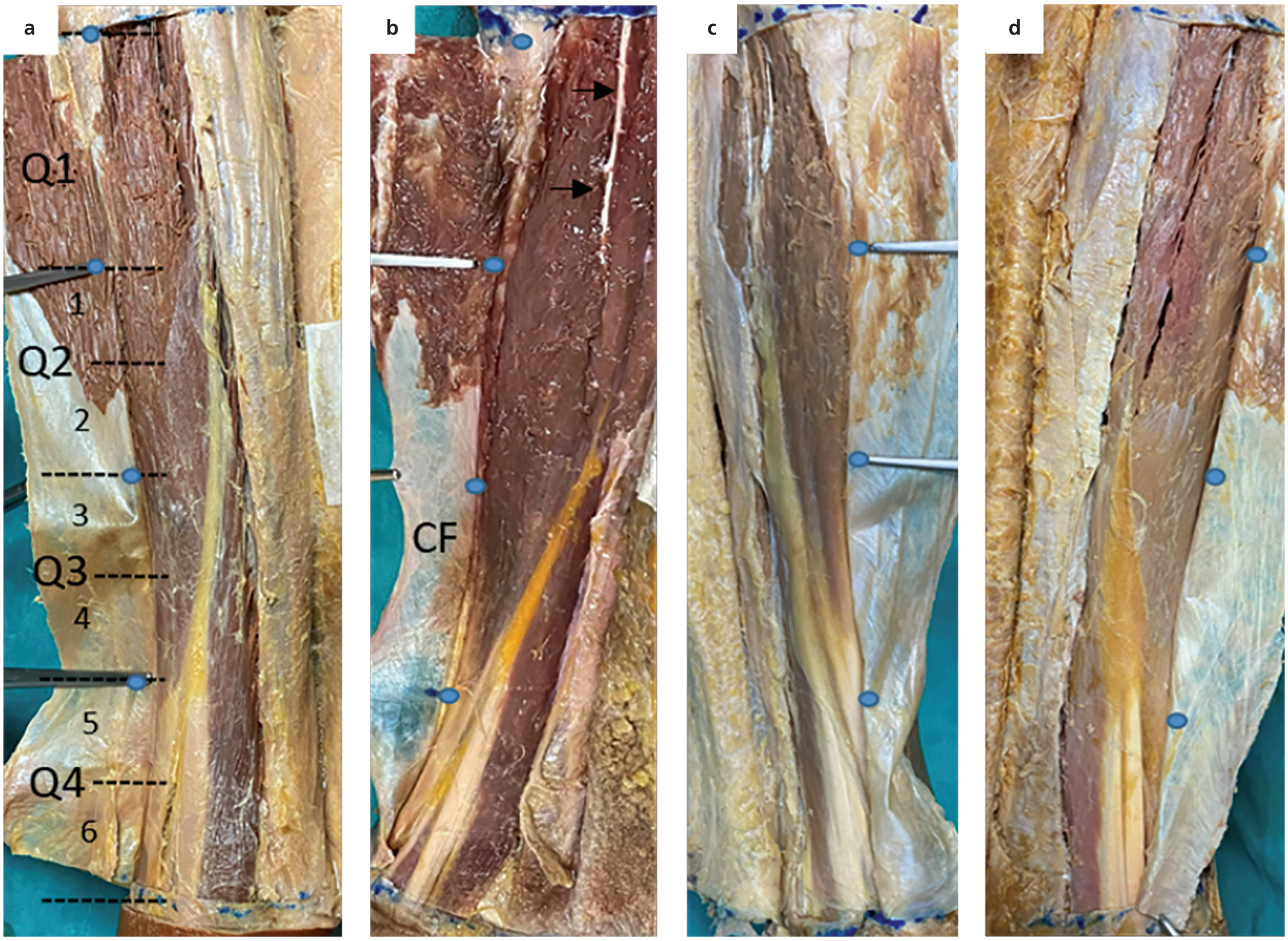

Figure 2. Description of six regions and appearances of the four types of IMATS. (**a**) Slim-long type (left side of a female cadaver). (**b**) Slim-short type (left side of a male cadaver) (**black arrows:** septum between TA and EDL). (**c**) Large-long type (right side of a female cadaver). (**d**) Large-short type (right side of a male cadaver). **1-6:** zones; **blue dots:** ¼ cut points for segmentation of the anterior compartment; **CF:** crural fascia deviated medially; **Q1:** first quarter; **Q2:** second quarter; **Q3:** third quarter; **Q4:** fourth quarter of the anterior compartment.

piercing the CF in a location appropriate to the oblique course of the IMATS (**Figure 3**).

