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Foot mobility and plantar fascia elasticity in patients with plantar fasciitis

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Objectives: In this study, we investigated the radiologic changes of feet in sagittal plane under weightbearing either with or without plantar fasciitis.

Methods: The study includes 64 feet of the 42 subjects with heel pain (Group 1: 32 women, 10 men, mean age 48 years, range 33-57 years) and 80 feet of the 40 patients (Group 2: 30 women, 10 men, mean age 47.2 years, range 35-56 years) without heel pain. Calcaneal inclination angle (CIA), calcaneal-first metatarsal angle (CMA), and plantar fascia length (PFL) were measured in the lateral radiographs of the weightbearing and non-weightbearing foot. The values of Group 1 and Group 2 were compared.

Results: The mean CIA was 26° (range 18-35°), CMA was 121° (range 115-133°), and PFL was 131 mm (range 110-158 mm) in non-weightbearing position for Group 1. The mean CIA was 27° (range 17-38°), CMA was 122° (range 110-135°), and PFL was 136 mm (range 120-155 mm) in non-weightbearing position for Group 2. The mean CIA was 13.6° (range 5-25°), CMA was 138° (range 130-153°), and PFU was 143.8 mm (range 118-158 mm) in weightbearing position for Group 1. The mean CIA was 9.9° (range 4-25°), CMA was 145° (range 130-155°), and PFU was 151.4 mm (range 137-167 mm) in weightbearing position for Group 2. The difference between CIA, CMA, and PFL values were -13°, 17°, and 12 mm under condition of weightbearing and non-weightbearing position values for Group 1; and -17°, 23°, and 15 mm for Group 2. The differences were significant between weightbearing and non-weightbearing position values ($p<0.05$).

Conclusion: The reduced CIA, CMA, and PFL changes during weight bearing might show reduced foot mobility and plantar fascia elasticity, which may lead to posterior heel pain syndrome.

Key words: Foot; foot mobility; heel pain; plantar fascia, plantar fasciitis.

With the exception of trauma, the most frequent cause of chronic pain in the lower surface of the heel is plantar fasciitis.[1-5] It is generally seen in patients who are older than 40 years of age, overweight, have a sedentary lifestyle, or who are long-distance runners. It is not associated with gender.[3,4] A principal factor in the development of the disease is mechanical overload.[3-10] Impaired biomechanical factors in the foot cause repeated microtrauma in the plantar fascia leading to traction periositis, micro tears, and degenerative changes. It accounts for 15% of all foot complaints in adults and affects approximately 10% of the population at some stage of their life.[3,5,11]

In the literature, chronic plantar heel pain has been reported as painful heel syndrome, plantar fasciitis,

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subcalcaneal bursitis, neuritis, medial arch pain, subcalcaneal pain, calcaneal periostitis, subcalcaneal spur, and calcaneodynia.[11] Although plantar fascia inflammation, entrapment neuropathy, calcaneal spur, painful heel pad, and plantar fascia avulsion have been defined as causes of heel pain, the real causes of heel pain are not always clear.[3,11-14] The occurrence of plantar fasciitis in cases with a body mass index (BMI) between 25 kg/m^2 and 30 kg/m^2 is approximately double, at least triple in cases with passive ankle dorsiflexion of less than 10°, and increases to 3.6 times in those with a history of standing for long periods.[3,11,14-17] Calcaneal spurs are present radiologically in 28% to 66% of plantar fasciitis cases.[15,18,19]

Despite the supporting clinical and static radiographic evidence of a probable relationship between reduced ankle dorsiflexion and static foot posture, the role of the dynamic foot arch function in heel pain is not very clear.[3] The angles and changes of the sagittal plane on lateral radiographs of the foot taken weightbearing and non-weightbearing may be indirect indicators of foot mobility and plantar fascia elasticity and may allow for the dynamic evaluation of the longitudinal arch of the foot.

This study aimed to evaluate the radiological changes occurring in the sagittal plane of the foot during weightbearing in cases of painful heels and pain-free heels.

Patients and methods

This prospective study comprised patients who had presented at our Orthopedic Clinic with complaints of pain on the sole of the heel. Cases were included in the study if they had at least 3 months of continuing heel pain with localised sensitivity of the plantar fascia close to its attachment to the calcaneal tubercle, and if symptoms increased on stepping after a period of non-weightbearing (Group 1). Those cases with less than 3 months of heel pain, who had clinically seronegative arthritis, osteoarthritis, calcaneal stress fracture, or were thought to have median calcaneal neuritis and tarsal tunnel syndrome, or those with a history of previous foot or ankle fracture or with a defective foot structure, were not included in the study. The control group (Group 2) was formed from patients who had presented at the Orthopedic Clinic for reasons other than heel pain.

