Shear Wave Elastography (SWE) between Patients with Plantar Fasciitis and healthy individuals; A case control study

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Abstract

Background: Planter fasciitis is the most common cause of heel pain which has impact on patient quality of life. it presented with pain at early morning or during long standing or walking, it although may represent with stiffness, swelling and limbing . Diagnosis of planter fasciitis depends mainly on clinical diagnosis but other methods of investigations are helpful in early diagnosis and rule out other causes of heel pain. We aimed to assess shear Wave Elastography (SWE) between Patients with Plantar Fasciitis and healthy individuals. **Methods:** our study included 30 case diagnosed with planter fasciitis compared to 30 healthy individuals with no heel pain, both groups underwent B-mode superficial ultrasonography and shear wave elastography of the planter fascia 1 cm from calcaneal insertion then comparing the findings of both groups. **Results:** Age, sex, BMI, and occupation were insignificantly different between the case and control groups. Planter fascia hypoechoicity, edema and thickness were significantly higher in group 1 than group 2 (P value <0.001). Planter fascia shear wave velocity and shear wave elasticity were significantly lower in group 1 than group 2 (P value <0.001). Shear wave velocity can significantly assess planter fasciitis (AUC= 0.990, P value <0.001) at cut off ≤4.1 m/s, 93.33% sensitivity, 100% specificity, 100% PPV and 93.7% NPV. Shear wave elasticity can significantly assess planter fasciitis (AUC= 0.903, P value <0.001) at cut off ≤48.1 Kpa, 76.67% sensitivity, 100% specificity, 100% PPV and 81.1% NPV. Thickness of planter fascia by ultra-sound can significantly assess planter fasciitis (AUC= 0.955, P value <0.001) at cut off >3.7 mm, 90% sensitivity, 100% specificity, 100% PPV and 90.9% NPV. **Conclusion:** Shear wave elastography is an easy, simple and effective additional method in diagnosing planter fasciitis with B-mode ultrasound and also helpful in early diagnosis of planter fasciitis.

Key words: Plantar Fasciitis - Shear Wave Elastography (SWE)

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Introduction:

Plantar fasciitis (PFis) is a common cause of inferior heel pain (1). The typical symptom in patients with (PFis) is pain while taking the first steps in the morning or after a period of inactivity (2). While standing or during other daily routine activities, patients often experience a progressive worsening of symptoms, with increased complaints of pain towards the end of the day. The pain in the plantar fascia (PF) normally originates at the plantar medial tubercle of the calcaneus, at the PF insertion (3). Although the etiology of plantar fasciitis is multifactorial, mechanical overload and degeneration have been regarded as the main factors (4).

The plantar fascia seems to be affected even by foot deformities like hallus valgus deformity (5). Therefore the importance of the plantar fascia as a main factor for foot health is evident. A prior systematic review revealed that increased age was also one of the factors associated with chronic plantar heel pain (6). Age-related changes in tendons, as well as specific changes to the elastic modulus with degeneration, have been reported in prior studies (7–9) and may also occur in the plantar fascia (10)

Planter fasciitis is frequently diagnosed clinically, although magnetic resonance imaging (MRI) and ultrasound (US) evaluation can confirm the diagnosis or rule out other causes of heel pain (10, 11).

Conventional US has been widely used to assist the diagnosis of (PFis) due to its easy availability and cost-effectiveness. Contemporary US findings of (PFis) include loss of normal architecture, a hypoechoic area within the fascia, perifascial fluid, and thickening of the PF (12). All these US features are related to (PFis) histological alteration, such as microtears in collagen fibers, fibroblastic hypertrophy, and chronic degeneration caused by repetitive overstrain (13).Some authors consider thickness values > 4 mm pathognomonic of (PFis) (14). These morphological changes, however, are not always observed with conventional US in patients with (PFis) (15, 16). Elastography is recently known to be a feasible diagnostic tool in case of inconclusive US findings, showing early changes in elasticity of the PF in symptomatic patients (17, 18).

Sono-elastography (SEL) is an ultrasound (US) imaging technique that allows for a non-invasive estimation of tissue stiffness (19). It is based on the fact that softer tissue has greater tissue displacement than hard tissue when externally compressed. SEL allows calculation and comparison of tissue displacement before and after tissue compression with conventional US equipment but modified software and is used in MSK application (20, 21). SEL is based on the external compression of the tissue by a probe, and therefore it offers only semi-quantitative and user-dependent information of tissue elasticity.

In contrast, using SWE (shear wave Elastography) an impulse is generated by a probe and elastographic parameters are quantitatively measured in Kilopascal (kPa) as an elastic module (Young's modulus, kPa) or as shear wave speed progression (m/s). Therefore, the method of SWE is considered to be user-independent. And allows for quantitative assessment of tissue stiffness (22 ,23).