The course of IMATS showed a near-longitudinal oblique continuity over the tendon, myotendinous junction, and the muscular portion of the EDL and/or TA, without any segmentation or interruption (**Figure 1**). IMATS, which was always flat, was located superficial to both of the tendons of the EDL and TA in 13 legs, and only superficial to the EDL tendon in 6 legs. The largest part of the IMATS, usually located in the lower half of the leg. In only one case, the lower end of the IMATS divided at the distal ¼ part; its medial end extended superficial to the TA tendon, and its lateral end superficial to the EDL tendon.

As such, the IMATS resembled a mass independent of epimysial continuity, forming a well-defined space, along a certain oblique line between the muscle and the CF, albeit of variable size, rather than a fatty mass dispersed throughout the compartment. It did not show any division conforming to the intermuscular border, i.e., the integrity of the IMATS body was not interrupted between the muscles or at the ventral-tendon transition points (**Figure 1c**).

According to appearance, large-short type (n=9/20, 45%) and slim-long type (n=5/20, 25%) were common, while slim-short type and large-long type were less common (for both n=3/20, 15%).

The widest part of the IMATS was wider in males than females (p=0.041 and the distance from the distal end to the anterior edge of the tibia was longer in males (p=0.049). Considering that limb length is also different according to gender, when the difference between genders

Table 1
Descriptive statistics and independent samples t-test results according to sex.

		Sex	n	Mean	SD	p-value
Extremity length (cm)		Male	13	94.46	3.13	**0.0001***
		Female	7	81.86	2.48	
Leg length (cm)		Male	13	31.35	1.41	**0.0001***
		Female	7	27.00	1.29	
SSTt (mm)		Male	13	2.30	0.81	0.450
		Female	7	1.98	1.06	
IMATS parameters	*Distal end – IML (mm)*	Male	13	75.08	18.36	0.845
		Female	7	73.42	16.89	
	IMATS length (mm)	Male	13	116.00	29.51	0.101
		Female	7	90.67	34.43	
	Width at the largest part (mm)	Male	13	12.91	5.14	**0.041***
		Female	7	8.44	1.87	
	Distal end – AMT (mm)	Male	13	14.23	4.04	**0.049***
		Female	7	10.87	1.36	
Normalized by extremity length	*Width at the largest part /extremity length*	Male	13	0.14	0.05	0.130
		Female	7	0.10	0.02	
	Distal end – AMT /extremity length	Male	13	0.15	0.04	0.321
		Female	7	0.13	0.18	

*p<0.05. **AMT:** anterior margin of tibia; **IML:** intermalleolar line, **SSTt:** skin-subcutaneous tissue complex.

was compared by calculating the ratio of these parameters to limb length, no significant difference was found between males and females for both variables (p=0.130, p=0.321, respectively) (**Table 1**).

There was no significant difference between the sides in terms of parameters related to the size and location of IMATS or in terms of limb and leg length (p>0.05).

According to Pearson's correlation coefficient, there was a negative correlation between the length of SSTt and IMATS and the distance of the lower end of IMATS to the intermalleolar line, and a weak positive correlation between the total length of the limb and the width of the largest point of IMATS. However, no significant correlations were found for the other parameters (**Table 2**).

Table 2
Relationship between the parameters by Pearson's correlation analysis.