Lateral foot radiographs, both weightbearing and non-weightbearing, were taken using the standard technique defined by Perlman et al.,[20] in order to evaluate changes in the sagittal plane during weightbearing in both Group 1 and Group 2. The non-weightbearing radiographs were taken with the patient sitting on a chair, and the weightbearing ones with the patient standing with the knees in extension with the heel and first toe at the same level. A film cassette was placed vertically between the feet. Equal weight bearing was desired for both feet while taking the weightbearing radiographs. The radiography unit tube was directed towards the base of the 5th metatarsal, parallel to the floor at a distance of 150 cm from the foot.

The calcaneal inclination angle (CIA), calcaneal-1st metatarsal angle (CMA), and the plantar fascia length (PFL) were measured on lateral radiographs.[21-23] The CIA was defined as the angle between the line tangentially crossing the inferior surface of the calcaneus and the sole of the foot; CMA as the angle between the line tangentially crossing the inferior surface of the calcaneus and the line crossing the midline of the first metatarsal; and PFL as the distance between the posterior surface of the calcaneus and the anterior surface of the head of the first metatarsal. A comparison was made of the values obtained from the radiographs taken of Group 1 and Group 2 weightbearing and non-weightbearing (Fig. 1 and 2).

Statistical analysis was made by SPSS 13.0 statistics program. The difference between the values measured after weightbearing and non-weightbearing was noted, and the changes in PFL were calculated as a percentage. Whether the data showed normal distribution or not was examined using the Shapiro-Wilk test. Normal distribution of the data for both groups was compared using the Mann-Whitney U test; comparison of categorical data was performed using the Pearson chi-square test; and comparison of group dependence was done by Wilcoxon signed rank test. Significance level was defined as $p<0.05$.

Results

Measurements were taken from 64 feet of 42 cases in Group 1 and 80 feet of 40 cases in Group 2. In Group 1, 26 cases had bilateral heel pain, and 16 cases had unilateral heel pain. Of the bilateral cases, two cases had been in plaster for a lateral malleolar fracture within the previous year and each had foot and ankle distortion, and one case had been in plaster for a Jones fracture; thus four feet were excluded from the study. Group 1 consisted of 32 females (76%) and 10 males (24%), with a mean age of 48 years (range 33-57 years). Group 2 consisted of 30 females (75%) and 10 males (25%), with a mean age of 47.2 years (range 35-56 years). There was no significant difference between the groups in terms of age and gender ($p>0.05$).

Calcaneal spurs were present in 25 (39%) of the 64 feet in the plantar fasciitis group and in 17 (21.2%) of the 80 feet in the control group; this difference was statistically significant ($p=0.019$). There was no correlation in either group between the presence of calcaneal spurs and reduction in arch mobility (Table 1).

Fig. 1. Calcaneal inclination angle (CIA), calcaneal-first metatarsal angle (CMA) and plantar fascia length (PFL) measurements on non-weight-bearing lateral foot radiograph.

Fig. 2. Calcaneal inclination angle (CIA), calcaneal-first metatarsal angle (CMA) and plantar fascia length (PFL) measurements on weight-bearing lateral foot radiograph.

Radiological measurements

Group 1 non-weightbearing radiograph measurements were CIA 26° (range 18°-35°), CMA 121° (range 115°-133°), PFL 131 mm (range 110-158 mm); and measurements of weightbearing radiographs were CIA 13.6° (range 5°-25°), CMA 138° (range 130°-153°), and PFL 143.8 mm (range 118-158 mm). Group 2 non-weightbearing radiograph measurements were CIA 27° (range 17°-38°), CMA 122° (range 110°-135°), and PFL 136 mm (range 120-155 mm); and measurements of weightbearing radiographs were CIA 9.9° (range 4°-25°), CMA 145° (range 130°-155°), and PFL 151.4 mm (range 137-167 mm).

While the non-weightbearing CIA and CMA values were similar ($p>0.05$), the difference in PFL values between two groups was significant ($p<0.05$). Each of the 3 values obtained weightbearing showed a statistically significant difference between the groups ($p<0.05$). The difference in CIA, CMA, and

Table 1

Change in CIA, CMA, and PFL with weight-bearing in subjects with or without spur (mean±SD)

	Group 1			Group 2		
	Spur	No spur	p value	Spur	No spur	p value
CIA (°)	12.3±2.4	12.4±2.7	0.97	16.4±2.4	17.2±2	0.28
CMA (°)	16.8±1.6	16.8±1.4	0.72	21.7±4.9	23.2±13.2	0.65
PFL (%)	0.09±0.03	0.10±0.02	0.48	0.11±0.016	0.11±0.02	0.93

CIA: Calcaneal inclination angle, CMA: Calcaneal–first metatarsal angle, PFL: Plantar fascia length.

