

REVIEW ARTICLE

Diagnostic accuracy of ultrasound elastography for detecting plantar fasciitis: A systematic review and meta-analysis

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Abstract

Plantar fasciitis (PF) is a leading cause of heel pain in adults, resulting in significant discomfort and reduced mobility. Conventional imaging methods, such as B-mode ultrasonography and magnetic resonance imaging (MRI), mainly assess structural changes but do not capture biomechanical alterations in the plantar fascia. Ultrasound elastography (UE), including strain elastography and shear wave elastography (SWE), provides a noninvasive and quantitative assessment of tissue stiffness and may enhance diagnostic accuracy. This systematic review and meta-analysis evaluated the diagnostic performance of UE for PF. A comprehensive search of PubMed, Scopus, Web of Science, Embase, and the Cochrane Library identified studies published between January 2015 and September 2025. Eligible studies compared UE findings with clinical, ultrasonographic, or MRI-based reference standards. Fifteen studies met the inclusion criteria for the systematic review; nine provided sufficient data for quantitative synthesis, involving 913 participants (419 PF cases and 494 controls). The pooled sensitivity and specificity were 90.8% (95% confidence interval [CI]: 78.6–96.4) and 76.0% (95% CI: 66.4–83.5), respectively, with a diagnostic odds ratio of 31.38 (95% CI: 10.06–97.91). The positive and negative likelihood ratios were 3.78 and 0.12, indicating strong discriminatory ability. SWE, in particular, demonstrated high diagnostic value. Standardized imaging protocols and diagnostic thresholds are needed to support wider clinical adoption.

Keywords: Plantar fasciitis; Ultrasound elastography; Shear wave elastography; Strain elastography; Diagnostic accuracy; Ultrasound imaging

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1. Introduction

Plantar fasciitis (PF) is considered one of the most common causes of heel pain among adults and one of the primary causes of musculoskeletal consultations concerning the foot. It manifests as degenerative changes and microtears in the plantar fascia due to repetitive stress, excessive load, and biomechanical changes in the foot.^{1,2} Although inflammation was once believed to be the primary cause, it is now considered to result from degenerative pathophysiological processes. PF is now understood to involve collagen disorganization, fibroblast proliferation, neovascularization, and chronic degenerative changes rather

than acute inflammation, reflecting a more complex pathogenesis. PF clinically manifests as localized heel pain that is the most severe during the first steps after rest and improves with movement. Its increasing prevalence places a substantial burden on modern healthcare systems due to reduced mobility, work absenteeism, and high demand for conservative and imaging-based management. Therefore, proper diagnosis is essential.³⁻⁵

PF is conventionally diagnosed based on clinical examination and imaging modalities, such as B-mode ultrasonography and magnetic resonance imaging (MRI).^{6,7} Ultrasonography has become a commonly accepted tool as a first-line imaging modality because it is readily available, noninvasive, and has the capacity to visualize the plantar fascia of the tissue and the loss of a normal fibrillar structure, as well as a decrease in echogenicity. MRI, however, offers better soft-tissue contrast and can be used to make diagnoses in subtle or complex cases. However, its cost and low accessibility are limiting factors for its routine use.⁸⁻¹⁰ Despite the usefulness of these modalities in diagnosis, they mostly provide only structural data and do not offer any information on the biomechanical characteristics of the fascia.

Ultrasound elastography (UE) has emerged as a promising noninvasive imaging method for measuring tissue elasticity and stiffness. Elastography involves two primary approaches: Strain elastography (SE) and shear wave elastography (SWE), which assess the mechanical responses of soft tissues to applied stress or shear waves, offering biomechanically relevant information aligned with PF pathology, such as fibrosis and collagen degeneration.¹¹⁻¹⁴ Elastography has been shown to identify normal and pathological fascia, and therefore should be used as an adjunct, providing more objective and quantitative information than traditional imaging alone.^{15,16} In addition, recent literature highlights the importance of chemokines, such as C-X3-C motif chemokine ligand 1 and its receptor C-X3-C motif chemokine receptor 1, in chronic musculoskeletal and degenerative processes, supporting the biological relevance of tissue-level biomarkers in conditions such as PF.¹⁷

However, the diagnostic accuracy of UE for PF is inconsistent in the literature. The variability in study design, patient populations, types of equipment, elastography parameters, and reference standards has led to inconsistent results across sensitivity, specificity, and optimal cutoff values.^{15,18} Besides, majority of the existing studies have small sample sizes and diverse methodologies, which makes the interpretation of the findings difficult and the development of standard diagnostic thresholds challenging.