	Leg length	Distal end – IML	IMATS length	Width at the largest part	Distal end – AMT	SSTt
Extremity length (cm)	**0.893*** (p=0.0001)	0.128 (p=0.589)	0.309 (p=0.184)	**0.566*** (p=0.009)	0.348 (p=0.133)	0.225 (p=0.340)
Leg length (cm)		0.139 (p=0.558)	0.398 (p=0.082)	0.439 (p=0.053)	0.426 (p=0.061)	0.112 (p=0.639)
Distal end – IML (mm)			**-0.540†** (p=0.014)	-0.026 (p=0.912)	0.216 (p=0.360)	**-0.467†** (p=0.038)
IMATS length (mm)				0.278 (p=0.236)	0.082 (p=0.731)	0.396 (p=0.084)
Width at the largest part (mm)					0.266 (p=0.258)	0.241 (p=0.307)
Distal end – AMT (mm)						0.000 (p=0.999)

*p<0.01; †p<0.05. **AMT:** anterior margin of tibia; **IML:** intermalleolar line; **SSTt:** skin-subcutaneous tissue complex.

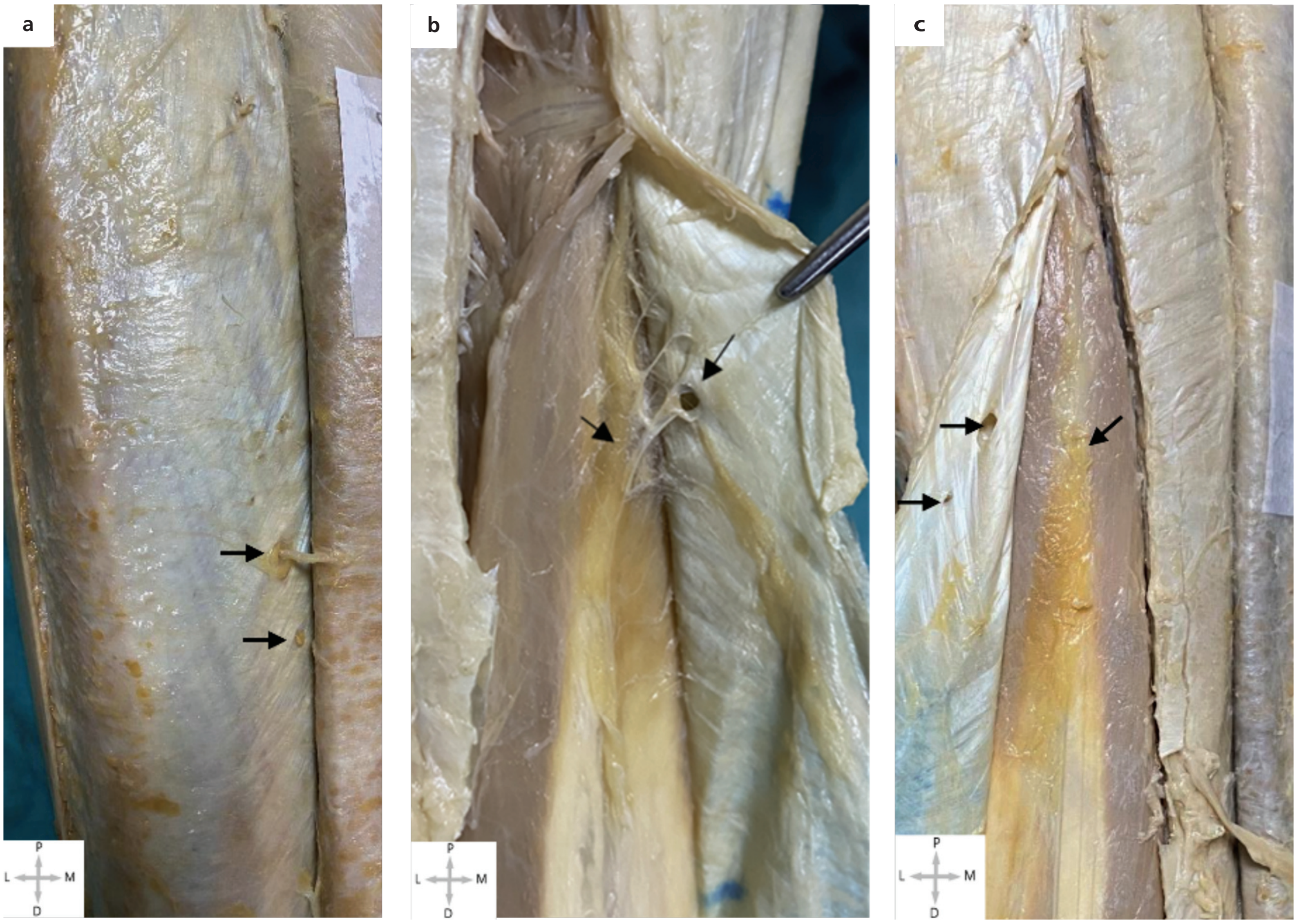

Figure 3. Relationship of the connecting vein between the superficial and deep veins with IMATS and CF (**a**) after skin-superficial fascia complex deviated laterally, appearance of the connecting vein piercing the crural fascia. (**b**) Connecting vein (**arrow**) from the inner aspect of CF attached to the IMATS. (**c**) After cutting the connecting vein, its hole on the crural fascia and its mark at the upper end of the IMATS.

Findings on segmental localization showed that the upper end of IMATS was located in zone 1 and zone 2 in 85% of cases and the lower end in zone 4 in 75% of cases. The level of connecting vessel attachment was most frequently located in zones 2–4 (n=16/20, 80%) (**Table 3**). Neither the upper and lower end of IMATS nor the appearance subtypes were significantly associated with the level of connecting vessel attachment (p>0.05).

The connecting vein findings regarding the location of the IMATS showed that in cases where the upper end of

Table 3
Distribution of the certain points on the zones.

	Q2 part		Q3 part		Q4 part		Total
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Upper end of the IMATS	7 (%35)	10 (%50)	3(%15)	-	-	-	20 (%100)
Lower end of the IMATS	-	-	-	15 (%75)	5 (%25)	-	20 (%100)
Largest point of the IMATS	-	3 (%15)	7(%35)	9 (%45)	1 (%5)	-	20 (%100)
Connecting vein point	2 (%10)	7 (%35)	5 (%25)	4 (%20)	2 (%10)	-	20 (%100)

