

AYAĞIN MORFOMETRİK ÖZELLİKLERİNE GÖRE PLANTAR FASYA KALINLIĞININ DEĞERLENDİRİLMESİ

EVALUATION OF PLANTAR FASCIA THICKNESS ACCORDING TO THE MORPHOMETRIC OF THE FOOT

Sinan BAKIRCI¹, Mahmut ÇAY², Ali Yavuz KARAHAN³

¹Izmir Katip Çelebi Üniversitesi Tıp Fakültesi, Anatomi Ana Bilim Dalı

²Uşak Üniversitesi Tıp Fakültesi, Anatomi Ana Bilim Dalı

³Uşak Üniversitesi Tıp Fakültesi, Fizik Tedavi ve Rehabilitasyon Ana Bilim Dalı

ÖZET

AMAÇ: Çalışmamızda plantar fasya kalınlığı ile ayak morfometrik değerleri ve Aşil tendonu kalınlığı arasındaki ilişkinin incelenmesi amaçlandı.

GEREÇ VE YÖNTEM: Araştırma, aktif düzenli spor yapmayan genç gönüllüler üzerinde gerçekleştirildi. Toplamda 64 ayakta (17 erkek, 15 kadın) morfometrik ölçümler yapıldı. Ultrason görüntüsündeki plantar fasyanın kalınlığı ölçüldü. Ayak morfometrik değişkenleri olarak ayak uzunluğu, ayak genişliği, topuk genişliği ve ayak bileği çevresi kullanıldı.

BULGULAR: Genç sağlıklı erkek bireylerin %14,7'sinde plantar fasya kalınlığının 4 mm'den fazla olduğu belirlendi. Genç kadın bireylerin tamamında plantar fasya kalınlığının 3,6 mm'den küçük olduğu görüldü. Erkeklerde plantar fasya kalınlığı ile ayak uzunluğu ve ayak bileği çevresi uzunluğu arasında orta derecede pozitif korelasyon olduğu görüldü ($p<0,05$). Ancak plantar fasya kalınlığı ile ayak genişliği arasında herhangi bir korelasyonun olmaması dikkat çekiciydi. Tüm katılımcılar bir arada değerlendirildiğinde plantar fasya kalınlığı ile ayak uzunluğu, ayak bileği çevresi ve Aşil tendonu kalınlığı arasında orta düzeyde pozitif korelasyon bulunurken, ayak genişliği ve topuk çapı ile zayıf korelasyon bulundu ($p<0,001$).

SONUÇ: Farklı ırk ve coğrafi koşullara bağlı olarak ayak morfometrisi ve plantar fasya verilerinin literatüre eklenmesi anatomistlere ve antropologlara gerekli karşılaştırmaları yapma olanağı sağlamaktadır. Plantar fasiit tanısını desteklemek için kabul edilen "plantar fasya kalınlığının 4 mm'den büyük olması" hem erkekler hem de kadınlar için ayrı ayrı gözden geçirilmeli ve tartışılmalıdır.

ANAHTAR KELİMELEER: Plantar fasya, Aşil tendonu, Ayak, Morfoloji.

ABSTRACT

OBJECTIVE: In our study, it was aimed to examine the relationship among plantar fascia thickness, foot morphometric values, and Achilles tendon thickness.

MATERIAL AND METHODS: The study was carried out on young volunteers who did not engage in any active regular sports. In total, morphometric measurements were performed on 64 feet (17 men, 15 women). The thickness of the plantar fascia on the ultrasound image was measured. Foot length, foot width, heel width, and ankle circumference were used as foot morphometric variables.

RESULTS: It was determined that the plantar fascia thickness was greater than 4 mm in 14.7% of young healthy male individuals. The plantar fascia thickness was found to be less than 3.6 mm in all young female individuals. In men, plantar fascia thickness was found to be moderately positively correlated with foot length and ankle circumference ($p<0.05$). However, it was interesting that there was no correlation between plantar fascia thickness and foot width. When all the participants were evaluated together, a moderate positive correlation was found between plantar fascia thickness and foot length, ankle circumference, and Achilles tendon thickness, while a weak correlation was found with foot width and heel diameter ($p<0.001$).

