CHAPTER **50**

BIOMECHANICS AND PLANTAR FASCIITIS: A Radiographic Study

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BACKGROUND

Plantar heel pain is an extremely common complaint heard by foot and ankle specialists, and plantar fasciitis is the most commonly made diagnosis. The differential diagnosis for plantar heel pain is actually quite broad and includes entrapment neuropathy (the first branch of the lateral plantar nerve), stress fracture of the calcaneus, infection, inflammatory arthritis, and plantar faciitis (Table 1).

The problem of a painful plantar heel also goes by many names: heel pain syndrome, heel spur syndrome, and chronic plantar heel pain are just a few. But, probably the most widely accepted and used term for this condition is plantar fasciitis. It has been estimated to account for nearly 15% of all adult foot complaints, and affect 2 million Americans per year, and perhaps 10% of the population over a lifetime.[1,2]

Plantar fasciitis is considered an overuse syndrome, and has been found to be increased in prevalence among athletes, overweight individuals, and those who are on their feet for the majority of the day. However, little is known as to the exact etiology of plantar fasciitis. Risk factors identified in the literature are numerous and include, but are not limited to, increased age, increased body mass index (BMI), reduced ankle joint range of motion, limb length discrepancy, low[3,4] or high arched foot, calcaneal spur, prolonged weightbearing, and improper foot wear.[2] Risk factors for plantar fasciitis can further be categorized into intrinsic or extrinsic factors. Intrinsic risk factors are biologic, or biomechanic characteristics, whereas extrinsic factors exist outside the body, like patient shoe wear, occupation, activity level, and so forth.[2,3,5] In the systematic review by Irving et al,[1] they identified strong relationships between body mass index and calcaneal spur, and plantar fasciitis. Less strongly associated factors included increased age, decreased ankle joint dorsiflexion, decreased first metatarsophalangeal joint extension, and prolonged standing. Calcaneal spur, long thought to be the cause of painful heel syndrome, is probably not the cause of plantar fasciitis, though several studies have found it strongly associated with the condition.[4-6] One study,[7] found the heel pad of patients with plantar heel pain syndrome to be stiffer than the contralateral painless side by an ultrasound method. Clearly, the pathoetiology of plantar fasciitis is multifactorial. The exact pathology of plantar fascitis is even a subject of debate, with several studies suggesting the very name for this condition is erroneous because there is a histologic lack of inflammatory findings, and therefore it is more consistent with a degenerative process (fasciosis).[8,9]

It has been suggested that the underlying etiology of plantar fasciitis is of biomechanic etiology; specifically identified are abnormal subtalar joint pronation,[10,11] midtarsal joint supination along its longitudinal axis,[12] and ankle joint equinus[13] as possible underlying biomechanic etiologies. Scherer et al[12] reported that 86% of symptomatic feet with heel spur syndrome demonstrated supination around the longitudinal axis of the midtarsal joint. Kibler et al[13] found individuals with plantar fasciitis to have significantly weaker calf muscles, and ankle joint dorsiflexion than control subjects and contralateral,

Table 1

DIFFERENTIAL DIAGNOSIS IN PLANTAR HEEL PAIN

- Paget disease
- Rupture of plantar fascia
- S1 radiculopathy
- Sickle cell disease
- Spondyloarthropathy (ie, Reiter syndrome, ankylosing spondylitis, psoriatic arthritis)
- Tarsal tunnel syndrome
- Abductor digiti quinti nerve entrapment
- Bone bruise
- Calcaneal epiphysitis (Sever disease)
- Calcaneal stress fracture
- Fat-pad atrophy
- Heel contusion
- Inflammatory arthropathies
- Neuropathic pain

asymptomatic limbs. A so-called "flatfoot" has often been implicated in the pathogenesis of plantar fasciitis.[1,5,11] Shama et al[10] looked at 1,000 random foot radiographs and found that the feet of those individuals with painful heel spurs were more pronated on weightbearing foot radiographs, than those who had spurs but were not painful, thus establishing a relationship between pronation and "painful heel spurs."

