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ORIGINAL ARTICLE

A Morphometric and Morphological Analysis of Plantaris in Fetal Cadavers

Fetal Kadavralarda Plantaris'in Morfometrik ve Morfolojik Analizi

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ABSTRACT

Objective: The plantaris is a muscle in the back of the leg that has a short body and a long, thin tendon. The muscle acts functionally with the gastrocnemius. Due to removal of the muscle does not cause a change in limb function, it is used as a potential source of graft. The aim of the present study was to investigate the morphological features and possible variations of plantaris in fetal cadavers.
Methods: This study was carried out on the fetal cadaver collection of University of Necmettin Erbakan, Faculty of Medicine, Anatomy Department. 11 male and 9 female fetal cadavers (ages range: 28 to 40 weeks) were used. The muscle belly length (LB), width (WB) and thickness (TB) were measured. The plantaris insertion was classified into 4 types. Furtermore, the distal part of the tendon was classified as the fan-shaped and flat-shaped.
Results: It was determined that plantaris was present in 36 of 40 (90%) lower extremities and absent in 4 (10%). The average muscle belly length (LB), width (WB) and thickness (TB) was found 13.29±3.73 mm, 4.72±1.77 mm and 3.65±1.17 mm, respectively. It was observed that the plantaris tendon often (Type 2, 67.5%) inserts in the anteromedial of the calcaneal tendon. Furthermore, the most common insertion type was observed as flat-shaped (86.11%).
Conclusion: We believe that the data obtained from our study will be useful in procedures such as flexor tendinoplasties, reconstruction of hand tendons and lateral ankle ligaments, and repair of atrioventricular valves, which are planned to be performed in infancy and childhood.

Keywords: Plantaris, fetal cadaver, variation, morphometry, graft, calcaneal tendon, flexor tendinoplasties

ÖZ

Amaç: Musculus plantaris, bacağın arka kısmında yer alan, kısa bir karın ve uzun, ince bir tendona sahip olan bir kastır. Musculus gastrocnemius ile birlikte fonksiyon gösterir. Bu kasın kaldırılması ekstremite fonksiyonunda bir değişikliğe neden olmadığından, potansiyel bir greft kaynağı olarak kullanılır. Çalışmamızda fetal kadavralarda musculus plantaris'in morfolojik özelliklerinin olası varyasyonlarının araştırılması amaçlanmıştır.
Gereç ve yöntemler: Bu çalışma, Necmettin Erbakan Üniversitesi, Tıp Fakültesi, Anatomi Anabilim Dalı'nda yer alan fetal kadavra koleksiyonu üzerinde gerçekleştirilmiştir. Çalışmada gestasyonel yaşları 28 ile 40 hafta arasında değişen 11 erkek ve 9 dişi fetal kadavra kullanılmıştır. Kasın karın uzunluğu (LB), genişliği (WB) ve kalınlığı (TB) ölçüldü. Kas tendonunun sonlanması 4 tip altında sınıflandırıldı. Ayrıca, sonlanma tendonu yelpaze şeklinde ve düz şeklinde olmak üzere 2 grupta sınıflandırıldı.
Bulgular: Çalışmamızda 40 alt ektremitenin 36'sında (%90) musculus plantaris'in var olduğu, 4 (%10) alt ekstremite de ise olmadığı gözlemlendi. Ortalama kas karın uzunluğu, genişliği ve kalınlığı sırasıyla 13.29±3.73 mm, 4.72±1.77 mm ve 3.65±1.17 mm olarak belirlendi. Kasın sıklıkla tendo calcaneus'un anteromedial'ine insersiyo yaptığı (Tip 2, %67.5) belirlendi. Ayrıca, kas tendonunun sıklıkla düz şekilde (%86.11) insersiyo yaptığı gözlemlendi.
Sonuç: Çalışmamızdan elde edilen verilerin bebeklik ve çocukluk döneminde yapılması planlanan fleksör tendinoplastiler, el tendonları ve lateral ayak bileği bağlarının rekonstrüksiyonu, atriyoventriküler kapakların onarımı gibi işlemlerde faydalı olacağını düşünüyoruz.

Anahtar Kelimeler: Musculus plantaris, fetal kadavralar, varyasyon, morfometri, greft, tendo calcaneus, flexor tendinoplasti

Introduction

The plantaris originates as a small muscle from the lower part of the lateral supracondylar line and oblique popliteal ligament and extends downward between the gastrocnemius and soleus. In the form of a tendon on the upper edge of the soleus, it extends down along the medial edge of the calcaneal tendon and usually ends at the calcaneal tuberosity (1). Sometimes the tendon of this muscle may join with the flexor retinaculum of foot and deep fascia of leg (2-5). Since human does not use this muscle to grasp objects like other primates, the plantaris does not play an important role in humans. It is believed that it became atrophied like a foot and evolved towards long-distance walking during the evolutionary process. Therefore, this muscle is considered a vestigial accessory muscle and studies have shown that it is absent in 4% to 20% of the population or double (1,3,6-8). The plantaris is considered unimportant as the knee flexor and ankle flexor because of the moving together with the gastrocnemius (9). Furthermore, it has been reported that it contains 9 times more muscle spindles than the gastrocnemius and acts as a larger and stronger proprioceptive organ for the plantar flexor muscles (3,4).