CONCLUSIONS: The addition of foot morphometry and plantar fascia data to the literature, depending on different racial and geographical conditions, allows anatomists and anthropologists to make necessary comparisons. To support the diagnosis of plantar fasciitis, the accepted "plantar fascia thickness greater than 4 mm" should be reviewed and discussed separately for both men and women.

KEYWORDS: Plantar fascia, Achilles tendon, Foot, Morphology.

Geliş Tarihi / Received: 28.08.2023

Kabul Tarihi / Accepted: 08.11.2023

Yazışma Adresi / Correspondence: Doç. Dr. Mahmut ÇAY
Uşak Üniversitesi Tıp Fakültesi, Anatomi Ana Bilim Dalı

E-mail: mcanatomi@gmail.com

Orcid No (Sirasıyla): 0000-0003-1170-6036, 0000-0002-7757-055X, 0000-0001-8142-913X

Etik Kurul / Ethical Committee: Uşak Üniversitesi Tıp Fakültesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu (18.07.2018/83-05).

INTRODUCTION

The plantar fascia is an important structure that provides support to the arch of the foot (1). While it provides active support to the arch of the foot during the progression phase of gait, it also passively prevents the deformation of the foot (2). Studies show the strong contribution of the plantar fascia to the stability of the foot (3 - 5). It has been observed that people who underwent plantar fasciotomy had a collapse in the arch of their feet and an increase in the tensile strength of the ligaments of the sole of the foot (6, 7).

There is a positive relationship between plantar fascia tension and the load transferred from the Achilles tendon to the sole of the foot. (8, 9). The relationship between the plantar fascia and the Achilles tendon is important for the stability of the foot arch and the resistance of the sole of the foot to the load carried (7, 10). Plantar fascia inflammation is one of the most common foot ailments. It is a condition that manifests itself with chronic heel pain. Ultrasound is important in the diagnostic approach. One of the most common evaluations for plantar fasciitis in cases presenting with heel pain is to look at the plantar fascia thickness on USG. There are several studies in the literature evaluating the relationship between foot morphometry and Achilles tendon thickness (11). However, there was no detailed study examining the relationship between plantar fascia thickness and foot morphometry. In our study, we aimed to examine the possible relationship between plantar fascia thickness, foot morphometry, and Achilles tendon thickness in asymptomatic healthy individuals.

MATERIALS AND METHODS

The study was carried out on 32 healthy and young volunteers aged between 18-22, in 64 feet (17 men, 15 women) in total. The purpose of the study was verbally explained to all individuals participating in the study and the "informed voluntary consent form" was asked to sign. Those with heel pain, inflammatory joint disease, a history of previous foot surgery, or sensory nerve disease were not included in this study. In addition, people who were actively involved in sports such as football, basketball, athletics, and volleyball were excluded from the study. All

measurements were repeated three times by a single researcher. Foot length, foot width, heel diameter, and ankle circumference measurements were taken from both feet of the subjects as morphometric variables. Morphometric measurements were carried out in the Anatomy Laboratory of Uşak University Faculty of Medicine.

Ultrasound Scanning Technique

The volunteers were placed on the examination table in the prone position. Plantar fascia thickness and Achilles tendon thickness measurements were performed by a medical doctor of physical therapy (with an anatomist), (**Figure 1 - 2**).

