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Ultrasonographic Measurement of Plantar Fascia Thickness in Patients with Hemiplegia

Hemiplejik Hastalarda Plantar Fasya Kalınlığının Ultrasonografik Değerlendirilmesi

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Abstract

Aim: In hemiplegic patients, changes in load distribution due to spasticity and paralysis cause trauma due to increased pressure and biomechanical problems in the plantar fascia on both sides. The aim of this study was to evaluate the plantar fascia thickness on both plegic and non-plegic sides by ultrasound in hemiplegic patients.

Material and Method: This cross-sectional study included patients with chronic hemiplegia (>6 months) and healthy control individuals. Clinical and demographic features were noted. Plantar fascia was visualized as hyperechoic fibrils by ultrasound. The thickness was measured in both sides and at one cm after the calcaneal connection.

Results: We included forty hemiplegic patients (22 males, 18 females) with a mean age of 58.60±11.8 years; and thirty-six age, sex, and body mass index (BMI) matched healthy subjects. Plantar fascia thickness values were significantly higher on the non-plegic side (3.82±0.1 mm) compared to that of plegic side (2.83±0.6 mm) and healthy groups sides (right side: 2.82±0,5; left side: 2.81±0,6) (p<0,001). There was no relationship found between plegic and healthy group sides (p>0,05). We also found significantly positive correlation between plantar fascia thickness of the non-plegic side and time since stroke (r=0.538, p<0.001) with tonus (r=0.378, p=0.016).

Conclusion: We can conclude that, plantar fascia thickness seems to be increased on the non-plegic side of patients.

Keywords: Plantar fascia, stroke, ultrasonography, walking disabilities.

Öz

Amaç: Hemiplejik hastalarda spastisite ve paralizi nedeniyle yük dağılımındaki değişiklikler bilateral plantar fasyada artan basınç ve biyomekanik problemlere bağlı travmaya neden olur. Bu çalışmanın amacı, hemiplejik hastalarda hem plejik hem de non-plejik taraftaki ve sağlıklı bireylerdeki plantar fasya kalınlığını ultrason ile değerlendirmektir.

Gereç ve Yöntem: Bu kesitsel çalışmaya kronik hemiplejili (>6 ay) hastalar ve sağlıklı bireyler dahil edildi. Klinik ve demografik özellikler not edildi. Plantar fasya ultrason ile hiperekoik fibriller olarak görüntülendi. Kalkaneal bağlantıdan 1 cm sonra hemiplejik hastalarda ve sağlıklı bireylerde bilateral plantar fasya kalınlıkları ölçüldü.

Bulgular: Ortalama yaşı 58.60±11.8 olan kırk hemiplejik hastayı (22 erkek, 18 kadın) ve yaş, cinsiyet ile vücut kitle indeksi (VKİ) uyumlu otuz altı sağlıklı bireyi dahil ettik. Plantar fasya kalınlık değerleri, plejik taraf (2.83±0.6 mm) ve sağlıklı gruplar (sağ taraf:2.82 ±0,50; sol taraf: 2.81± 0,6) ile karşılaştırıldığında non-plejik tarafta (3.82±0.1 mm) anlamlı olarak daha yüksekti (p<0,001). Plejik taraf ve sağlıklı grup plantar fasya kalınlığı değerleri arasında ilişki bulunmadı (p>0,05). Non-plejik tarafın plantar fasya kalınlığı ile inme sonrası geçen süre (r=0.538, p<0.001) ve tonus (r=0.378, p=0.016) arasında anlamlı pozitif korelasyon bulduk.

Sonuç: Hemiplejik hastaların non-plejik tarafında plantar fasya kalınlığının plejik taraf ve sağlıklı bireylere göre artmış olduğu sonucuna varabiliriz.

Anahtar Kelimeler: Plantar fasya, inme, ultrasonografi, yürüme bozuklukları.