The plantaris is a potential source of graft for surgeons as it has a long tendon and, if removed, does not affect lower limb function in the presence of a normal soleus and gastrocnemius (10). Because the tension of the tendon is higher, it is used for flexor tendon

replacement in hand surgery (11). It is a potential graft in the anterior talofibular, calcaneofibular and anterior cruciate ligament reconstruction (12,13). It is also used in hernia repair and atrioventricular valve repair (10,11). The morphological structure of plantaris should be taken into account in all these attempts. The distal and proximal parts of the plantaris show a high degree of variation (2,4,5,8,10,14-20). There are many studies conducted on adult groups in which it is aimed to determine both the morphometric properties and the presence of the plantaris (5,6,11,12,14,15,21-24). It has been mentioned in the literature that the course and type of insertion of the plantaris tendon may predispose to the development of Achilles tendinopathies (5,14,25). However, studies in younger age groups are limited. The assumption that calcaneal tendinopathy may be developmentally related to the plantaris has revealed how important the data of studies conducted in younger age groups on the subject can be.

The aim of this study was to determine the morphometric properties of the belly and tendon of the plantaris and the anatomical associations between the course of the plantaris tendon and the calcaneal tendon in fetal cadavers. Furtehrmore, another target was to reveal the variations in the termination of the tendon of the plantaris.

Material and Methods

This study was carried out on the fetal cadaver collection of University of Necmettin Erbakan, Faculty of Medicine, Anatomy Department. Fetal cadavers with morphological anomalies detected by inspection were excluded from the study. The study was performed after approval Drug and Non-Medical Device Research Ethics Committee of Necmettin Erbakan University, Faculty of Medicine date on 16.12.2016 of 2016/764. 11 male and 9 female fetal cadavers with gestational ages ranging between 28 and 40 weeks (3rd trimester according to Polin and Fox (26) were used in the study. The fetal cadavers were through using the immersion technique in 10% formalin. Digital caliper (Mitutoyo, Japan, measuring range: 0-150 mm, precision: 0.01 mm) was used for the measurements of the parameters. First, two superficial incisions were made on the skin in the posterior region of the leg. The first incision was made in the transverse direction connecting the medial and lateral edges of the popliteal fossa. The second incision was made along a vertical line from the midpoint of the popliteal fossa to the calcaneal tendon. During the incisions, the neurovascular structures on the surface were tried to be preserved. The fascia covering the ceiling of the popliteal fossa was slightly lifted from the lateral part. Then, the location of the tibial nerve was determined between the two heads of the gastrocnemius. At this level, it was observed that the distal part of the plantaris belly was located below the branch separated from the tibial nerve and innervating the lateral head of the soleus and gastrocnemius. Then the plantaris belly was followed up to the lateral supracondylar part of the femur, which is the origin point. It was determined that the tendon of the plantaris started from the lateral side of the tendinous arch of soleus (Figure 1). Finally, the course of the plantaris tendon at the gastrocnemius medial edge were determined. In the distal, the relationship between the tendon of the plantaris and the calcaneal tendon was evaluated.

The parameters were measured (Figure 1 and 2);

1. The belly length of the plantaris: The length was measured between the point of origin and the junction of musculotendinous.

2. The belly width of the plantaris: The width was taken from the midpoint of the muscle belly.

3. The belly thickness of the plantaris: The thickness was taken from the midpoint of the muscle belly.

4. The distance between the junction of musculotendinous and where the tendon is visible from the medial edge of the gastrocnemius (LT_1).

5. The distance between the point where the tendon appears from the medial edge of the gastrocnemius and the point where it ends distally in the calcaneus (LT_2).

6. The plantaris insertion classification made by (15) was revised and plantaris insertion was classified into 4 types (Figure 3).

Type 1: Insertion to the calcaneal tuberosity on the anterior of the calcaneal tendon.

Type 2: Insertion to the calcaneal tuberosity on the anteromedial of the calcaneal tendon.

Type 3: Insertion to the calcaneal tuberosity on the posteromedial of the calcaneal tendon.

Type 4: Insertion to the calcaneal tuberosity on the posterior of the calcaneal tendon.

7. Furthermore, the distal part of the tendon of the plantaris was classified in the fan-shaped and flat-shaped (Figure 4).