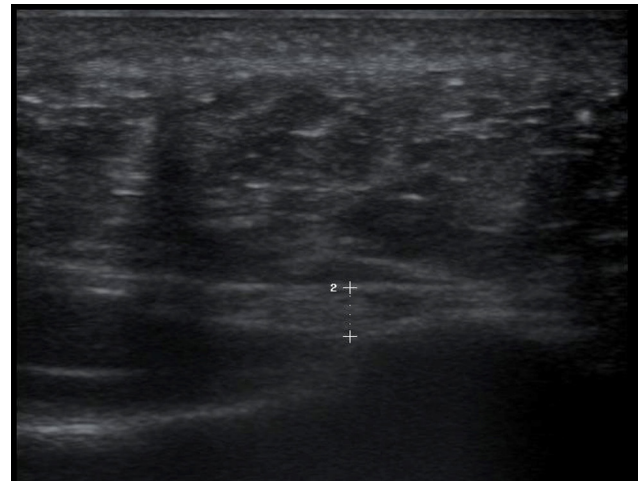


Figure 1: Plantar fascia thickness measurement

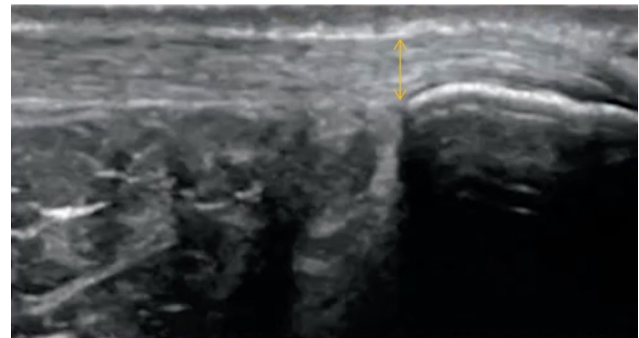


Figure 2: Achilles tendon thickness measurement

Measurements were made on the right and left feet of all volunteers. Standard ultrasound gel and a linear 10 megahertz probe (MINDRAY DC-8 EXP Mindray DS USA, Inc.) were used for measurements. Plantar fascia thickness was measured at the 5 mm distal from medial calcaneal tubercle. The Achilles tendon was measured from the inferior border of the malleus medialis. At the beginning of the measurement process, the probe was placed perpendicular to the long axis of the Achilles tendon and the antero-posterior thickness was measured in the axial plane. In-

dividuals with any pathological condition such as bursitis, calcification, or plantar fasciitis were excluded from the study. The ultrasonographic evaluation was carried out at the Uşak University Faculty of Medicine FTR outpatient clinic.

Ethical Committee

Approval for the study was granted by the Non-Invasive Clinical Research Ethics Committee of the Uşak University Faculty of Medicine (date/number: July 18, 2018/83-05). The informed consent was obtained from the volunteers before starting the study.

Statistical Analysis

Microsoft Office 2016 and IBM SPSS version 20 software (IBM Corp., Armonk, NY, USA) were used for the statistical analysis. The conformity of the data to the normal distribution was tested with the Kolmogorow-Smirnov test. Pearson correlation analysis was used for the correlation between foot morphometric measurements and Achilles tendon thickness and plantar fascia thickness. The independent sample T test was used for the differences between the parties and the genders (12).

RESULTS

The mean (std) values of morphometric variables, plantar fascia thickness, and Achilles tendon thickness for both feet are given in **Table 1**. There was a significant difference between the sexes in terms of all measured variables except the plantar fascia and Achilles tendon thickness of the left side ($p < 0.05$) (Table 1). On the contrary, the differences between the values of the right and left sides were not significant in terms of all variables in both genders Table 1.