Consequently, the proposed systematic review and meta-analysis are expected to provide a synthesis of existing evidence on the diagnostic accuracy of UE (both strain and shear wave modalities) in the identification of PF. By comparing elastography results with available reference standards, such as clinical diagnosis, B-mode ultrasonography, or MRI, this study aims to provide a comprehensive evaluation of the diagnostic role and potential clinical application of elastography in PF.

2. Methodology

2.1. Study design

The study is a systematic review and meta-analysis to determine the diagnostic accuracy of UE in PF. The review was conducted in accordance with Preferred Reporting Items guidelines of Systematic Reviews and Meta-Analyses (PRISMA 2020).¹⁹ The structure of the research question was based on the population, intervention, comparison, and outcome (PICO) framework as follows:

- Population (P): Patients who present with heel pain or who are clinically suspected of PF
- Intervention (I): UE (strain or shear wave elastography) assessing the stiffness or elasticity of the plantar fascia
- Comparator (C): Clinical diagnosis, B-mode ultrasonography, MRI, or histopathological confirmation are some common examples of reference standards
- Outcome (O): Diagnostic accuracy, such as sensitivity, specificity, and the area under the receiver operating characteristic curve (AUC).

2.2. Literature search strategy

A comprehensive literature search was conducted in seven large electronic databases, including PubMed, Scopus, Web of Science, Embase, Cochrane Library, Cumulative Index to Nursing and Allied Health Literature, and Institute of Electrical and Electronics Engineers Xplore Digital Library, involving all studies published from January 2015 to September 2025.

Medical subject headings and free-text keywords were searched together with the aid of the Boolean operators (AND/OR). The search strategy was as follows:

(Plantar fasciitis OR heel pain OR plantar fascia inflammation) AND (ultrasound elastography OR shear wave elastography OR strain elastography OR sonoelastography) AND (diagnosis OR detection OR diagnostic accuracy).

The studies were limited to English. The reference lists of included studies and other relevant reviews were screened manually to identify any additional eligible publications.

2.3. Eligibility criteria

2.3.1. Inclusion criteria

Studies were included based on the following criteria to ensure relevance and appropriateness for the research objectives:

- Original research articles that assessed UE in the diagnosis of PF
- Studies that have quantitative diagnostic performance measures (e.g., sensitivity, specificity, accuracy, AUC)
- Research conducted on an acceptable reference standard (clinical diagnosis, B-mode ultrasound, or MRI)
- Published in the English language, the full text was available to the author.

2.3.2. Exclusion criteria

Studies were excluded based on the following criteria to eliminate irrelevant or low-quality evidence:

- Abstracts or partial data of review articles, case reports, letters, or conference abstracts
- Studies for which the diagnostic accuracy results are not provided, or there are incomplete data to construct a 2×2 contingency table (true positive, false positive, false negative, true negative)
- Studies involving experimental or animal models
- Redundant or overlapping datasets.

2.4. Study selection process

All identified citations were imported into EndNote reference management software (X9, Clarivate, United States of America), and duplicate records were removed. Titles and abstracts were screened for relevance, followed by a comprehensive full-text evaluation to determine final eligibility according to the predefined inclusion and exclusion criteria. Any uncertainties during the selection process were resolved through thorough examination of the study content. The entire selection process was documented using a PRISMA flow diagram, illustrating the number of studies identified, screened, excluded, and finally included in the review (Figure 1).