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INTRODUCTION

In patients with post-stroke hemiparesis, spasticity, muscle weakness, abnormal muscle motor activity, abnormal muscle synergies, joint contractures, loss of proprioception and consequently mobility and gait disturbances are seen at different clinical levels. Muscle imbalance on the affected side often causes foot and ankle problems. Spasticity of plantar flexors or inverters and inadequate ankle dorsiflexion have been described following a stroke.[1] As a result, because only the forefoot touches the ground in the stance phase, there is no heel strike and the stance phase is shortened.[2] This increases the risk for muscle changes which affect the functional ambulation of walking and standing, and cause mechanical stress. The plantar fascia supports the middle part of the foot and joint metatarsophalanges. It provides stability at the end of the discharge phase and at the beginning of the release phase of gait.[3] Asymmetrical gait disturbances due to spasticity and paralysis are seen in stroke patients,[4] and these may cause increased pressure and biomechanical problems in both the plegic and the intact plantar fascia, and micro tears may also be seen in the plantar fascia.[5] If repeated excessive pressure is applied to the plantar fascia, it causes inflammation at the calcaneal attachment site and ultimately plantar fasciitis.[6] Although plantar fascia problems are common in patients after stroke, proper diagnosis and treatment is important. Ultrasonography has recently started to be used to evaluate the plantar fascia.[7]

To the best of our knowledge, there are few studies which have evaluated the plantar fascia with ultrasound in hemiplegic patients. Ultrasonography is easy to implement, inexpensive, does not expose the patient to ionizing radiation, is widely available, and is an imaging technique that allows for repeated measurements. Accordingly, the aim of this study was to evaluate the plantar fascia thickness using ultrasound on the plegic and non-plegic sides of hemiplegic patients.

MATERIAL AND METHOD

Study design and Participants

This cross-sectional study was conducted between August 2020 and October 2020. The plantar fascia thickness was measured using ultrasound in the plegic and non-plegic feet of ambulatory patients who were admitted to our outpatient clinic or hospitalized after stroke. The patients were selected consecutively.

The study included 40 chronic ischemic or hemorrhagic stroke patients (22 males and 18 females) with walking difficulties who were diagnosed with hemiplegia due to cerebrovascular event in the last 2 years. We also included healthy thirty-six (20 males and 16 females) individuals as a control group. Chronic stroke was defined as a 2-year period that started 6 months after stroke. Demographic and descriptive data such as age (years), gender (male or female), weight (kg), height (m) and lesion side (right or left), etiology, and disease duration were gathered.

A record was made for each patient of ankle joint range of motion and ankle tone, the Functional Ambulation Scale (FAS) score, use of a walking aid, and the presence of pain in the plantar fascia. The Ashworth Scale was used in the evaluation of hemiplegic tone.

Inclusion criteria were: (1) hemiplegic patients diagnosed with stroke at least 6 months prior to the study and (2) ability to walk. The exclusion criteria were defined as: (1) non-ambulatory patients, (2) the presence of ankle injury (fractures, sprains, tears in the post-stroke period) or tendinopathies (3) history of botulinum toxin injection to the gastro-soleus muscles (4) previous surgery in the lower extremities (5) fixed ankle contracture and (6) no cause for pes planus.

Approval for the study was granted by Hospital Ethics Committee (Date: 29.07.2020, Decision No: 1028) and the study was conducted in compliance with the Helsinki Declaration. All patients and the control group signed the informed consent form.

Ultrasound Assessment

The patients were positioned supine with the ankles in a neutral position. Care was taken to keep the ultrasound beam perpendicular to the plantar fascia to avoid anisotropy. The calcaneal attachment was visualized in the sagittal plane. The plantar fascia appears as a "linear fibrous hyperechoic band" against the background of a hypoechoic matrix.[8] The thickness of the plantar fascia was measured at the calcaneus insertion (**Figure 1**). Ultrasonographic examinations of all patients were performed by the same physician. The measurements were repeated thrice, and the average of the three values was used in the analysis. Ultrasonographic evaluations were applied using an ALOKA Prosound Alpha 6 (Hitachi Aloka Medical Systems, Tokyo, Japan) and the images were obtained with a 7.2 MHz linear array transducer.

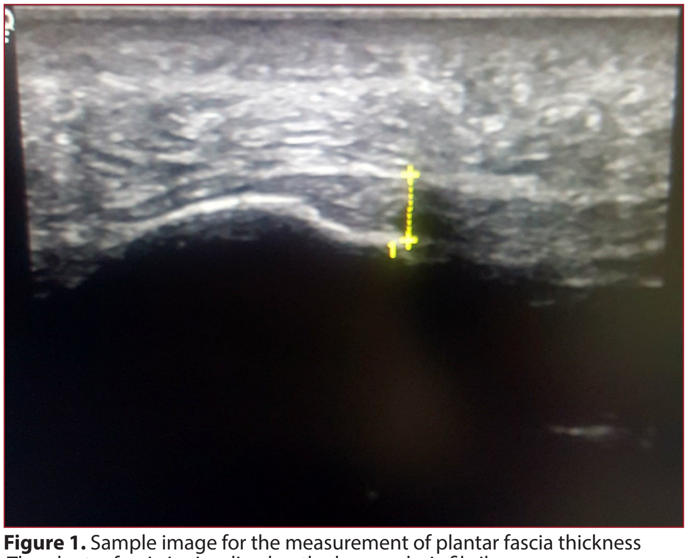

Figure 1. Sample image for the measurement of plantar fascia thickness
The plantar fascia is visualized as the hyperechoic fibrils.