The diagnosis of plantar fasciitis has been well described, is usually fairly straightforward, and is typically made by a thorough history and careful physical examination only. Subjective symptoms include infracalcaneal heel pain, often worse with first step in the morning or with first step after a period of nonweightbearing. This has been referred to as post static dyskinesia. Objective findings include tenderness to palpation at the inferior medial calcaneal tubercle, and possibly, subtle swelling or tenseness to the heel. Sometimes pain can be exacerbated by dorsiflexing the toes and palpating at the same time, which puts increased tension on the plantar fascia, by activating the windlass mechanishm. Radiographs will often reveal calcaneal spur, but not always. Plantar fascial thickness and fat pad abnormalities can also be seen and may be helpful in the diagnosis.[6] If further tests are needed to make the diagnosis, ultrasound and magnetic resonance imaging (MRI) can both show abnormal thickening of the plantar fascia. Additionally, MRI can show increased edema of the fascia, and also marrow edema of the adjacent medial calcaneal tubercle.[14]

The treatment of plantar fasciitis is as varied as the terminology used to describe it, and the clinical features associated with it. Randomized, controlled trials have demonstrated the effectiveness of foot orthotics and strappings,[15-20] night splints, various injection therapies,[21] oral nonsteroidal anti-inflammatory medications,[22] and stretching exercises.[23,24]

Radiographic angles have been used for a long time to assist in managing foot and ankle disorders. They are considered a standard part of the radiologic examination of the foot and ankle. Normal values for these angles have been established, with usually small differences among investigators in describing what is "normal" for various angles. Angular measurements of the foot and ankle are often thought of as structural or positional. Some angles change significantly with the various motions and movements of the foot. Other angles change very little with motion, often because they are created by bony structures that are fixed in their position. Looking at these angles all together often helps the clinician assess the static position of the foot, whether it is pronated, supinated, or neutral. These radiographic parameters, when combined with the clinical impression, are helpful to the clinician to understand the presenting foot dysfunction, and thus guide therapy.

The purpose of this study was to evaluate the radiographic angles of foot position and structure in a group of patients with plantar fasciitis, and see how these angles varied from normal values that are reported in the medical literature.

The goal of this study was to determine if people with plantar fasciitis have an associated pronated, supinated, planus, or cavus foot, as determined by weightbearing, angle, and base of gait radiographic analysis. The null hypothesis is that plantar fasciitis is not associated with a pronated, supinated, planus, or cavus foot. In other words, their angular measurements will not be different from the normal values. The alternative hypothesis is that plantar fasciitis is associated with a pronated, supinated, planus, or cavus foot type.

MATERIALS AND METHODS

The medical records from a multipractitioner private practice were retrospectively reviewed from January 1, 2004 to December 18, 2006. Eighty-four consecutive patients, representing 109 feet, who received a diagnosis of plantar fasciitis during that period, were identified. Demographic data on each patient, including age, sex, height, and weight were recorded. Duration of symptoms was recorded for each patient and for each foot, if both sides were involved. All of these data were self reported.

Some patients received a unilateral diagnosis; data regarding this foot was recorded. Other patients had a bilateral diagnosis and therefore had both feet included in the study. Bilateral cases were segregated by the most painful side. In this particular private practice, it was usual practice to obtain weightbearing foot radiographs in angle and base of gait[25] on nearly all patients presenting with infracalcaneal heel pain. Individuals were largely diagnosed by history and physical examination, and radiographs were taken to rule out less common bony pathology as a cause of pain, as well as to evaluate foot structure and function. Only patients with radiographs taken at time of presentation were included in this study. These radiographs were obtained by experienced medical staff, with years of radiologic experience, and all knowledgable and well trained in obtaining radiographs in the angle and base of gait.

Inclusion criteria for the study included any subject with a diagnosis of plantar fasciitis. Exlcusion criteria included any person with infracalcaneal heel pain not consistent with plantar fasciitis, and history of trauma or surgery to the heel.

There were 49 females and 35 males, average age 49.4 ± 14.1 years (21-79 years). Twenty-five patients had bilateral presentations; therefore 109 feet were included in the study. Average height was 67.6 ± 4.4 inches (59-80 inches). Average weight was 189.6 ± 44.8 pounds (106-320 pounds). Average BMI was 29.3 ± 7.1 (15.7-60.5); this is considered overweight, but not obese. BMI is calculated by the following formula: weight (lb) /[height (in)]^2 x 703. Average duration of symptoms for all of the feet was 10.3 ± 9.2 months (0.25-36 months). Table 2 shows the patient's physical characteristics.

Independent sample *t*-test was performed and indicated that there was no statistical difference between the BMI of the men and women in this study ($P = 0.100$). There was also no statistically significant difference between the age of men and women studied ($P = 0.409$). Statistical analysis of all data in this study was performed by using Microsoft Excel and EzAnalyze computer software. Statistical significance was considered at the $\alpha = 0.05$ level.