PFL values from the weightbearing and non-weightbearing radiographs of Group 1 were 12.4°, 17°, and 12.8 mm (9.7%), respectively; and of Group 2 17.1°, 23°, and 15.4 mm (11.3%). A comparison of the values between the groups showed a significant difference ($p<0.05$) (Table 2).

Discussion

Pain in the base of the heel is a widespread orthopedic problem. The etiology of plantar fasciitis is still not well understood, and many factors have been shown to give rise to this complaint. Some of the factors playing a role in the etiology are the anatomic and biological characteristics, which make the person prone to this complaint. These are advancing age, being overweight,[15,17] and pathologies such as reduced ankle dorsiflexion,[5] limb length inequality,[24] thickness of the heel fatty pad, increased thickness of the plantar fascia,[25] pes planus, over-pronation of the foot,[18] pes cavus, imbalance of muscle strength, reduced movement of the first metatarsophalangeal joint,[3] and calcaneal spur.[15-18] In addition to the anatomic and biological characteristics there are known factors of weightbearing for long periods, unsuitable footwear, previous foot injury, and changing conditions of athletes (changes in the running environment, frequency, distance, and surface).[15]

To be able to demonstrate the role played in the etiology of plantar fasciitis by the foot and ankle anatomic structure and function, clinical and static and dynamic radiological studies have been made.[4,5,18,19-22,26,27] In clinical evaluation of the foot arch and movement, definite results may not be obtained from radiological measurements for navicular height, talar height, and arch height and length. Using surface markers to make clinical measurements indicating bone markers does not completely reflect the underlying bones, and it has been shown that the measurements may be inaccurate.[23,28] More definite results can be obtained in studies which have used small screws in the bone to accurately measure bone movements, but difficulties arise in the application, as this is an invasive technique.[29]

Radiographic studies have shown a probable relationship between the foot structure, foot function, and plantar fasciitis, although it has been reported that static radiograph measurements of the foot arch show dynamic foot function poorly.[12,25] However, Saltzman et al.[23] on examining the medial longitudinal arch, designated radiological measurements of the arch structure as the gold standard. The reason for this is that because the bone components of the medial longitudinal arch shown in a two-dimensional image present a clear section, and the reliability of radiological studies is high, they defined a strong correlation between the foot radiographic parameters and lower extremity injuries. On the other hand, it is possible to evaluate the foot arch movement in vivo using computerised fluoroscopy.[21] However, appropriate facili-

Table 2

Non-weight-bearing CIA, CMA, and PFL values with the changes with weight-bearing (mean±SD)

	Group 1	Group 2	p value
Non-weight-bearing			
CIA (°)	26±3.9	27±5	0.11
CMA (°)	121±4.3	122±4.5	0.07
PFL (mm)	131±10.5	136±6.9	<0.01
Change with weight-bearing			
CIA (°)	12.4±2.6	17±2.1	<0.01
CMA (°)	16.8±1.5	23±11.9	<0.01
PFL (%)	0.10±0.03	0.11±0.02	0.017

CIA: Calcaneal inclination angle, CMA: Calcaneal–first metatarsal angle, PFL: Plantar fascia length.

ties are necessary for this technique, and its application is difficult. From radiographs taken both weightbearing and non-weightbearing, calculations of changes created in CIA, CMA, and PFL values yield sufficient information about the movement of the sagittal plane of the foot. To the best of our knowledge, there is no other study evaluating foot arch movement and indirectly the plantar fascia elasticity using the same technique, and we believe this technique to be easy to apply with a low risk of error.

Static foot posture has been evaluated in various clinical and radiological studies.[4,18,21,26,27] This study proposes that there may be a higher occurrence of plantar fasciitis in feet with either low or high arches. In a study by Prichasuk and Subhadrabandhu[18] examining the radiographs of 82 painful heels and 400 normal cases, the CIA value of the normal cases when weightbearing was 20.54°, whereas in the painful heel cases it was 15.99°. The findings support the idea that a low calcaneal pitch angle, advancing age, and increasing body weight parallel decreasing CIA, thereby increasing the load on the sole of the foot and playing an important role in progressing the development of plantar fasciitis.

Conversely, it has been reported that a high arch foot type is a factor in the development of plantar fasciitis.[3,4] Taunton et al.,[4] in a 2002 retrospective examination of running injuries, found that in 159 cases of plantar fasciitis, 30 (19%) were had an abnormal arch structure (pes planus, pes cavus). However, no relationship was shown between abnormal arch structure and plantar fasciitis in the study by Wearing et al.[21] In an in vivo biomechanical study by Kim and Voloshin,[8] it was reported that an increase in the load from impaired foot mechanics on the plantar fascia, of the total load on the foot, 14% was taken on the plantar fascia and 86% on the intrinsic foot muscles, extrinsic muscle tendons, and other structures of the foot arch. In our study, in an examination of the non-weightbearing static radiographs, the mean CIA values of Group 1 and Group 2 were found to be similar. In the weightbearing measurements, the CIA of the plantar fasciitis cases was found to be higher. When the measured values were evaluated among themselves, no direct relationship was found between plantar fasciitis and the foot arch structure. The reason for the higher CIA values in comparison with the control group from the examination of the weightbearing radiographs is that the plantar fasciitis cases may have reduced foot arch movement. Therefore, we are of the opinion that plantar fascia elasticity and foot mobility are reduced when the foot arch is excessively high or low, thus increasing the load on the plantar fascia.