Table 1: Mean (std) values of the right and left foot variables of the groups

| | Men | | Women | | p | Total | |
|-------------------|---------------------------|-------|--------|-------|--------|-------|--------------|
| | Mean | (Std) | Mean | (Std) | | Mean | (Std) |
| Right foot | Foot_Length | 26.56 | (1.49) | 23.61 | (1.01) | * | 25.18 (1.96) |
| | Foot_Width | 10.37 | (0.69) | 8.85 | (0.51) | * | 9.66 (0.98) |
| | Heel_Diameter | 6.7 | (0.81) | 5.72 | (0.43) | * | 6.24 (0.82) |
| | Ankle_Circumference | 24.27 | (1.47) | 21.65 | (1.46) | * | 23 (1.96) |
| | Plantar_Fascia_Thickness | 0.33 | (0.74) | 0.28 | (0.38) | * | 0.31 (0.65) |
| | Achilles_Tendon_Thickness | 0.48 | (0.90) | 0.4 | (0.57) | * | 0.44 (0.86) |
| Left Foot | Foot_length | 25.18 | (1.63) | 26.58 | (0.91) | * | 23.58 (2.01) |
| | Foot_Width | 9.53 | (0.74) | 10.26 | (0.60) | * | 8.71 (1.02) |
| | Heel_Diameter | 6.81 | (0.77) | 5.65 | (0.45) | * | 6.27 (0.86) |
| | Ankle_Circumference | 22.83 | (1.38) | 24.11 | (1.44) | * | 21.47 (1.93) |
| | Plantar_Fascia_Thickness | 0.32 | (0.06) | 0.29 | (0.47) | * | 0.31 (0.56) |
| | Achilles_Tendon_Thickness | 0.46 | (0.75) | 0.42 | (0.63) | | 0.44 (0.71) |

* $p < 0.05$ represents only the differences between the sexes. Also there was no statistically significant difference between the right and left side variables.

Plantar fascia thickness was positively correlated with foot length and ankle circumference in men ($p=0.004$; $p < 0.001$). Contrary to expectations, no correlation was found between foot width and heel width, and plantar fascia thickness. Unlike men, there was no correlation between foot morphometric variables and plantar fascia thickness in women (**Table 2**).

Table 2: Correlation analysis of the plantar fascia thickness

| Gender | | Foot length | Foot width | Heel Diameter | Ankle Circumference | Achilles Tendon Thickness |
|--------|---|-------------|------------|---------------|---------------------|---------------------------|
| Men | r | .486** | .254 | .111 | .664** | .463** |
| | p | .004 | .147 | .532 | .000 | .006 |
| | n | 34 | 34 | 34 | 32 | 34 |
| Women | r | .169 | .037 | .109 | .174 | .261 |
| | p | .373 | .847 | .568 | .357 | .164 |
| | n | 30 | 30 | 30 | 30 | 30 |
| Total | r | .523** | .393** | .313* | .553** | .489** |
| | p | .000 | .001 | .012 | .000 | .000 |
| | n | 64 | 64 | 64 | 62 | 64 |

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Achilles tendon thickness correlated with the foot width and ankle circumference variables in men ($p < 0.001$; $p = 0.008$). However, it does not show any correlation with foot length. Achilles tendon thickness correlated only with the foot width in women ($p = 0.002$) (**Table 3**). When all individuals were evaluated in total, a moderate positive correlation was found between Achilles tendon thickness and plantar fascia thickness, and foot morphometric variables (Table 2 - 3).

Table 3: Correlation analysis of the Achilles tendon thickness

| Gender | | Foot length | Foot width | Heel Diameter | Ankle Circumference | Plantar Fascia Thickness |
|--------|---|-------------|------------|---------------|---------------------|--------------------------|
| Men | r | .133 | .568** | .128 | .462** | .463** |
| | p | .452 | .000 | .472 | .008 | .006 |
| | n | 34 | 34 | 34 | 32 | 34 |
| Women | r | -.052 | .552** | -.002 | -.088 | .261 |
| | p | .786 | .002 | .992 | .644 | .164 |
| | n | 30 | 30 | 30 | 30 | 30 |
| Total | r | .346** | .631** | .318* | .412** | .489** |
| | p | .005 | .000 | .011 | .001 | .000 |
| | n | 64 | 64 | 64 | 62 | 64 |

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

Plantar fascia thickness can be affected by many factors and these factors can cause difficulties in clinical interpretation. One of the most important questions that may come to mind is whether gender and foot morphometric values have an effect on plantar fascia thickness. There is an insufficiency in the literature regarding studies evaluating plantar fascia thickness with foot morphometry. In our study, it was found that plantar fascia thickness showed a moderate positive correlation with both foot len-

gth and ankle circumference in men ($p < 0.01$). However, contrary to expectations, no correlation was found between plantar fascia thickness and foot width. It is interesting that, unlike men, no correlation was found between plantar fascia thickness and any of the foot morphometric variables in women. Our study was conducted on a very narrow age range. In their research, Abdul et al. mention a positive correlation between age and plantar fascia thickness (13). Their study results may answer the results we obtained from the women in our study.