The aim of this study was to assess shear Wave Elastography (SWE) between Patients with Plantar Fasciitis and healthy individuals.

Patients and Methods

The study was conducted in the Radio diagnosis department of Zagazig University Hospital and received approval from the Zagazig University Institutional Review Board (I.R.B). It was a case-control study conducted from June 2022 to December 2022 and targeted 60 individuals referred from the Rheumatology, Rehabilitation, and Orthopedic Surgery departments and outpatient clinics. Participants were informed of the purpose and nature of the study and provided written consents.

Group 1 consisted of 30 patients with plantar heel pain that was worst at the beginning of the day and tenderness along the medial calcaneal tuberosity, clinically indicative of plantar fasciitis. 80% (24) of these patients were females and 20% (6) were males, with a mean age of 42.1 +/- 6.88 years. 40% .

Group 2, the control group, consisted of matched 30 healthy individuals without any heel pain complaints. 60% (18) were female and 40% (12) were male, with a mean age of 39.27 +/- 5.57 years.

The inclusion and exclusion criteria for all patients were as follows:

Inclusion Criteria for Group 1 (cases):

- Patients clinically diagnosed as plantar fasciitis based on inferior heel pain that typically worsens with their first steps in the morning or after a period of inactivity, with maximum tenderness over the anteromedial aspect of the heel (Pain assessed on the visual analogue scale (VAS) of pain greater than 4 out of 10).
- Patients showed thickening of the plantar fascia on ultrasound assessment.
- Both males and females were eligible.
- Patients must be 18 years or older.

Inclusion Criteria for Group 2 (controls): Asymptomatic individuals matched to case group ages, physical activity and BMI with no pain or discomfort in either foot at any time.

Exclusion Criteria:

- Patients who declined to participate in the study.
- Previous local trauma, fractures or stress fractures.
- Presence of plantar fascia masses, tumors.
- Previous surgery.

METHODS:

All patients were subjected to:

I-Full medical history including:

• Personal history: name, age, sex, occupation, residence, and special habits.

• present history including:

❖ Complain:

II) **Symptoms and signs including:**

- Heel pain that was worst at the beginning of the day.
- Tenderness along the medial calcaneal tuberosity.
- Localized swelling along the medial calcaneal tuberosity.
- Foot stiffness.
- Limping.

III- **Imaging study:**

Ultrasonography and Shear Wave Elastography (SWE):

1. All examinations were performed in the same air-conditioned room with a standardized temperature of 20°C.
2. Sonographic examinations were performed using a Toshiba Aplio 500 US scanner with a multifrequency 5-18 MHz linear probe.
3. **Foot position**: Individuals were lying in the prone position with the foot hanging relaxed over the examination table The measured foot was kept in the neutral position without any active or passive dorsiflexion of the big toe.
4. **Technique of examination:**
   - A standardized examination protocol was followed, starting with the left foot (neared to operator) and conducting B-mode US before shear wave elastography (SWE) followed by right foot.
   - Copious amounts of coupling gel were applied to the probe.
   - The operator uses superficial musculoskeletal examination protocol, freely adjust the focus, the gain and the contrast to ensure good penetration of the thick skin of the heel without over compression and to minimize artifacts of fat and soft tissues.

     A- **B-Mode examination**;
     - Performed in longitudinal and short-axis planes to evaluated echoic patterns and thickness. Sagittal ultrasound scans were performed with a slight medial inclination toward the attachment of the plantar fascia to the os calcanium for better visualization of the long axis of the plantar fascia fibers.
     - The thickness of the plantar fascia was measured at a standard reference point; where the plantar fascia crosses the anterior aspect of the medial inferior calcaneal border; vertically from the anterior edge of the medial calcaneal border to the inferior border of the fascia. Plantar fasciitis was diagnosed when the fascia thickness was more than 4.0 mm with reduced echogenicity, along with other findings such as perifascial edema or calcaneal spurs.
     - The maximum thickness of the fascia on both sides was obtained.

- Any associated abnormalities such as focal thickening, abnormal echoic pattern, subcutaneous edema, or fluid collection were recorded.
- Any other incidental pathologies or calcaneal spurs were reported.

B- Shear wave elastography:

- In the same heel position, the transducer was kept stationary with light pressure and a generous amount of coupling gel during the acquisition of each SWE sonogram.
- B-mode was used to ensure longitudinal transducer alignment with the plantar fascia.
- A 2 cm^2 SWE measurement window was applied and a 2-mm-diameter region of interest (ROI) was manually tracked and centered to thickest part of the fascia within 1 cm from the calcaneal insertion.
- Three quantitative measurements of shear wave stiffness (kPa) and velocity (m/s) were obtained after unfreezing and freezing. The mean of the three measurements was obtained.