Statistical Analysis

Data obtained in the study were analyzed statistically using IBM SPSS statistics for windows, version 21.0. (IBM Corporation, Armonk, NY, USA) software. Descriptive data were reported as mean±standard deviation (SD) values, number (n) and percentage (%). Conformity of the data to normal distribution was assessed with the Kolmogorov Smirnov Test and histograms. The Paired t-test and one-way analysis of variance were used to compare the plegic, non-plegic sides and healty group values. Pearson's correlation coefficient was used for analyzing correlation between Modified Ashworth Scale, FAS, duration of hemiplegia and the plantar facia thickness within groups. A value of p< 0.05 was accepted as statistically significant.

RESULTS

We enrolled forty consecutive chronic hemiplegia patients (22 males and 18 females) with a mean age of 58.60±11.8 years (range: 26-84 years), and thirty-six (20 males and 16 females) age, sex, and body mass index (BMI) matched healthy subjects (mean age: 57±12.5 years). Pain along the plantar fascia on the hemiplegia side was reported by 5 (12.5%) patients, and pain on the non-hemiplegia side by 12 (17.5%). The clinical and demographic characteristics of the patients are summarized in **Table 1**.

Table 1. Clinical and demographic characteristics

Variables	Hemiplegic Patients (n=40)	Healty group (n=36)	P value
Age (years)	58.60±11.8	57±12.5	NS
Gender			
Male, n(%)	22 (55)	20 (56)	
Female, n(%)	18 (45)	16 (44)	NS
BMI(kg/m^2)	28±4.2	27±3.4	NS
Time after stroke (months)	12 (8-24)	-	
Type of stroke			
Thromboembolic	35 (87.5)		
Hemorrhagic	5 (12.5)	-	
Hemiplegia Side			
Right	19 (47.5)		
Left	21 (52.5)	-	
Use of ambulation orthosis	22 (55)	-	
Functional ambulation category		-	
2	2 (5)		
3	10 (25)		
4	26 (65)		
5	2 (5)		
Modified Ashworth Scale		-	
0	7 (17.5)		
1/1+	9 (22.5)		
2	10 (25)		
3	14 (35)		
Range of Motion		-	
Normal	7 (17.5)		
Limited	33 (82.5)		

BMI= body mass index; NS=Non-significant

Plantar fascia thickness values were significantly higher on the non-plegic side (3.82±0.1 mm) compared to that of plegic side (2.83±0.6 mm) and healthy groups sides (right side:2.82±0.50; left side: 2.81±0.6) (p<0.001) (**Table 2**, **Figure 2**).

Table 2. Comparision of plantar facia thickness mesurements within groups

	Non-plegic side	Plegic side	Healthy group right side	Healthy group left side	P value
Plantar Facia Thickness (mm)	3.82±0.1^{ab}	2.83±0.6^{c}	2.82±0.5	2.81±0.6	<0.001

*P=ANOVA(ono-way analysis of variance), ^{a}p=0,001 versus hemiplegic side, ^{b}p=0,001 versus normal sides, ^{c}p>0,05 versus normal side

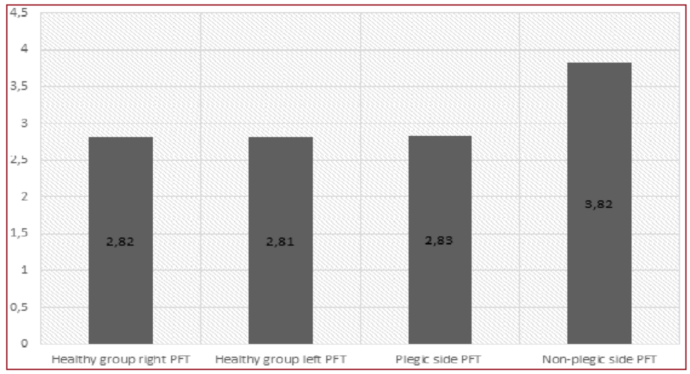

Figure 2. Plantar Fascia Thickness of the Healthy sides, Plegic side, Non-plegic Side
Plantar fascia thickness (PFT) values were significantly higher on the non-plegic side (3.82±0.1 mm) compared to that of plegic side (2.83±0.6 mm) and healthy sides (right side PFT:2.82±0,5; left side PFT: 2.81± 0.6). (p<0,001)