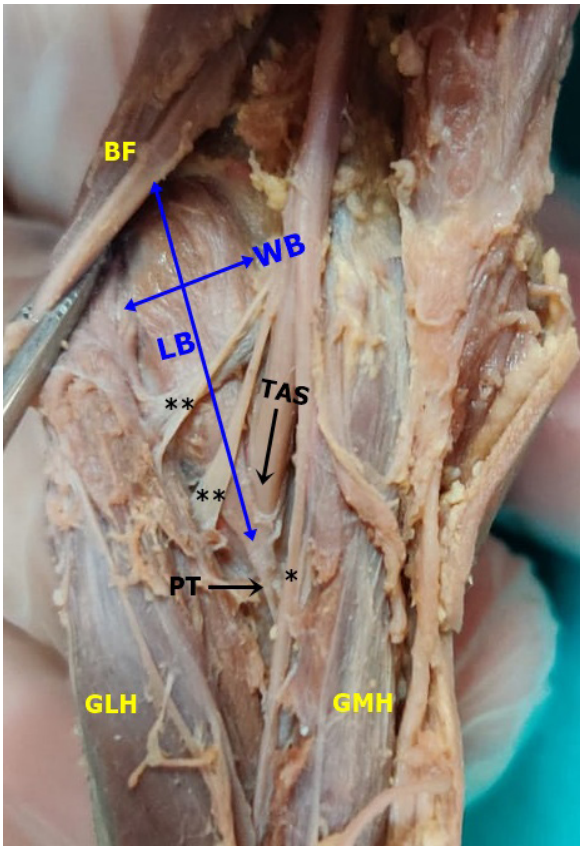

Figure 1: The belly length (LB) and width (WB) measurements of plantaris belonging to the 3rd trimester (TAS: Tendinous arch of soleus, GLH: Gastrocnemius, lateral head, GMH: Gastrocnemius, medial head, PT: The tendon of plantaris, BF: Biceps femoris, *Medial sural cutaneous nerve, ** The branches from tibial nerve)

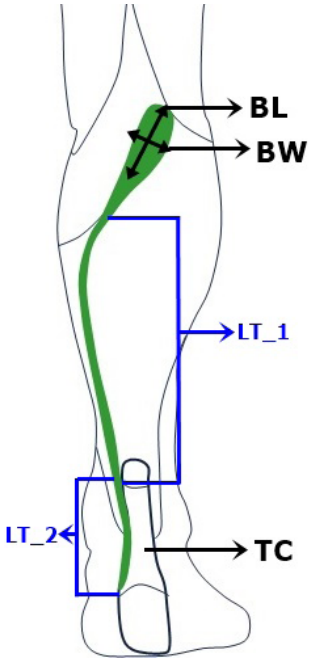

Figure 2: The measurements of plantaris belonging to the 3rd trimester (LB: The length of belly, WB: The width of belly, TC: Calcaneal tendon, LT_1 and LT_2: The tendon lengths of of plantaris in differrent parts)

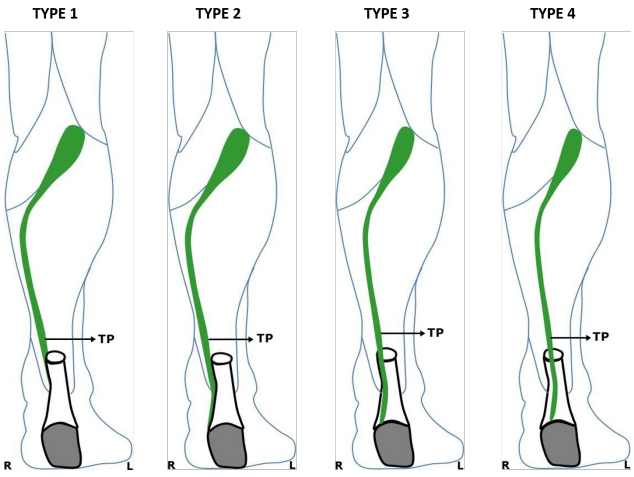

Figure 3: The schematic drawings of plantaris insertion types according to the calcaneal tendon (Type 1: Anterior insertion, Type 2: Anteromedial insertion, Type 3: Posteromedial insertion, Type 4: Posterior insertion, TP: The tendon of plantaris, R:Right, L:Left)

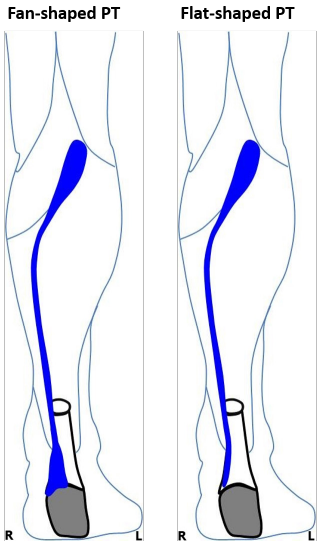

Figure 4: The schematic drawings of plantaris tendon according to insertion shape (R:Right, L:Left).