IV- **Statistical analysis**

Data was analyzed using SPSS v26 (IBM Inc., Armonk, NY, USA). Normality was evaluated using the Shapiro-Wilks test and histograms. Parametric data was expressed as mean and SD, and analyzed by t-test. Non-parametric data was expressed as median and interquartile range IQR, and analyzed by Mann Whitney-test. Qualitative data was expressed as frequency and percentage, and analyzed by Chi-square or Fisher's exact test. Pearson's correlation was used to assess the relationship between two quantitative variables. ROC curve analysis and AUC were used to evaluate the overall diagnostic performance, with an AUC >50% indicating acceptable performance and an AUC of 100% being the best. A two-tailed P value <0.05 was considered statistically significant.

Results:

This case-control study was conducted at Radio-diagnosis department, Zagazig university hospitals on 60 individual :

- **Group 1 (cases):** 30 patients clinically diagnosed with unilateral or bilateral plantar fasciitis.
- **Group 2 (control):** 30 asymptomatic individuals with no pain or discomfort in both PF at any time.

Age, sex, BMI, and occupation were insignificantly different between the case and control groups **Table 1**.

Planter fascia hypoechoicity, edema and thickness were significantly higher in group 1 than group 2 (P value <0.001) **Table 2**.

Planter fascia shear wave velocity and shear wave elasticity were significantly lower in group 1 than group 2 (P value <0.001) **Table 3**.

Shear wave velocity can significantly assess planter fasciitis (AUC= 0.990, P value <0.001) at cut off ≤4.1 m/s, 93.33% sensitivity, 100% specificity, 100% PPV and 93.7% NPV.

Shear wave elasticity can significantly assess planter fasciitis (AUC= 0.903, P value <0.001) at cut off ≤48.1 Kpa, 76.67% sensitivity, 100% specificity, 100% PPV and 81.1% NPV.

Thickness of planter fascia by ultra-sound can significantly assess planter fasciitis (AUC= 0.955, P value <0.001) at cut off >3.7 mm, 90% sensitivity, 100% specificity, 100% PPV and 90.9% NPV **Table 4**.

Table 2: Demographic data of the studied groups

		Group 1 (n=30)	Group 2 (n=30)	P value
Age (years)	**Mean ± SD**	42.1 ± 6.88	39.27 ± 5.57	0.085
	Range	29 – 55	28 – 55	
Sex	**Male**	6 (20%)	12 (40%)	0.091
	Female	24 (80%)	18 (60%)	
BMI (kg/m^2)	**Mean ± SD**	31.63 ± 2.59	30.23 ± 3.88	0.105
	Range	26.95 – 36.11	19.84 – 34.55	
Occupation	**Builder**	1 (3.33%)	0 (0%)	0.119
	Worker	2 (6.67%)	6 (20%)	
	Co-worker	1 (3.33%)	0 (0%)	
	Office worker	1 (3.33%)	0 (0%)	
	Electric worker	2 (6.67%)	0 (0%)	
	Technician	0 (0%)	4 (13.33%)	
	Teacher	2 (6.67%)	3 (10%)	
	Doctor	5 (16.67%)	8 (26.67%)	
	Nurse	9 (30%)	6 (20%)	
	Housewife	7 (23.33%)	3 (10%)	

BMI: body mass index

Table 2: Planter fascia B-mode ultrasonography of the studied groups

		Group 1 (n=30)	Group 2 (n=30)	P value
Morphology	**Isoechoic**	9 (30%)	30 (100%)	**<0.001***
	Hypoechoic	21 (70%)	0 (0%)	
Edema	**Yes**	17 (56.67%)	0 (0%)	**<0.001***
	No	13 (43.33%)	30 (100%)	
Thickness (mm)	**Mean ± SD**	5.25 ± 1.32	2.93 ± 0.49	**<0.001***
	Range	3.4 - 8.3	1.8 - 3.7	

*: significant as P value ≤0.05

Table 3: Planter fascia shear wave elastography of the studied groups

		Group 1 (n=30)	Group 2 (n=30)	P value
Shear wave velocity (m/s)	**Mean ± SD**	3.01 ± 0.74	5.92 ± 1.21	**<0.001***
	Range	1.9 - 4.8	4.4 - 9.1	
Shear wave elasticity (Kpa)	**Mean ± SD**	49.35 ± 18.3	109.1 ± 26.66	**<0.001***
	Range	18 - 82	65.4 - 164.2	