the IMATS was at zone 1, the connecting vein attachment point was most frequently at zone 2 (n=4/7, 57.1%). In those with the upper end at zone 2, the vein attachment point was most frequently at zone 2 and 3 (n=9/10, 90%). In the cases with the upper end at zone 3, the vein attachment point was located at the zone 4 (n=2/3, 66.7%). Accordingly, the vein attachment point was mostly located in the two zones closest to the upper end of IMATS (n=15/20, 75%). In cases with the lower end was at zone 4, the connecting vein attachment level was most frequently at zone 2 and 3 (n=9/15, 60%), while in those with the lower end at zone 5, the vein attachment level was almost equally distributed at zone 2 and 3. In cases with the lower end is at zone 4, the connecting vein attachment level was most frequently at zone 2 and 3 (n=9/15, 60%). In those with the lower end at zone 5, the vein attachment level was almost equally distributed at zone 2 to 5. In cases with slim IMATS, the venous attachment point was mostly found at zone 2 and 3 (n=6/8, 75%). Similarly, in cases with large IMATS, it was most frequently located at zone 2 to 4 (n=9/12, 75%). In cases with long type, the vein attachment level was mostly located at zone 1 to 3 (n=6/8, 75%), while in cases with short type, the vein attachment point was most frequently located at zone 2 to 4 (n=11/12, 91.7%). There was no significant relationship between largest point and vein entry levels ($p>0.05$).

There was no statistically significant relationship of the IMATS upper or lower end levels with the largest part of IMATS ($p>0.05$). The largest part of IMATS was closest to the lower end of IMATS in 75% of the cases: In cases with the lower end in zone 4, the largest point was in zones 3 or 4 (n=13/15, 86.7%). In cases with the lower end in zone 5, the largest point was in zone 4 (n=2/5, 40%). The largest point was more frequently located in the zone 3 and 4s for both slim types (n=6/8, 75%) and large types (n=10/12, 83.3%). This point was also more frequently found in the same zones (3rd and 4th zones) for both long (n=6/8, 75%) and short types (n=10/12, 83.3%).