2.5. Data extraction

Data extraction was performed using a standardized form. For each eligible study, information was collected on the following aspects: general details (author, year, country, and study design—prospective or retrospective); participant characteristics (number of subjects, mean age, sex distribution, and clinical diagnosis method); imaging parameters (type of elastography—strain or shear wave, ultrasound equipment used (SWE, conventional B-mode, SE, etc.), anatomical site of measurement, and stiffness or

elasticity cutoff values); and reference standards, including clinical examination, B-mode ultrasonography, or MRI. Diagnostic performance indicators, such as sensitivity, specificity, positive and negative predictive values, accuracy, and AUC, were extracted. When necessary, missing diagnostic parameters were calculated using 2×2 contingency tables derived from available data. All extracted data were carefully verified for completeness, consistency, and accuracy before analysis.

2.6. Quality assessment of included studies

The Quality Assessment of Diagnostic Accuracy Studies-2 tool was used to determine the methodological quality of included studies.²⁰ The instrument assesses four criteria: (i) Patient selection, (ii) Index test, (iii) Reference standard, and (iv) Flow and timing. The rating for each domain was low, high, or unclear risk of bias. The findings were presented as a graphical summary and tabulation to provide a general overview of the study's quality.

2.7. Statistical analysis and data synthesis

Quantitative synthesis was conducted using the MetaDiSc software (Version 2, Clinical Biostatistics Unit of the Ramón y Cajal Research Institute, Spain).²¹ In every study, 2×2 contingency tables were constructed from data on sensitivity and specificity. A bivariate random-effects model was used to compute pooled estimates of sensitivity, specificity, diagnostic odds ratio (DOR), and area under the summary receiver operating characteristic (SROC) curve.

The I^2 test and Cochran's Q test were used to assess heterogeneity. The test of publication bias was conducted using the funnel plot asymmetry test of Deeks, with a p -value below 0.05 being considered statistically significant.

3. Results

This systematic review included 15 articles published from 2015 to 2025, involving 1,368 participants, including 1,652 plantar fasciae (PF). The enclosed studies were conducted in various countries, including the United States, Germany, China, Pakistan, India, Turkey, Iran, Austria, Italy, and Taiwan. The study designs were different; they included prospective cohort and diagnostic accuracy studies, as well as cross-sectional comparative and retrospective analyses. The sample population ranged from 38 to 242, and the mean age was 20–56 years, including both symptomatic and asymptomatic individuals (Tables 1 and 2).

Studies employed conventional B-mode ultrasonography, SE, and SWE methods. The majority of studies were devoted to the anterior part of the plantar fascia at the area of calcaneal insertion, the most frequent