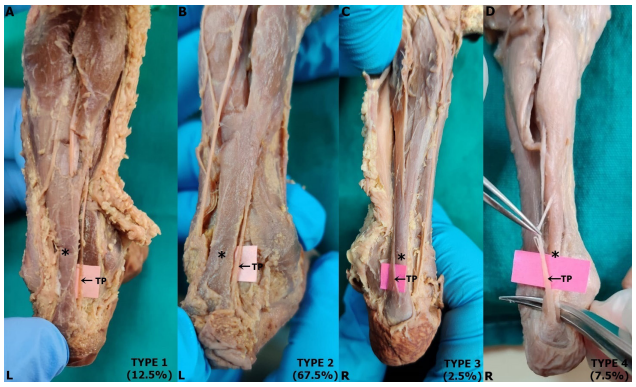

Figure 5: The plantaris insertion types according to the calcaneal tendon in fetal cadavers (Type 1: Anterior insertion, Type 2: Anteromedial insertion, Type 3: Posteromedial insertion, Type 4: Posterior insertion, TP:

The tendon of plantaris, R:Right, L:Left, *Calcaneal tendon)

Figure 6: The plantaris tendon according to insertion shape (A: The fan-shaped, B: The flat-shaped insertion, TP: The tendon of plantaris, R:Right, L:Left, *Calcaneal tendon).

Statistical Analysis

The obtained data for this study were evaluated by SPSS 21.0 (Statistical Package for Social Sciences). First, normality analysis was performed for the data. According to the results obtained through the Shapiro-Wilk test, it was determined that our data showed a normal distribution (Table 1). Then, descriptive (mean, standard deviation, minimum and maximum values) and quantitative statistical methods (Independent T test and Paired Sample T test) were used. Results were evaluated statistically in 95% confidence interval and differences were accepted as significant if $p<0.05$.

Results

The study was carried out on 20 fetal cadavers bilaterally (11 male and 9 female). It was determined that plantaris was present in 36 of 40 (90%) lower extremities and absent in 4 (10%). We found that plantaris was not bilateral in 1 out of 20 fetal cadavers (5%) and not unilateral in 2 of them (10%). On the other hand, 1 (50%) of those with unilateral agenesis were determined to be female, while 1 of them (50%) were male. Unilateral agenesis in female and male fetal cadavers was observed in the right limbs.

The average muscle belly length (LB), width (WB) and thickness (TB) were found 13.29±3.73 mm, 4.72±1.77 mm and 3.65±1.17 mm, respectively. The mean LT_1 was found 23.69±7.70 mm. The mean LT_2 was found 27.60±6.23 mm, too (Table 2). The most common insertion type was found Type 2 (67.5%) within the calcaneal tuberosity on the anteromedial of the calcaneal tendon, followed by Type 1 (12.5%), Type 4 (7.5%) and Type 3 (2.5%), respectively (Table 3, Figure 5). The fan-shaped insertion of plantaris tendon was observed in only 5 (13.8%) of legs. It was determined that the tendon of the plantaris was flat-shaped in almost all of the legs (86.11%) (Figure 6). In 91.6% of fetal cadavers (n=33), the tendon of the muscle was separated from the calcaneal tendon. In 8.3% of fetal cadavers, the muscle's tendon was contiguous to the calcaneal tendon. No statistically significance was observed in the parameters between the body sides and the gender (Table 4 and 5).

Table 1: Test of normality with Kolmogorov-Smirnov and Shapiro-Wilk

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
LB	0.118	36	0.200*	0.959	36	0.202
WB	0.095	36	0.200*	0.947	36	0.082
TB	0.104	36	0.200*	0.967	36	0.340
LT_1	0.101	36	0.200*	0.956	36	0.162
LT_2	0.081	36	0.200*	0.980	36	0.731

(LB: The lenght of the plantaris belly, WB: The width of the plantaris belly, TB: The thickness of the plantaris belly, LT_1:The distance between the junction of musculotendinous and where the tendon is visible from the medial edge of the gastrocnemius, LT_2: The distance between the point where the tendon appears from the medial edge of the gastrocnemius and the point where it ends distally in the calcaneus, *=p<0.005)

Table 2: Mean, mininum, maximum values and standard deviations of parameters in all fetal cadavers

Parameters	N	Min.	Max.	Mean	SD
LB	36	6.44	20.52	13.29	3.73
WB	36	1.71	7.84	4.73	1.77
TB	36	1.20	6.54	3.65	1.17
LT_1	36	0.00	36.79	23.69	7.71
LT_2	36	10.75	41.44	27.60	6.23