Twenty-five patients had bilateral plantar fasciitis; comparing these individuals with those who had only unilateral diagnosis, there was no statistically significant difference of age ($P = 0.166$), or BMI ($P = 0.796$). There was, however, a difference between duration of symptoms ($P = 0.001$), and this was significant (Table 3).

All radiographic foot angles were made by hand, by the author, using a standard, commercially available goniometer. The same goniometer was used throughout the entire study. The radiographs were positioned onto a standard view box. A radiographic pencil was used to mark directly onto the radiographs, and then the measurements were made directly from these markings. Radiograph angles taken in this manner are reliable and reproducible.[26,27]

The concept of what is "normal" and abnormal in the foot and ankle has been a subject of debate for a long time, and the radiographic angles used to define the foot are certainly no exception. Definitions of the various angles have been described previously by numerous authors,[28-31] and "normal" values have been established. Although, there is some question as to how scientifically rigorous some of these previous studies came about their normal values. A recent report in the literature[31] suggests this problem as well, and also notes that not much work has been done recently to identify normal values, thus the need for their own study. The present study is not meant to be an authoritative or definitive study of the "normal" radiographic angles in the adult foot.

Thomas et al[31] examined most of the traditionally measured angles of the foot with the exception of 2 angles that were used in the present study; cuboid abduction (CA) angle and talonavicular coverage (TNc) angle. The study by Thomas et al evaluated 200 feet of 50 men and 50 women. Excluded were any persons with history of osseous foot surgery, or foot trauma; the same criteria used for the present study. They were essentially "normal," asymptomatic feet. CA angle has been reported several times,[28-30] and the TNc angle has been described by several others as well.[33-35] Table 4 shows the values for normal feet found by Thomas et al. However, a few discrepancies and important differences are evident. For example, in measuring the metatarsus adductus (MA) angle, they used a modified forefoot reference line; perpendicular to the base of the intermediate cuneiform. This line is actually similar to the angle described by Engel et al[36] Thus, the MA angle in Thomas et al's report is actually an overestimation of a true MA angle, but is really more of an Engel's angle. Definitions and values of these angles are in Table 4.

In the anteroposterior view, 5 angles were measured: talocalcaneal (TC; Kite's) angle, TNc angle, MA angle, forefoot adductus (FA) angle, and CA angle. In the lateral view, four angles were measured: calcaneal inclincation (CI) angle, talar declination (TD) angle, lateral talocalcaneal (lTC) angle, and lateral talus-first metatarsal (lat talo-first met; Meary's) angle.

Again, another important difference is present in the Thomas study. For the CI angle, the inferior reference they used is the support surface of the foot. However, traditionally the line formed from the calcaneal tubercle

Table 2

PATIENT PHYSICAL CHARACTERISTICS

84 patients (49 female, 35 male) 109 feet

	Mean ± SD
Age (years)	49.4 ±14.1
Height (inches)	67.6 ± 4.4
Weight (pounds)	189.6 ± 44.8
Body Mass Index	29.3 ± 7.1

Table 3

DURATION OF SYMPTOMS

	Months (mean ± SD)
Unilateral	5.469 ± 7.450
Bilateral	12.920 ± 11.045

Table 4

DEFINITIONS OF RADIOGRAPHIC ANGLES: ANTEROPOSTERIOR[30]

		Mean ± SD	Structural or Positional
Metatarsus adductus (MA) angle	Angle formed by the bisection of the forefoot (bisection of the 2nd metatarsal) and the bisection of the lesser tarsus (modified forefoot reference line, perpendicular to the base of the intermediate cuneiform, similar to Engel's angle[39])	17.9 ± 5.3	Structural; not effected by pronation or supination
Talocalcaneal (TC; Kite's) angle	Angle formed by the bisection of the head and neck of the talus, and the bisection of the tarsus (calcaneal bisection line)	21.1 ± 6.0	Postitional; increases in pronation, decreases in supination
Talonavicular coverage (TNc)	Angle formed by the bisection angle of the head and neck of the talus, and the bisection of the navicular	7 ± ? (no SD found)	Positional; increases in pronation, decreases in supination
Forefoot adductus (FA) angle	Angle formed by the bisection of the tarsus (calcaneal bisection line) and the bisection of the forefoot (bisection of the 2nd metatarsal)	13.2 ± 5.8	Positional; decreases in pronation, increases in supination
Cuboid Abduction (CA) angle	Angle formed by the bisection of the tarsus (calcaneal bisection line) and a line along the lateral border of the cuboid	Range 0-5 (no mean, or SD found)	Positional; increases in pronation, decreases in supination

to the base of the fifth metatarsal head is used. Thus, the CI angle is underestimated. Similarly, the talar declination (TD) angle is overestimated, compared with traditional values, by using the support surface as the reference line. Definitions and values of these angles are in Table 5.