Information that the plantar fascia thickness is over 4 mm on USG is interpreted by the clinician as a diagnosis of plantar fasciitis (13 - 15). In our study, the plantar fascia thickness was found to be greater than 4 mm and the maximal plantar fascia thickness was 4.6 mm in 14.7% of healthy young male individuals. Gadala et al. reported that in men, the plantar fascia thickness was greater than 4 mm in 21.5% of the feet and the maximal plantar fascia thickness was 7 mm (16). In our study, the plantar fascia thickness was found to be smaller than 3.6 mm in all young female individuals (unlike the literature). In their study, Gadala et al. reported that the plantar fascia thickness was greater than 4 mm in 26.5% of the feet in women and the maximal plantar fascia thickness value was 5 mm (16). The reason for the difference between these results and the results of our study may be that Gadala et al. studied a very wide age range (17-79 years). Wall et al. found the plantar fascia thickness to be greater than 4 mm in 25% of the feet in women and its maximal value to be 4.2 mm (17). In a study conducted by Abdul et al., they reported that the plantar fascia thickness was greater than 4 mm in 5.1% of individuals and the maximum thickness value was 4.3 mm (13). Both our study and many studies in the literature reveal that the plantar fascia thickness may be greater than 4 mm in some healthy individuals. From the results of Wall et al.'s study, it is understood that the plantar fascia thickness values are above 5.5 mm in the majority of people diagnosed with plantar fasciitis (17). When all these results are evaluated, it may be reasonable to reconsider the "4 mm" limit value mentioned in the literature to help diagnose plantar fascia inflammation. We would also like to draw the attention of clini-

ans to the "vast majority of plantar fascia thickness values" reported in Wall et al.'s article (17).

Plantar fascia thickness has been evaluated with different methods in the literature. Stecco et al. evaluated the plantar fascia in MR images. They found the plantar fascia thickness to be less than 4 mm in all individuals without Achilles tendinitis and its average value was 2.09 mm. They reported the maximum plantar fascia thickness as 2.46 mm in women and 2.43 mm in men (18). The plantar fascia thickness values obtained by Stecco et al. are much smaller than the values obtained in our study (Table 1). The difference between the two studies may be due to the age distribution of the individuals included in the study. In addition, the main reason for the difference may be that the studies were conducted with two different methods such as USG and MRI.

In our study, a statistically significant difference was found between genders in terms of plantar fascia thickness (Table 1). Wall et al. reported that there was no difference between genders (17). One of the reasons for the difference between the results of the two studies may be that the individuals in our study were younger. Wall et al. measured in older individuals, and it is likely that the thickness of the plantar fascia thickens with age (17). As a second reason for the difference between the results of both studies, it can be assumed that there may be racial differences between foot types. In our study, a moderate positive correlation was found between Achilles tendon thickness and both foot width and ankle circumference in both genders ($p < 0.01$). Unlike our study, in their study, Canbolat et al. found a weak positive correlation between Achilles tendon thickness and both foot length and foot width (11). In our study, no significant difference was found between right and left side Achilles tendon thicknesses. However, there are studies in the literature that obtain contrary results, showing lateralization and reporting a significant difference between right and left Achilles tendon thicknesses (19, 20). The possible reason for the differences may be the different age distributions of the people included in the studies or racial characteristics.

There seems to be a need for studies from different races and populations evaluating the cor-

relation between plantar fascia thickness and foot morphometry. To support the diagnosis of plantar fasciitis, the accepted "plantar fascia thickness greater than 4 mm" should be reviewed and discussed separately for both men and women. The fact that plantar fascia thickness does not correlate with foot morphometry in the evaluation of female patients in our society will facilitate the clinician's interpretation of heel pain.