(LB: The lenght of the plantaris belly, WB: The width of the plantaris belly, TB: The thickness of the plantaris belly, LT_1:The distance between the junction of musculotendinous and where the tendon is visible from the medial edge of the gastrocnemius, LT_2: The distance between the point where the tendon appears from the medial edge of the gastrocnemius and the point where it ends distally in the calcaneus, N: number of samples, Min.:Minimum, Max.:Maximum, SD: Standard deviation, mm)

Table 3: The frequencies of the insertion types of plantaris tendon (n:number of sample)

Insertion Types	n	%
Type 1	5	12.5
Type 2	27	67.5
Type 3	3	7.5
Type 4	1	2.5
Total	36	90.0

Table 4: Mean, mininum, maximum values and standard deviations of parameters according to the gender

	MALE					FEMALE					
Parameters	N	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD	P
LRB	10	6.44	20.52	13.15	4.46	7	9.59	18.25	14.04	3.25	0.641
WRB	10	2.58	7.16	3.96	1.35	7	2.47	7.67	4.97	1.71	0.215
TRB	10	1.20	4.56	3.34	1.01	7	1.27	4.87	3.59	1.18	0.659
RLT_1	10	10.75	36.79	22.73	8.08	7	13.61	32.41	25.18	5.98	0.484
RLT_2	10	17.86	35.37	27.56	5.89	7	22.84	36.94	29.24	5.73	0.567
LLB	11	6.84	19.33	12.86	4.30	8	9.50	18.36	13.40	2.75	0.746
WLB	11	1.71	6.92	4.59	1.68	8	2.35	7.84	5.66	2.20	0.272
TLB	11	1.91	6.54	3.75	1.29	8	1.20	5.36	3.96	1.31	0.741
LLT_1	11	0.00	32.67	21.64	9.26	8	13.79	34.73	26.42	6.42	0.201
LLT_2	11	10.75	41.44	28.17	8.37	8	19.90	32.17	25.45	3.58	0.352

(LRB and LLB: The lenght of the plantaris belly for the right and left side, WRB and WLB: The width of the plantaris belly for the right and left side, TRBand TLB: The thickness of the plantaris belly for the right and left side, RLT_1 and LLT_1:The distance between the junction of musculotendinous and where the tendon is visible from the medial edge of the gastrocnemius for the right and left side, RLT_2 and LLT_2: The distance between the point where the tendon appears from the medial edge of the gastrocnemius and the point where it ends distally in the calcaneus for the right and left side, N: number of sample, Min.:Minimum, Max.:Maximum, SD: Standard deviation, p: significance value, mm)

Table 5: The comparison of the parameters according to the body sides

	RIGHT LOWER EXTREMITIES					LEFT LOWER EXTREMITIES					
	N	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD	P
LB	17	6.44	20.52	13.52	3.92	19	6.84	19.33	13.09	3.65	0.384
WB	17	2.47	7.67	4.37	1.54	19	1.71	7.84	5.04	1.93	0.107
TB	17	1.20	4.87	3.45	1.05	19	1.20	6.54	3.84	1.27	0.057
LT_1	17	10.75	36.79	23.74	7.19	19	0.00	34.73	23.65	8.34	0.137
LT_2	17	17.86	36.94	28.25	5.71	19	10.75	41.44	27.02	6.77	0.905

(LRB and LLB: The lenght of the plantaris belly for the right and left side, WRB and WLB: The width of the plantaris belly for the right and left side, TRB and TLB: The thickness of the plantaris belly for the right and left side, RLT_1and LLT_1:The distance between the junction of musculotendinous and where the tendon is visible from the medial edge of the gastrocnemius for the right and eft side, RLT_2 and LLT_2: The distance between the point where the tendon appears from the medial edge of the gastrocnemius and the point where it ends distally in the calcaneus for the right and left side, N: number of sample, Min.:Minimum, Max.:Maximum, SD: Standard devitation, p: significance value, mm)