RESULTS

Of the anteroposterior angles, of the 109 feet examined in this study, the average MA angle was 14.8 ± 4.3 degrees (3 to 25 degrees). The average TC angle was 18.7 ± 6.7 degrees (3-34 degrees). The average TNc angle was 11.1 ± 8.1 degrees (-17 to 34 degrees). The average FA angle was 5.5 ± 5.5 degrees (-10 to 21 degrees). The average cuboid abduction angle was 13.3 ± 5 degrees (2-31 degrees). These results are summarized in Table 6. A one-sample *t*-test was performed to determine the statistical significance. Thomas et al found a mean MA angle of 17.9 degrees, however, if we substract 3 degrees from this value, to account for an overestimation of the measurement due to their different methodology (more like Engel's angle), then the mean MA angle is about 14.9 degrees. A *P* value of 0.645 is computed, and therefore no statistically significant difference is found.

Of the lateral view angles, the average CI angle was 23.2 ± 4.9 degrees (9-35 degrees). The average TD angle was 22.5 ± 4.5 degrees (11-52 degrees). The average lTC angle was 45.4 ± 5.9 degrees (32-61 degrees). The average lat talo-first met angle was 0.867 ± 6.1 degrees (-13 to 13 degrees). These results are summarized in Table 7. One-sample *t*-test was performed to determine the statistical significance.

Comparisons of the radiographic angles of individuals with unilateral versus bilateral plantar fasciitis was also done. (i.e, the average MA angle of all the subjects with bilateral pain, compared with the MA angle of all the subjects with a single painful heel). There was no statistically significant difference seen for any of the angles.

For the MA angle, 83 of 109 feet (76%) had a value less than the mean. A total of 75 of 109 feet (69%) had a lower than mean TC angle. There were 69 of 109 feet (63%) that had a greater than mean TNc angle; and 101 of 109 feet (93%) had a FA angle less than normal, and 103 of 109 feet (95%) had a cuboid abduction angle greater than normal.

Eighty of 109 feet (73%) had a CI angle greater than the mean; 92 of 109 feet (84%) had a TD angle less than mean. There were 49 of 109 feet (45%) that had a lTC angle greater than normal, whereas 58 of 109 feet (53%) had less than normal lTC angle. Also, 78 of 109 feet (72%) had a less than normal lat Talo-1st met angle.

Table 5

DEFINITIONS OF RADIOGRAPHIC ANGLES: LATERAL

		MEAN ± SD	STRUCTURAL OR POSITIONAL
Calcaneal inclination (CI) angle	Angle formed by a line from the most inferior-anterior part of the calcaneal tubercle to the inferior point of the 5th metatarsal head (support line), and a line from that same calcaneal point to the anterior inferior point of the calcaneus at the calcaneal-cuboid joint	19.6 ± 6.2	Structural; does not change with foot position
Talar Declination (TD) angle	Angle formed by the support line, and the bisection of the head and neck of the talus on the lateral view	26.4 ± 4.1	Postitional; increases with pronation, decreases with supination
Lateral talocalcaneal (ITC) angle	Angle formed between the calcaneal inclincation angle and the talar declination angle	45.9 ± 7.5	Positional; increases with pronation, decreases with supination
Lateral Talo-1st metatarsal (lat talo-1st met; Meary's) angle	Angle formed between the bisection of the head and neck of the talus and the bisection of the first metatarsal	4.4 ± 5.5	Combined; increases with pronation, decreases with supination

Table 6

ANTEROPOSTERIOR ANGLES. MEAN, STANDARD DEVIATION, MAX, AND MIN OF 109 FEET WITH PLANTAR FASCIITIS

	MEAN	SD	MIN	MAX	*P* VALUE
Metatarsus adductus (MA) angle	14.8	4.3	3	25	< 0.001
Talocalcaneal (TC; Kite's) angle	18.7	6.7	3	34	0.002
Talonavicular coverage (TNc) angle	11.1	8.1	-17	34	< 0.001
Forefoot adductus (FA) angle	5.5	5.5	-10	21	< 0.001
Cuboid Abduction (CA) angle	13.3	5.0	0	31	< 0.001