REFERENCES

1. Fessel G, Jacob HA, Wyss C, et al. Changes in length of the plantar aponeurosis during the stance phase of gait--an in vivo dynamic fluoroscopic study. *Ann Anat.* 2014;196(6):471-8.
2. McKeon PO, Fourchet F. Freeing the foot: integrating the foot core system into rehabilitation for lower extremity injuries. *Clin Sports Med.* 2015;34(2):347-61.
3. Huang CK, Kitaoka HB, An KN, et al. Biomechanical evaluation of longitudinal arch stability. *Foot & ankle.* 1993;14(6):353-7.
4. Kitaoka HB, Luo ZP, An KN. Effect of plantar fasciotomy on stability of arch of foot. *Clin Orthop Relat Res.* 1997;344:307-12.
5. Thordason DB, Hedman T, Lundquist D, et al. Effect of calcaneal osteotomy and plantar fasciotomy on arch configuration in a flatfoot model. *Foot & ankle Int.* 1998;19(6):374-8.
6. Gefen A. Stress analysis of the standing foot following surgical plantar fascia release. *J Biomech.* 2002;35(5):629-37.
7. Cheung JTM, Zhang M, An KN. Effects of plantar fascia stiffness on the biomechanical responses of the anklefoot complex. *Clin Biomech.* 2004;19(8):839-46.
8. Erdemir A, Hamel AJ, Fauth AR, et al. Dynamic loading of the plantar aponeurosis in walking. *J BJS.* 2004;86(3):546-52.
9. Józsa L, Kvist M, Bálint BJ, et al. The role of recreational sport activity in Achilles tendon rupture. A clinical, pathoanatomical, and sociological study of 292 cases. *Am J Sports Med.* 1989;17(3):338-43.
10. Huerta JP. The effect of the gastrocnemius on the plantar fascia. *Foot Ankle Clin.* 2014; 19(4):701-18.
11. Canbolat M. A Study of Morphometric Characteristics of Achilles Tendon by Using Ultrasound Imaging Over 18 Years Old Healthy Population. Inonu University, Faculty of Medicine, Department of Anatomy, Doctoral Thesis, Malatya, Turkey 2015.
12. Cohen J. Statistical power analysis for the behavioral sciences. Academic press. 2013.
13. Abul K, Ozer D, Sakizlioglu SS, et al. Detection of normal plantar fascia thickness in adults via the ultrasonographic method. *Journal of the American Podiatric Medical Association.* 2015;105(1):8-13.
14. McMillan A, Landorf K, Barrett J, et al. Diagnostic imaging for chronic plantar heel pain: a systematic review and meta-analysis. *J Foot Ankle Res.* 2011;4:1.
15. Karabay N, Toros T, Hurel C. Ultrasonographic evaluation in plantar fasciitis. *J Foot Ankle Surg.* 2007;46(6):442-6.
16. Gadalla N, Kichouh M, Boulet C, et al. Sonographic evaluation of the plantar fascia in asymptomatic subjects. *Journal of the Belgian Society of Radiology.* 2014;97(5):271-3.
17. Wall JR, Harkness MA, Crawford A. Ultrasound diagnosis of plantar fasciitis. *Foot & Ankle.* 1993;14(8):465-70.
18. Stecco C, Corradin M, Macchi V, et al. Plantar fascia anatomy and its relationship with Achilles tendon and paratenon. *Journal of Anatomy.* 2013;223(6):665-76.
19. Bohm S, Mersmann F, Marzilger M, et al. Asymmetry of Achilles tendon mechanical and morphological properties between both legs. *Scand J Med Sci Sports.* 2015;25:124-32.
20. Ogugua AE, Chukwudi OO, Salami E, et al. Normal thickness of the tendo calcaneus (TCT) in an adult Nigerian population: An imaging based normographic study. *British Journal of Medicine & Medical Research.* 2014;4(10):2100-11.