Table 6: Incidence of the absence of plantaris according to the researchers

Researchers	Sample	Technique	Incidence of the absence (unilateral or bilateral)
Daseler and Anson (31)	750 lower extremities	Adult Cadaver	50 (6.67%)
Harvey et al. (37)	658 lower extremities	Cadaver	18.2%
Moss (38)	300 lower extremities	Adult Cadaver	7.3%
Simpson et al. (39)	25 patients	USG	2 (8.7%)
Wehbe (40)	240 lower extremities	Adult Cadaver	19%
Alagoz et al. (24)	34 limbs	Adult Cadaver	5.9%
Dos santos et al. (15)	30 embalmed lower limbs	Adult Cadaver	1(3.33%)
Arago et al. (6)	20 legs	Adult Cadaver	0(0%)
Jakubietz et al. (19)	46 legs	Adult Cadaver	4(8.7%)
Van Sterkenburg et al. (14)	107 lower extremities	Adult Cadaver	0(0%)
Yıldız et al. (23)	48 lower extremities	Fetal Cadaver	3(14.40%)
Joshi et al. (11)	84 lower limbs	Adult Cadaver	8(9.52%)
Kose et al. (41)	480 limbs	MRI	14.8%
Sangeeta et al. (12)	40 embalmed legs	Adult Cadaver	0(0%)
Desdicioğlu et al. (35)	102 fetal legs	Fetal cadaver	44(43.14%)
Jayasree et al. (21)	50 lower limbs	Adult Cadaver	4(8%)
Olewnik et al. (5)	50 lower limbs	Adult Cadaver	2(4%)
Olewnik et al. (22)	130 lower limbs	Adult Cadaver	14(10.8%)
Szaro et al. (36)	36 fix fetuses	Fetal cadaver	9(12.5%)
Waśniewska et al. (1)	47 aborted human fetuses	Fetal cadaver	20(21.3%)
Our study	40 lower limbs	Fetal cadaver	4(10%)

Discussion

The plantaris, which has a short belly and a long tendon, is located in the posterior superficial compartment of the leg together with the soleus and gastrocnemius (6,27). The plantaris differentiates into a superficial-lateral flexor muscle mass together with the soleus and the gastrocnemius in an 11 mm embryo (8,28,29). The plantaris separates from the lateral head of the gastrocnemius in the 2nd month of embryonic life (21,30).

Some researchers consider the plantaris as a vestigial organ because it has little effect on the knee and ankle (7,8,31). Cruveilhier (32) was the first to suggest that the plantaris lost its connection to the lower part of the foot in the evolutionary process and made a secondary connection to the calcaneus and therefore it is a vestigial organ. Although the plantaris has little effect in the presence of other strong flexors such as the gastrocnemius and soleus, the sensory function of this muscle is remarkable. The plantaris moves parallel to the other large flexor muscles between the joints. However, it has been determined that the plantaris, which is a member of the parallel muscle combination, may have a 'kinesiological monitors' function that provide important proprioceptive information to the central nervous system (1,7,8).

The plantaris is a potential source of graft for surgeons. It is used in the reconstruction of the hand flexor tendon and ankle anterior talofibular and calcaneofibular ligaments due to its excellent tensile strength (10,11,16,33). It has also been tried for atrioventricular valve repair (10,11). In recent studies, it has been determined that the plantaris may increase the possibility of tendinopathy due to its relationship with the calcaneal tendon and the tendon of the tibialis posterior (22). Besides, tennis leg is a common clinical condition characterized by rupture of the medial head of the gastrocnemius and acute sports-related pain in the mid-calf. Rupture of plantaris may accompany this clinical condition (34).

In the literature, absence of plantaris are expressed in a spectrum varying between 4-20% in adults. Regarding plantaris in fetal cadavers, the absence of this muscle has been shown to range from 9.5% to 31.4% (1,33-35). We also observed that the plantaris was absent in 4 lower extremities (10%) (Table 6). Waśniewska et al. (1) reported in the study with the highest rate (22-43.14%) of plantaris absence by Desdicioğlu et al. (35) and the lowest (9-12.5%) by Szaro et al. (36). However, the rate (4-10%) we obtained from our study was lower than these researchers.

In our study, the plantaris insertion classification made by Dos Santos et al. (15) was revised and plantaris insertion was classified into four types. In our study, it was determined that the plantaris tendon often inserts in the anteromedial aspect of the calcaneal tendon (Type 2-67.5%) (Table 3). Szaro et al. (36) classified the insertion of the plantaris under five types based on the studies of Olewnik et al. (5) in their study on 36 fetuses. They classified as Type 1 if the fan-shaped plantaris tendon inserts to the anteromedial of the calcaneal tendon, Type 2 if it inserts anteromedial of the calcaneal tendon but has a flat shape rather than a characteristic fan-shaped, Type 3 if it inserts anterior to the calcaneal tendon, Type 4 if it inserts into the crural fascia and Type 5 if it inserts in the posteromedial of the calcaneal tendon. In their study, they determined the most common insertion type as Type 2 (25-34.7%). They specified the following insertion types as Type 1 (22-30.6%), Type 4 (7-9.7%), Type 3 (6-8.3%) and Type 5 (3-4.2%), respectively. When the data obtained from our study were compared with the data of the Szaro et al. (36), it was determined that the plantaris in both studies often made an insertion into the anteromedial part of the calcaneal tendon in the form of a wide-fan or a flat tendon. Unlike the studies of Szaro et al. (36), in our study, the insertion of the plantaris tendon was grouped as fan-shaped and flat-shaped. It was determined that the most frequently observed one in our study was the flat-shaped by 86.11%.