Pes planus and pes cavus is often defined based on the calcaneal inclination angle. This angle is structural and has been shown to vary little with pronation and supination of the foot.[32] Severe cavus foot has been defined as a CI angle greater than 40 degrees. None of the 109 feet in this study had such an angle. Moderate cavus is defined as CI angle of 31-40 degrees; 5 feet (4.6%) in this study fit into this category. Normal angle is reported to be 18-30 degrees (43); 94 of 109 feet (86.2%) were within this range. Moderate planus foot is considered CI angle of 10-17 degrees; 9 of 109 feet (8.3%) fell into this range. Lastly, a severe planus foot is considered when CI angle is less than 10 degrees, and only one foot (0.9%) was in this range. Results are summarized in Table 8.

DISCUSSION

Plantar fasciitis, or heel pain syndrome, is an extremely common problem encountered by the clinician. Most of the evidence to date would seem to indicate that the pathoetiology of this common entity is multifactorial.

Table 7

LATERAL ANGLES. MEAN, STANDARD DEVIATION, MAX, AND MIN OF 109 FEET WITH PLANTAR FASCIITIS

	MEAN	SD	MIN	MAX	*P* VALUE
Calcaneal inclination (CI) angle	23.2	4.9	9	35	< 0.001
Talar Declination (TD) angle	22.5	4.5	11	52	< 0.001
Lateral talocalcaneal (lTC) angle	45.4	5.9	32	61	0.225
Lateral Talo-1st metatarsal (lat talo-1st met; Meary's) angle	0.867	6.1	-13	13	< 0.001

Many have linked the cause of plantar fasciitis to an overpronated foot, but the evidence for this may be lacking. This study hypothesized that there would be no difference of radiographic angles of foot structure and position between asymptomatic normals and individuals with plantar fasciitis.

Radiographic angles are relied upon often in the evaluation of foot and ankle disorders. Traditionally, certain values for these angles have been reported in the podiatric literature and have been taught in podiatric biomechanic courses. However, as pointed out more recently by Thomas et al,[31] there may be a lack of sound scientific methodology behind some of the supposed normal values. In their recent study, Thomas et al[31] recorded radiographic angles in 200 asymptomatic feet in a standardized population with no significant history of foot pathology. However, the average age of men and women in their study was 34.3 and 34.7 years, respectively, whereas the mean ages of men and women in the present study was roughly 47 and 50 years, respectively. It is unclear how differences in age, or other discrepancies such as ethnicity, might affect foot structure.

This study found that this cohort of patients with plantar fasciitis had no statistically different MA angle ($P < 0.001$). MA angle is a structural angle; it does not appreciably change with foot pronation and spination. The forefoot adductus (FA) angle, however, was found to be significantly ($P < 0.001$) lower than the normal. The FA angle is a positional angle. A decreased angle indicates pronation. During closed kinetic chain, triplanar foot pronation, the forefoot abducts relative to the rearfoot (bisection of the 2nd metatarsal relative to the bisection of the tarsus). A recent study by Theodorou et al[37] found an association between an increased MA angle and FA angle and stress fractures of the lateral metatarsals, mostly in the fourth and fifth metatarsals. They identified forefoot adductus angles of 21-37 degrees in people with this problem. Normal is 8-14 degrees. They reasoned the deformity caused abnormal loading mechanics across the lateral metatarsals. Extrapolating from their findings, it may be reasonable to deduce that those with a decreased FA angle, like in this study, may have abnormal loading mechanics across the medial metatarsals (the medial longitudinal arch). This could lead to increased tensile forces through the plantar fascia, and lead to plantar fasciitis.[11-13,32,38,39] This would be consistent with the clinical characteristics of plantar fasciitis, that of pain along the medial fascial band, and pain at the medial calcaneal tubercle.