In the correlation analyses, a statistically significant positive correlation was determined between the plantar fascia thickness of the non-plegic side and the time since stroke (r=0.538, p<0.001) (**Figure 3**), and tonus (r=0.378, p=0.016) (**Figure 4**). As the tonus or time since stroke increased, so the plantar fascia thickness of the non-plegic side increased.

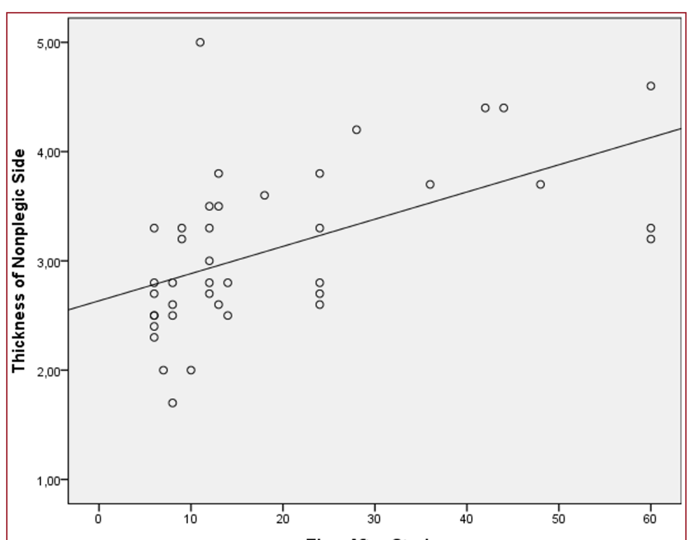

Figure 3. Plantar fascia thickness of the non-plegic side correlated significantly with the time since stroke (r=0.538, p<0.001). As the time since stroke increased, so plantar fascia thickness of the non-plegic side increased.

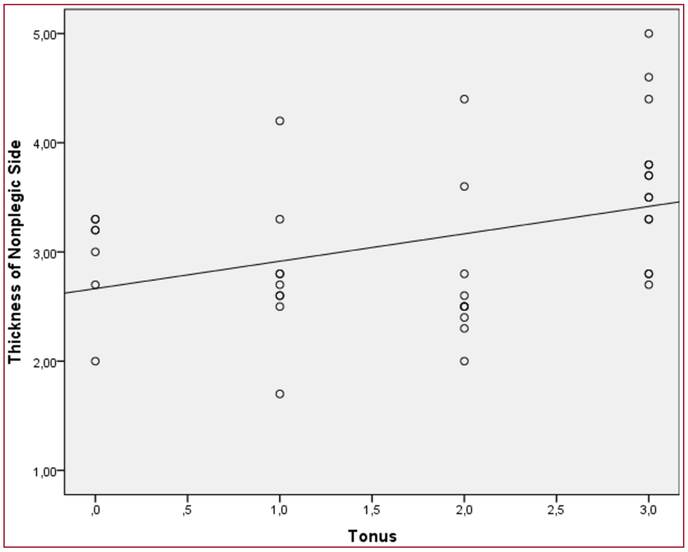

Figure 4. Plantar fascia thickness of the non-plegic side correlated significantly with tonus (r=0.378, p=0.016). As tonus increased, so plantar fascia thickness of the non-plegic side increased.

DISCUSSION

In this study, ultrasonography was used for plantar fascia thickness measurement in chronic stroke patients. According to the study results, it was concluded that chronic stroke patients have a thicker plantar fascia on the non-plegic side and that the plantar fascia thickness of the non-plegic side is significantly correlated with the time since stroke and tone.

The plantar fascia begins in the inner lump region of the calcaneus tubercle and includes the thick middle part and bilateral thinner parts.[9] In the histology of the plantar fascia, the extracellular matrix consists of collagen and elastic fiber, and spasticity causes changes in the alignment of elastic fibers induced by excessive pressure.[10] During ambulation, the plantar fascia plays an important role in supporting the plantar arch during the heel strike, full compression and thrust phases.[9] Therefore, it was thought that ambulation pathologies seen in hemiplegic patients may affect plantar fascia thickness. The study findings support this view, and there were thought to be several factors that could explain these findings.