In our study, we found the muscle belly length as 13.29±3.73 mm. Yıldız et al. (23) determined the belly length of the muscle as 17.82±2.26 mm on the right side and 17.34±2.79 mm on the left side in fetal cadavers belonging to the third trimester. Desdicioğlu et al. (35) determined this length as 12.67±2.57 mm in group 2 (26-37 weeks) and 15.97±1.95 mm in group 3 (38-40 weeks). Waśniewska et al. (1) determined this length as 15.9±2.7 mm in fetal cadavers with gestational weeks between 18 and 38 weeks. While our data obtained from our study were compatible with Yıldız et al. (23), it is lower than the data obtained from Desdicioğlu et al. (35). The reason for this was attributed to the low number of full-term fetal cadavers in our study. The average of muscle belly width (WB) was found as 6.0 mm by Desdicioğlu et al. (35), 5.8 mm by Yıldız et al. (23) and 5.7 mm by Waśniewska et al. (1). In our study, this value was specified as 4.73±1.77 mm (Table 2). When compared with other researchers, muscle belly thickness was lower than all of them. It has been suggested that this situation may be related to the fact that fetal cadavers are compressed by other tissues during fixation, resulting in inaccurate results. In our study, unlike other studies, it was determined that in 8.3% of fetal cadavers, the plantaris tendon followed adjacent to the calcaneal tendon.

Conclusion

Our study is one of the limited studies examining the morphometric features of the plantaris on fetal cadavers. It was determined in our stduy, that this muscle was present in 36 of 40 (90%) the lower extremities and the tendon of the muscle often inserted into the calcaneal tuberosity in the anteromedial of the calcaneal tendon (Type 2-67.5%). The data obtained from our study may contribute to the literature in terms of presenting the anatomical features of plantaris in fetal cadavers in detail.

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Author contributions

All authors have participated in conception and design, or analysis and interpretation of the data; drafting the article or revising it critically for important intellectual content; and approval of the final version.

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Ethical review committee statement

This study conformed tothe Helsinki Declaration.

References

1.Waśniewska A, Olewnik Ł, Diogo R, Polguj M. Morphological variability of the plantaris muscle origin in human fetuses. Ann Anat 2022;239:151794.

2.Dalmau-Pastor M, Fargues-Polo B, Casanova-Martínez D, Vega J, Golanó P. Anatomy of the triceps surae: a pictorial essay. Foot Ankle Clin 2014;19(4):603-35.

3.Spina AA. The plantaris muscle: anatomy, injury, imaging, and treatment. J Can Chiropr Assoc 2007;51(3):158.

4.Gonera B, Kurtys K, Karauda P, Polguj M. Possible effect of morphological variations of plantaris muscle tendon on harvesting at reconstruction surgery-case report. SRA 2020;42(10):1183-8.

5.Olewnik Ł, Wysiadecki G, Polguj M, Topol M. Anatomic study suggests that the morphology of the plantaris tendon may be related to Achilles tendonitis. SRA 2017;39(1):69-75.

6.Aragão JA, Reis FP, Guerra DR, Cabral RH. The occurrence of the plantaris muscle and its muscle-tendon relationship in adult human cadavers. Int J Morphol 2010;28(1):255-8.

7.Menton DN. The plantaris and the question of vestigial muscles in man. J Creation 2000;14(2):50-3.

8.Spang C, Alfredson H, Docking S, Masci L, Andersson G. The plantaris tendon: a narrative review focusing on anatomical features and clinical importance. Bone Joint J 2016;98(10):1312-9.

9.Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice, 41st Edition. 2016.

10.Sharma S, Kullar M, Bhardwaj S. Unilateral accessory plantaris muscle: a rare anatomical variation with clinical implications. Glob J Med Res. 2014;14:4H.

11.Joshi MM, Joshi SD, Joshi SS. Morphological variations of muscle plantaris: anatomical and clinical insight. Int J Anat Res 2014;2(4):621-4.

12.Sangeeta M, Varalakshmi K, Naik S. Study of morphometry of plantaris muscle and its clinical relevance. Int J Curr Res 2015;7(11):70.

13.Josipović M, Vlaić J, Serdar J, et al. Plantaris tendon: a novel graft for anterolateral ligament reconstruction and additional reinforcement for anterior cruciate ligament autografts in combined reconstructive procedures. Knee Surg Sports Traumatol Arthrosc 2020:28(8)-2604-2608.

14.Van Sterkenburg MN, Kerkhoffs GM, Kleipool RP, Niek van Dijk C. The plantaris tendon and a potential role in mid-portion Achilles tendinopathy: an observational anatomical study. J Anat 2011;218(3):336-41.