Shama et al[10] found that over 80% of patients in their study with "painful heel spur," had evidence of a foot in a "pronated position." They defined pronation as "anterior break in the cyma line with the longitudinal axis of the talus falling below the longitudinal axis of the first metatarsal," and "an articulation between the talus and navicular, with less than 75% congruency." This definition of pronation can be applied to the present study, though with slightly modified criteria. Sixty-two of 109 feet (56.8%) in the present study had a positive lat Talo-first met angle. Sixty nine of 109 feet (63.3%) had an increased (>7°) TNc angle. However, only 41 of 109 feet (37.6%) met both of these "pronation" criteria. Therefore, far fewer individuals in the present study seemed to have a pronated foot, based on these criteria. Thomas et al[31] found the normal "M1 Talus" angle to be 4.4 degrees. This means the bisection of the talar head passed below the bisection of the 1st metatarsal on the lateral view. This angle is considered a combined angle, with an increasingly positive value seen in pronation, and a negative value in supination. Generally, a linear anatomic relationship between the talar head and the axis the first metatarsal is considered normal. The present study found a mean Lat talo-first met (Meary's) angle of 0.867 degrees. This is probably a neutral angle, that does not indicate excessive pronation or supination.

The talonavicular coverage (TNc) angle of the individuals in this study was significantly ($P < 0.001$) less that the reported normal. TNc angle quantifies the articulation between the talus and navicular. A normal value is reportedly 7 degrees, and an increase in this value is indictive of pronation; increases in this angle is also seen in pathological foot conditions such as adult acquired flatfoot secondary to posterior tibilalis tendon insufficiency.[33-35] But, based on the authors review of the literature for TNc angle, it is not clear where the reportedly normal value of 7 degrees comes from. There are discrepancies in the description of the angle noted by some authors.[34,35] TNc angle is similar to talonavicular congruency, also called talonavicular angle.[28] This parameter is actually measured as a percentage of articulation between the navicular and talar head (i.e., a navicular that totally covers the talar head represents 100% congruency). Normal values for this are reported to be in the 60 to 80 percent range.[29]

It is probably reasonable to assume though, that TNc angle of 7 degrees is fairly accurate, as it is generally felt that normal anatomic alignment of the navicular to the talus is rather linear, thus creating a low angle, or high percentage of coverage. This group of patients with plantar fasciitis had a mean TNc angle that was significantly greater than normal, thereby suggestive of increased pronation in the foot.

The CA angle is a postional angle that is said to increase in pronation and decrease with supination. The mechanism of this involves triplanar motion that occurs at the calcaneocuboid half of the midtarsal joint. The normal is said to be in the range or 0 degrees to 5 degrees. The mean CA angle identified in this study was 13.24 ± 5.0 degrees. This difference was significant ($P < 0.001$) and indicates that CA angle was increased in this group patients with plantar fasciitis, and indicates increased pronation. A total of 103 of 109 (95%) feet in this study had a greater than normal CA angle. This angle may be sensitive in identifying those with, or at risk of, plantar fasciitis.

Prichasuk et al[3] examined the calcaneal pitch of 400 normal people, and in 82 people with plantar heel pain. Their normal subjects had a mean calcaneal pitch (i.e., calcaneal inclination angle) of 20.54 degrees; those with heel pain had a mean of only 15.99 degrees. The difference was significantly different. Additionally, the presence of heel spur was higher in the heel pain group,

Table 8

CALCALEAL INCLINATION ANGLE IN 109 FEET WITH PLANTAR FASCIITIS

FOOT TYPE	CALCANEAL INCLINATION ANGLE (DEGREES)	RESULTS (NO. %)
Severe cavus	>40	0 (0%)
Mod cavus	31-40	5 (4.6%)
Normal	18-30	94 (86.2%)
Mod planus	10-17	9 (8.3%)
Severe planus	<10	1 (0.9%)

and they also tended to be heavier, older, and female. The present study found a mean CI angle of 23.298 degrees, which is significantly higher than the mean of Thomas et al[31] and is also significantly different than the 20.54 of Prichasuk et al ($P < 0.001$). Prichasuk et al[3] proposed that the increased weight seen in their study subjects, leads to lowering of the calcaneal pitch, and increased spur formation. However, calcaneal inclination angle is considered a structural angle; pronation and supination of the foot does not significantly alter this angle.[28,30] The CI angle is often used to describe a foot as planus or cavus and it tends to dictate the overall sagittal plane foot structure. However, 94 of 109 feet (86.2%) in the present study demonstrated a CI angle within the 18 to 30 degree range (see Table 8). This indicates very few severe, or even moderate, planus or cavus feet. A few studies have suggested the connection between pes cavus and plantar fasciitis. The proposed pathoetiologic mechanism would be reduced shock absorption often seen in highly arched feet, but the overall causal relationship has not been established, nor has it been with the low arched foot.[13,32] Overall, this group of patients with plantar fasciitis demonstrated a normal CI angle, suggesting neither pes planus or pes cavus.