Spasticity, muscle weakness, abnormal muscle motor activity, abnormal muscle synergies, joint contractures, loss of proprioception and consequently mobility and gait disturbances are seen at different clinical levels in stroke patients. While normal walking tends to be both spatially and temporally symmetrical, post-stroke gait is generally asymmetrical.[11,12] In patients with spastic hemiparesis, the center of foot pressure (CoP) shifts towards the non-plegic side when standing[13] and there is asymmetry in weight bearing.[14] In addition, the oscillation phase is longer than the normal, with prolonged single support time and double support time on the non-plegic side,[15,16] decreased step length on the plegic side, and shortened pressure time. Therefore, it is not easy to transfer body weight from the non-plegic side to the plegic side.[17] It can be considered that the thickness of the plantar fascia on the non-plegic side is affected in chronic stroke due to asymmetry in balance-load transfer.

Hemiplegic patients often have inadequate ankle dorsiflexion due to loss of motor control, spasticity of the gastrocnemius-soleus or invertor group, and / or ankle contracture.[18] These muscle changes affect functional ambulation, leading to an increased risk of mechanical stress on the foot when walking.[19] Spasticity and dynamic varus and plantar flexion deformation are common, especially in the plantar flexors of the ankle joint, which causes difficulties in supporting body weight.[20] In the current study, 35% of the patients had 3 points on the Ashworth Scale, and 25% had 2 points. Thus, the Ashworth Scale score of the spastic ankle was determined to be significantly correlated with the plantar fascia thickness of the non-plegic side.

Therefore, stretching and strengthening exercises for spastic muscles, botulinum toxin injections and solid ankle-foot orthoses in chronic stroke patients aim to stabilize the ankle in a neutral position and provide a more symmetrical and gait close to normal.

Plantar fascia problems in hemiplegic patients have been previously studied in the literature. Park Ji-won et al.[21] reported that plantar fascia thickness on the normal and plegic sides of stroke patients became statistically significant with the degree of spasticity, Riddle et al.[22] found that the risk of plantar fasciitis development was high in normal subjects due to the decrease in the degree of dorsiflexion of the ankle joint, and Irving et al.[23] reported that the decrease in ankle dorsiflexion ROM was significantly associated with the onset of plantar fasciitis. The current study was a cross-sectional ultrasonographic study. Ultrasound imaging equipment is useful for examining plantar fasciitis as it is non-invasive, easy-to-use, and changes in plantar fascia thickness can be easily and rapidly checked.[24,25]

These results were not consistent with those of a study by Tae-Gon Kim et al.[26] which showed that the plantar fascia thickness on the plegic and non-plegic side of the stroke patient group became statistically significant. In the current study, 12 patients had heel pain on the non-plegic side, and the modified Ashworth scale score was 3 in just over a third of the patients (35%). According to the functional ambulation scale, 30% of the patients were at a dependent level. The time since the stroke was 12 months on average (range, 8-24 months), and 55% of the patients used a walking aid or orthosis. In this study, the increase in tone on the plegic side of the patients, their being more dependent according to the FAS level, and the fact that patients with more acute episodes were included compared to similar studies, were interpreted as a change in plantar fascia thickness on the non-plegic side due to incomplete load transfer to the plegic side and the presence of asymmetrical walking.

While previous studies have focused on the plantar fascia content, in this study the function of the lower limb was evaluated with objective assessment on ultrasound of the thickness of the plantar fascia due to stiffness.

There were some limitations to this study, primarily the small sample size, lack of a control group and lack of more walking / functional parameters. In addition, that ultrasonography is user-dependent prevents generalization of the study results.

CONCLUSION

Chronic stroke patients have a thicker plantar fascia on the non-plegic side. In hemiplegic patients, the symmetry of weight transfer between plegic and non-plegic sides when standing and walking is important, and ambulation should be evaluated early in acute stroke patients. Specific treatment approaches based on symmetrical weight transfer between the sides of the body should be the primary focus in the early stages of rehabilitation. In addition, the management of changes in plantar fascia thickness is very important, and spasticity management is as important as treatment, as these changes are ultimately affected by spasticity. In the light of the findings of this study, it can be considered that the early initiation of conventional rehabilitation approaches, including spasticity therapy and balance load transfer, will be beneficial in the correction of foot biomechanics including plantar fascia disorders in hemiplegic patients.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Adana City Training and Research Hospital Clinical Research Ethics Committee (Date: 29/07/2020, Decision No:1028).

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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