*: significant as P value ≤0.05

Table 4: Diagnostic accuracy of planter fascia shear wave elastography and thickness (mm) by B-mode ultrasonography in assessing planter fasciitis

	Cut-off	AUC	Sensitivity	Specificity	PPV	NPV	P va
Shear wave velocity (m/s)	≤4.1	0.990	93.33	100	100	93.7	**<0.0**
Shear wave elasticity (Kpa)	≤48.1	0.903	76.67	100	100	81.1	**<0.0**
Thickness (mm)	>3.7	0.955	90	100	100	90.9	**<0.0**

AUC: area under the curve, PPV: positive predictive value, NPV: negative predictive value, *: significant as P value ≤ 0.05

Discussion

In the current study, abnormal thickening of the plantar fascia thickness was detected by ultrasound in planter fasciitis cases with range from 3.4 mm to 8.3 mm with mean 5.25±1.32 while asymptomatic control cases shows planter fascia thickness ranging from 1.8 mm to 3.7 mm (2.93 ± 0.49) ,which in coincidence with **Chueh-Hung Wu (24)** who reported that The thickness of the plantar fascia was significantly thicker in the fasciitis group than in the healthy subjects at conventional US examination (3.7 mm 6 0.9 vs 2.7 mm 6 0.5, P , .001) .Also **Baur et al. (25)** reported that mean thickness of healthy patients is 3.28 ±0.41 (ranged 2.4mm-3.9mm) compared to 6.07±2.37 (ranged 2mm-22mm) while **Schillizzi et al. (26)** reported that symptomatic patients showed a median value of PF thickness of 5 mm (4; 6.9), whereas all asymptomatic PF subjects showed a thinner PF (< 4 mm; p < 0.001).

In this study, we compared the shear wave velocity and shear wave elasticity between patients with plantar fasciitis and healthy individuals. Our results showed that the shear wave velocity among plantar fasciitis patients was in the range of 1.9 m/sec to 4.8m/sec with a mean ± SD of 3.01 ± 0.74, while the shear wave velocities among healthy individuals were in the range of 4.4 to 9.1 m/sec with a mean ± SD of 5.92 ± 1.21. Additionally, the shear wave elasticity among plantar fasciitis patients was in the range of 18 to 82 Kpa sec with a mean ± SD of 49.35 ± 18.3 , while the shear wave elasticity among healthy individuals was in the range of 65.4 to 164.2 Kpa with a mean ± SD of 109.1 ± 26.66. Our results showed that both the shear wave velocity and shear wave elasticity were significantly lower in the plantar fasciitis group compared to the healthy group (p value <0.001).

These findings agreed with **Schillizzi et al (26)**, who reported that the symptomatic plantar fascia has a significantly lower shear wave velocity than the asymptomatic plantar fascia, indicating that it is "less elastic" or "softer***."***

Furthermore, our study supports the findings of **Gatz et al (27)**, who demonstrated that SWE can improve the diagnostic accuracy in plantar fasciitis patients compared to B-mode US, with a sensitivity of 85% and specificity of 83% for SWE and 61% sensitivity and 95% specificity for B-mode US. Also showed that there is a significant reduction in Young's moduli in the symptomatic PF, with lower values of 31.9 kPa and 3.26 m/s compared to higher values of 93.3 kPa and 5.58 m/s in the asymptomatic group***.***

Our study found that both Shear wave velocity and Shear wave elasticity can effectively assess plantar fasciitis, with AUC values of 0.990 and 0.903 respectively, and P values of <0.001. The cut off values for Shear wave velocity was ≤4.1 m/s with 93.33% sensitivity, 100 % specificity, 95.8% PPV, and 93.7% NPV, while the cut off value for Shear wave elasticity was ≤48.1 Kpa with 76.67% sensitivity, 100% specificity, 100% PPV and 81.1% NPV. Our results are consistent with those of **Gatz et al (27),** who found a cut off value of shear wave elasticity in plantar fasciitis to be <51.5 kPa, and a cut off value of shear wave velocity in plantar fasciitis to be 4.141 m/s. However, our findings differ from those of **Baur et al. (25)**, who found the cut-off value of shear wave velocity to be 6.16 m/s (AUC: 0.87, 95% CI: 0.80–0.94), and the cut-off value of stiffness to be 125.57 kPa (AUC: 0.85, 95% CI: 0.77–0.92) ,these difference may related to smaller sampler size of our study and **Gatz et al (27)** than **Baur et al. (25).**

Conclusion:

Shear wave elastography is an easy, simple and effective additional method in diagnosing planter fasciitis with B-mode ultrasound and also helpful in early diagnosis of planter fasciitis.

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