Discussion

All of the cadavers dissected in our study had IMATS, an intermuscular adipose tissue mass located in the anterior compartment, mostly in the mid-lower leg, and almost always along the same longitudinal boundary line. The largest portion of the IMATS was located mostly in the upper regions of the lower half of the leg. Morphological features of the IMATS, such as its continuation superficial to the TA and EDL, independent of muscle-muscle or muscle-tendon boundaries, and its consistent association with at least one connecting vein perforating the CF, specify the developmental characteristics of the IMAT.

The only study we could find mentioning an IMAT in the anterior compartment is the ultrasound and dissection study by Ortiz-Miguel et al.[22] which states that this mass enters between the TA and EDL tendons and separates them. According to our observations, IMATS was not inserted between the tendon or muscle fiber groups but was located in the superficial part of the muscle fibers and tendons and surrounded by an epimysial cover. Vettor et al.[5] reported that close anatomical contact between fat and muscle cells can elicit a reciprocal effect and that various myokines and metabolites in muscle can influence IMATS function.

There are conflicting statements regarding the relationship between IMAT dimensions and the amount of subcutaneous fatty tissue.[10,24] Fairclough et al.[24] reported that there was no correlation between the thickness of the subcutaneous fat tissue in the lateral thigh and the IMAT deep in the iliotibial band and suggested that the properties of the IMAT are constant, similar to the Hoffa fat pad, palmar and sole fat pads. In our study, while there was no correlation between SSTt and IMATS dimensions in our study, there was a weak correlation such that the distal end of IMATS approaches the intermalleolar line as SSTt increases, suggesting that the IMATS area may be expanding as the subcutaneous thickness increases. Nevertheless, for a stronger conclusion regarding the IMATS-subcutaneous tissue relationship, subcutaneous fat tissue measurements of different regions (thigh, abdominal wall, etc.) in non-formalin-fixed tissue need to be compared with IMATS dimensions.

It is controversial in the literature whether the amount of IMAT varies by sex. According to Manini et al.[7] thigh and calf IMAT volume is less in healthy young adult men than in women. Goodpaster et al.[10] reported that although women have more subcutaneous thigh fat tissue, there is no difference between sexes in terms of IMAT volume, and Katsiaras et al.[9] also found no difference between genders in terms of thigh IMAT cross-sectional area. Döner et al.[25] found that the IMAT surface area in the Kager triangle of the leg was greater in male. In our study, IMATS width and distance to the anterior edge of the tibia were greater in male. However, regarding their weak correlations with extremity length, which is greater in men, when we proportioned these IMATS parameters to extremity length, it was noteworthy that the sex difference disappeared. Döner et al.[25] found no side differences for the Kager fat pad, an example of IMAT. Similarly, in our study, no side differences were detected in IMATS parameters.

The mechanisms that change the fate of the differentiation process of satellite cells around myofibrils, which are considered as the source of IMAT, towards adipocytes are not clear. It is suggested that, in addition to many factors, mechanical effects and local cellular changes due to trauma also play a role in this.[5] The definition of IMAT as the visible storage of fat deposits resulting in the infiltration of adipose tissue between muscle fibers[4] may suggest that IMAT will be intertwined with the muscle mass from which it originates. Our findings, such as the fact that IMATS is mostly located to the outer surface of both EDL and TA without being segmented, confined along a narrow, oblique line and that it is not inserted between muscle fibers, indicate that the origin and growth history of IMATS cannot be explained only by molecular mechanisms, independent of the anatomical features of the compartment.

Adipocytes that differentiate from satellite cells or other stem cells to form IMATS appear to accumulate in a "selected area" rather than randomly within the compartment. Then, the factors that determine the "selected area" (is it an anatomical potential space, is it an area where the surrounding tissues are more exposed to friction and trauma due to the intensity of tendon movements, is it an area where the CF is less elastic, so requiring elasticity compensation? etc.) requires further research at the anatomical, biomechanical and molecular levels.