Various studies have been made oriented to the response of the plantar fascia to the load which occurs on it during weightbearing by the foot. Some of these were studies under laboratory conditions or on the feet of cadavers or in vitro studies on biomechanical models. In an in vitro study by Wright and Rennels[30] of lower limbs amputated because of ischemia, evaluation was made of the deformity extension occurring in the plantar fascia with loading; it was found that there was a 3.5% to 4.5% extension in the plantar fascia when a load was applied. Arangio et al.[31] found a 7.3% extension in the plantar fascia with loading in a study using a biomechanical model. According to the techniques used in in vitro studies, although various rates of extension have been measured in the plantar fascia, the data may not exactly coincide with in vivo conditions.[32] Therefore, different dynamic methods of measurement have been developed for use in in vivo studies to evaluate the anatomic structure and function of the foot and ankle. Although more accurate results are obtained from the direct measurement method of inserting small screws into the bone, difficulties arise, as this is an invasive procedure.[29] Recent research has developed noninvasive methods. In a study by Gefen,[32] the plantar fascia in vivo elastic properties during the contact phase of walking were evaluated by recording skeletal movements with radiographic fluoroscopy combined with a pressure-sensitive optical walking platform. From the measurements of cases with no foot complaints, a deformation and elongation of the plantar fascia of 9% to 12% was found. In this situation, it has been reported that an important factor may be an alternating-crosswise structure (rather than straight) in the arrangement of the collagen and elastic fibres created by the plantar fascia during weightbearing.

Another dynamic study of plantar fasciitis cases by Messier and Pittala[27] examined the foot arch movement from film taken during 5 min running. No difference was found in these variables between the study and control group. Wearing et al.[21] used digital fluoroscopy to obtain dynamic lateral radiographs of the foot in a comparison of 10 unilateral plantar fasciitis cases and 10 normal cases. No difference was found between two groups in the foot arch and arch movement. Thus no relationship was seen between chronic plantar fasciitis and low arch types or increase or decrease in medial longitudinal arch sagittal movement while walking. In the same study of plantar fasciitis cases, the dynamic low arch feet were found to have increased fascia thickness. The same increase was not shown in the normal feet, despite their similar arch shape and movement. Supporting this, it was reported that the mechanical role of the plantar fascia arch started after the first injury mechanism; then after symptoms developed, the dynamic arch shape was affected by loading of the plantar fascia. However, the sample of this study was small (n=10).

Although in the past, calcaneal spurs were thought to be the cause of heel pain, they are now accepted as a result of the pathologic process.[14,17] The rate of calcaneal spurs observed in plantar fasciitis is high. In a study by Prichasuk and Subhadrabandhu[18] calcaneal spurs were found in 66% of the plantar fasciitis cases and in 15.5% of the control group, and they emphasized an increase in the frequency of spurs observed in women over 40 years of age. In another study of painful heel cases by Ürgüden et al.,[14] the presence of calcaneal spurs was seen in 58% of the painful side and in 37% of the pain-free side. Rano et al.[15] determined that in plantar fasciitis patients, those without spurs were more active, and the period before symptom development was shorter in cases with spurs. A rate of 15% has been observed in cases with no foot complaints.[33] In our study, calcaneal spurs were found in 39% of the plantar fasciitis cases and in 21.2% of the control group; this difference was statistically significant (p=0.019). However, no correlation was shown between presence of calcaneal spurs and reduced arch mobility in either group.

One limitation of our study is that the BMI was not measured in either the plantar fasciitis cases or the control group. A high BMI may affect the angular values measured in the foot.[18] Also, using a one-dimensional measurement of plantar fascia deformation in lateral foot radiographs, when in reality this tissue has three-dimensional movement, may give rise to comments of some limitations of the results. However, we are of the opinion that the radiological technique which was used gives sufficient information about arch movement during weightbearing on the foot and consequently foot mobility and plantar fascia elasticity.

A comparison in our study of the plantar fasciitis cases with the cases with no foot complaints determined that in the plantar fasciitis cases, when there was weightbearing of the foot with arch movement, there was a reduction in plantar fascia elasticity. We are of the opinion that this proven reduction in arch movement and plantar fascia elasticity may increase the load borne by the plantar fascia and be a factor in the start of the pathology in the plantar fascia.

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