Talar declination (TD) angle is a postional angle. Talar declination angle was significantly ($P < 0.001$) different from the normal value of 26.4 reported by Thomas,[31] but their estimation of this angle was probably overestimated due to their measurement method, as was explained earlier. Others, like DiGiovanni et al,[32] state the normal TD angle is 21 degrees. The group of individuals with plantar fasciitis in the present study had a mean TD angle of 23 degrees, which falls in between the two reported normal values. In pronation, the relative motion of the talus is plantarflexion and internal (medial rotation); the TD angle increases as the head of the talus moves downward; the opposite is true during supination. More than likely, the value measured in the present study patients is a fairly neutral angle.

Lateral talocalcaneal (lTC) angle was not significantly (P = 0.225) different from normal. The lTC angle is a positional angle formed by the sum of the talar declination angle and calcaneal inclination angle. It increases in a pronated foot, and decreases in a supinated foot. The mean value for this angle in this studies plantar fasciitis patients did not differ significantly because the CI angle was observed to be essentially normal, same for the TD angle.

In 1991, Scherer et al,[12] in a study looking at biomechanical causes of plantar fasciitis, stated that the plantar fascia tightens with pronation of the subtalar joint and supination around the long axis of the midtarsal joint. They identified 3 foot types that cause this: everted heel, forefoot valgus, and plantarflexed 1st ray. They found 115 of 133 (86%) patients with plantar heel pain had one of these "structural abnormality" causing midtarsal joint supination along its long axis. It was not subtalar pronation alone acting as the sole cause of the disorder. In the present study FA, CA , and possibly TNc angles were all significantly different than normal in the subjects with plantar fasciitis. FA angle was decreased, CA angle was increased, and TNc was also possibly increased, all of which suggest pronation. However, their motion occurs in the transverse plane, and occurs at the level of the midtarsal joint. The radiographic signs of pronation demonstrated in this study, may correlate to the clinical signs of pronation found by Scherer et al. The concept of planal dominance[40] states that a "high" subtalar joint axis will produce more tranverse plane motion, whereas a "low" subtalar joint axis will produce more frontal plane motion. Patients with plantar fasciitis may have a high subtalar joint axis, as they demonstrated abnormal radiographic angles of foot position occurring in the tranverse plane. Table 9 summarizes the angular measurements, their results, and their interpretation. Italics denote the mean value found in the present study subjects. Values adjacent to these are the reported normal values.

Weaknesses inherent to this study include the cross sectional design without a control group. It would have been more meaningful to have studied a control group at the same time. Also, it would have been interesting to study the contralateral, asymptomatic foot of those with unilateral plantar fasciitis. Since all measurements were made by a single person, there may have been bias introduced into the data.

In conclusion, there were differences of the radiographic angle of foot position between this group of patients with plantar fasciitis and normal. However, not every difference reached statistical significance. Some of these differences were suggestive of increased pronation. Excess pronation was observed in the tranverse plane, possibly indicating a relationship between tranverse plane-dominant foot type and plantar fasciitis. Plantar fasciitis may be associated with a pronated foot, but was not seen with pes planus or pes cavus to a significant degree.

Table 9

SUMMARY OF ANGULAR MEASUREMENTS

MEASUREMENT	DIFFERENCE	SIGNIFICANCE
Metatarsus adductus (MA) angle	no difference *14.8* / 14.9	Rectus foot
Talocalcaneal (TC; Kite's) angle	? difference 18 / *18.7* / 21.1	P = 0.287 P = 0.002 Probably normal
Talonavicular coverage (TNc) angle	*11.1 / 7*	? Normal value ? suggest pronation
Forefoot adductus (FA) angle	*5.5* / 13.2	Suggests pronation
Cuboid Abduction (CA) angle	*13.3* / 5	Suggests pronation
Calcaneal inclination (CI) angle	19.6 / *23.2* / 24.5	Neither planus or cavus
Talar Declination (TD) angle	26.4 / *22.5* / 21	? neutral
Lateral talocalcaneal (lTC) angle	45.9 / *45.4* / 46.4	No effect on hypothesis
Lateral Talo-1st metatarsal (lat talo-1st met; Meary's) angle	*0.86*	No effect on hypothesis

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