The vascular microenvironment is known to play an important role in controlling the fate of normally quiescent satellite cells, a specialized population of stem cells. Satellite cells are anatomically located close to capillaries and therefore can differentiate through molecular interaction with endothelial cells.[26] It has been shown that satellite cells can differentiate into myogenic lineages under different stimuli or into adipogenic lineages using alternative mesenchymal differentiation pathways.[5] Our findings of a constant spatial relationship of 1–3 connecting veins to the IMATS in each case, regardless of the size or type of the IMATS, are remarkable. This relationship, when evaluated together with the literature that satellite cells can differentiate depending on vascular-derived factors and turn into adipose tissue (i.e. IMAT) as well as myocytes, strengthens the claim that these vessels may be associated with the development of IMATS in a specific area in the anterior compartment. More research is needed to clarify the dimensions of such a relationship.

IMAT is considered to have the functions like fill potential anatomical gaps by deforming when a force is applied, to support movement between tendon or ligament and bone, to play a mechanical role due to the presence of a large number of nerve endings in the adipose tissue at the attachment sites, to reduce the load applied to each unit and neurovascular structures and to act as a shock absorber that distributes stress.[1,27,28] Our observations regarding IMATS were that it was a mass that, as its size increased, made room for itself between the muscles and CF on a certain line in the distal half of the compartment, rather than a mass filling an already existing anatomical space between the muscles.

In our previous study, in which we showed that the horizontal elasticity of the CF decreases towards the distal, it was suggested that the traumatic effect of the traction force applied to the CF may be greater in the mid-lower leg.[29] The location of IMATS, deep in the area with lower fascial elasticity, may be the "selected area" to absorb the traumatic effect of the pulling force of the CF. On the other hand, considering that satellite cells of muscles exposed to intense exercise or trauma can differentiate in an adipogenic direction, with the participation of neutrophils and macrophages in the regeneration and repair process and by mechanisms that have not yet been determined,[6] a local repetitive stress in the area may predispose to the formation of such fatty tissue.

It is known that the loading that the lower extremity is exposed to during aerobic exercises such as brisk walking, running, cycling can cause chronic injury, not alone but when combined with a repetitive cyclic pattern.[30] It is thought that the complaint of pain due to medial tibial stress syndrome along the posteromedial tibial border may be a result of inflammation of the IMAT in that area.[21] Considering that during performance, IMATS plays a role in absorbing the load and in distributing the load to the muscle-bone-fascia trio in the leg, it can be inferred that IMATS inflammation due to stress also plays a role in performance-related anterior middle-lower leg pain.

The limitations of the study are that the exposure of the embalmed cadavers to formaldehyde for different periods of time is a factor that may affect the fat volume in the tissue. However, it has been assumed that subcutaneous and intermuscular fatty tissues are equally exposed to this chemical. Volume measurement for IMATS could not be included in the study's method. Histological comparison of IMATS with fat pads such as Hoffa and Kager, whether it contains pain receptors or plays a proprioceptive role was not included in this study and may be the subject of future studies. IMATS was compared with the subcutaneous tissue in the area closest to the area. Whether IMATS dimensions changes in correlation with subcutaneous fat tissue thickness in the same person can be more reliably revealed by taking tissue from other parts of the body (e.g. thighs, abdominal wall, etc.). Only the fat pad superficial to the muscles was evaluated, and deeper fat deposits in the anterior compartment were not considered.

Conclusion

In this study, it was demonstrated that the IMATS is always located subfascially in a fixed, limited area on an oblique line running from lateral to medial top to bottom in the mid-lower part of all anterior compartments and does not penetrate between muscle fibers. The largest point of the IMATS is usually located in zones 3 or 4 and in the two zones closest to the lower end of the IMATS. It is still unclear why the IMATS always develops along a limited and almost identical longitudinal line and what determines whether it is short or long, wide or thin. The remarkable implication of the study is that this location of the IMATS overlaps with the CF region, which is biomechanically stiffer in the transverse direction as described in our previous study. The fact that a connecting vessel is always connected to the IMATS along a fixed longitudinal line, albeit at variable levels, is a finding that reinforces the idea that the developmental history of both the IMATS and the vessel may intersect.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors contributed equally to protocol/project development, data collection, data analysis, manuscript writing/editing.

Ethics Approval

This study was approved by the Clinical Research Ethics Committee (26.04.2023-287) and supported by Mersin University Scientific Research Projects Unit (2023-1-TP2-4903).

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