15.Dos Santos MA, Bertelli JA, Kechele PR, Duarte H. Anatomical study of the plantaris tendon: reliability as a tendo-osseous graft. SRA 2009;31(1):59-61.

16.Álvarez MF, Bueno CA, Ballesteros LE. Agenesis of the Medial Gastrocnemius and Plantar Muscle. Case Presentation. Int J Morphol 2017;35(1):34-6.

17.Soni S, Saxena A, Ghulyani T, Rani-Das A. A biceps plantaris in the popliteal region-case report. Eur J Anat 2014;18(1):32-3.

18.Kumar A. Bicipital origin of plantaris muscle–a case report. Int J Anat Var 2011;4:177-9.

19.Jakubietz MG, Jakubietz DF, Gruenert JG, Zahn R, Meffert RH, Jakubietz RG. Adequacy of palmaris longus and plantaris tendons for tendon grafting. J Hand Surg Am 2011;36(4):695-8.

20.Herzog RJ. Accessory plantaris muscle: anatomy and prevalence. HSS Journal®. 2011;7(1):52-6.

21.Jayasree K, Ashalatha P, Nair SS, Joy J. Variations of muscle plantaris: anatomical and clinical implications. JEMDS 2016;5(45):2792-7.

22.Olewnik Ł, Wysiadecki G, Podgórski M, Polguj M, Topol M. The plantaris muscle tendon and its relationship with the achilles tendinopathy. Biomed Res Int 2018;2018.

23.Yildiz S, Kocabiyik N, Çilingiroğlu S, Ozan H. İnsan fetuslarinda m. plantaris' in morfometrisi. Gulhane Medical J 2011;53(3).

24.Alagoz MS, Uysal AC, Tuccar E, Tekdemir I. Morphologic assessment of the tendon graft donor sites: palmaris longus, plantaris, tensor fascia lata. J Craniofac Surg 2008;19(1):246-50.

25.Shaw HM, Vázquez OT, McGonagle D, Bydder G, Santer RM, Benjamin M. Development of the human Achilles tendon enthesis organ. J Anat 2008;213(6):718-24.

26.Polin RA, Fox WW, Abman SH. Fetal and Neonatal Physiology: Expert Consult-Online and Print: Elsevier health sciences; 2011.

27.Yammine K, Saghie S, Assi C. A meta-analysis of the surgical availability and morphology of the plantaris tendon. J Hand Surg Am (Asian-Pacific Volume). 2019;24(02):208-18.

28.Boyle EK, Mahon V, Diogo R. Muscles lost in our adult primate ancestors still imprint in us: On muscle evolution, development, variations, and pathologies. Mol Biol Rep 2020;6:32-50.

29.Diogo R, Siomava N, Gitton Y. Development of human limb muscles based on whole-mount immunostaining and the links between ontogeny and evolution. Development. 2019;146(20):dev180349.

30.Marchi D, Leischner CL, Pastor F, Hartstone-Rose A. Leg Muscle Architecture in Primates and Its Correlation with Locomotion Patterns. Anat Rec 2018;301(3):515-27.

31.Daseler EH, Anson BJ. The plantaris muscle: an anatomical study of 750 specimens. JBJS 1943;25(4):822-7.

32.Cruveilhier J. Traité d'anatomie descriptive: Béchet jeune; 1834.

33.Prakash S, Ojha P. Morphological study of plantaris muscle in cadavers and its clinical significance. Indian J Clin Anat Physiol 2018;5(1):17-9.

34.Delgado GJ, Chung CB, Lektrakul N, et al. Tennis leg: clinical US study of 141 patients and anatomic investigation of four cadavers with MR imaging and US. Radiology 2002;224(1):112-9.

35.Desdicioglu K, Uguz C, Sakallı B, Koyuncu E, Malas MA. Anatomy and variations of plantaris muscle in fetuses. JASI 2015;64(1):79-86.

36.Szaro P, Witkowski G, Ciszek B. The twisted structure of the fetal calcaneal tendon is already visible in the second trimester. SRA 2020:1-8.

37.Harvey FJ, Chu G, Harvey PM. Surgical availability of the plantaris tendon. J Hand Surg Am 1983;8(3):243-7.

38.Moss A. Is there an association between an absence of palmaris longus tendon and an absence of plantaris tendon? Eur J Plast Surg 1988;11(1):32-4.

39.Simpson SL, Hertzog MS, Barja RH. The plantaris tendon graft: an ultrasound study. J Hand Surg Am 1991;16(4):708-11.

40.Wehbé MA. Tendon graft donor sites. J Hand Surg Am 1992;17(6):1130-2.

41.Köse Ö, Ege T, Demiralp B, Sanal T, Bek D, Başbozkurt M. Prediction of the presence of plantaris tendon through examination of palmaris longus tendon. Is there a link? Int J Morphol 2014;32(2):589-592