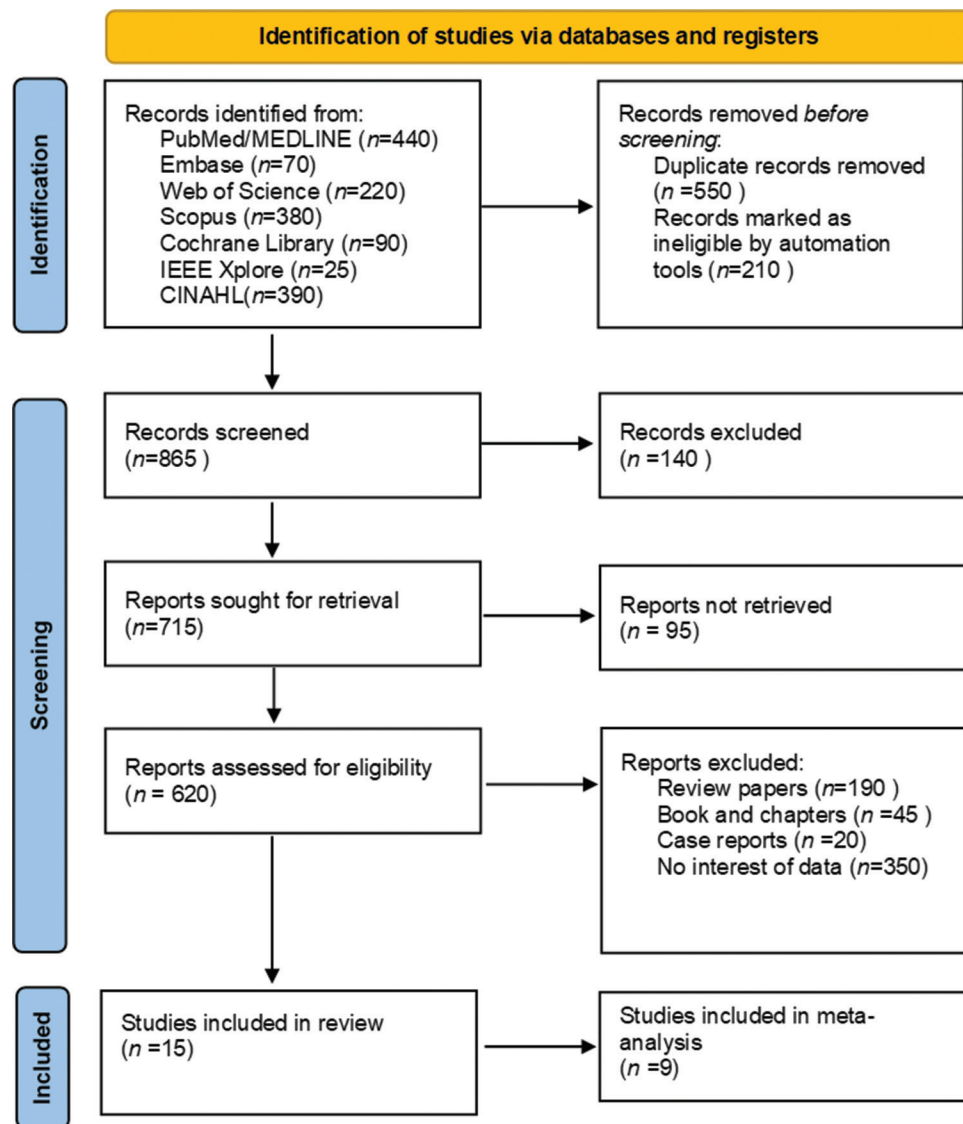


Figure 1. Preferred Reporting Items guidelines of Systematic Reviews and Meta-Analyses diagram for the study selection process. Image created by the author.

site of pathologic alteration. Most of the studies compared elastographic parameters with clinical diagnosis, B-mode ultrasound, or MRI as the reference standards.

In the literature review on traditional B-mode ultrasonography, PF is commonly associated with thickening of fascia (>4 mm) and loss of echogenicity. As an example, Argerakis *et al.*²² and Butt *et al.*²⁵ reported the mean plantar fascia thickness in PF patients and controls as 5–6 mm and 2–3 mm, respectively, resulting in the highest sensitivity and specificity of the diagnoses of 97% and 100%, respectively. Similarly, Khan *et al.*²³ revealed high correlations between ultrasound and MRI results, demonstrating that B-mode ultrasonography is a reliable and first-line imaging mode in detecting PF.

As observed in studies using SE (e.g., Wu *et al.*²⁶), the plantar fascia in PF patients were less elastic (higher tissue stiffness) than those of controls, even when B-mode results were normal. These findings suggest the capacity of SE to identify the earliest or subclinical degenerative changes before the structural thickening effects being observed.

The most commonly used elastographic technique was SWE, which was implemented in over 50% of the included studies. SWE provided quantitative data of tissue stiffness in kPa or m/s. Research has consistently indicated that fasciae with PF were softer and thicker than healthy fasciae. As an illustration, Gatz *et al.*²⁴ recorded much lower values of Young's modulus in symptomatic PF (31.9 kPa) than in asymptomatic fasciae (93.3 kPa), and Wang *et al.*³³ reported

Table 1. Characteristics of the selected studies

References	Country	Study design	Sample size (n)	Population type	Mean age (years)	Gender (M/F)	Elastography type
Argerakis <i>et al.</i> ²²	USA	Retrospective	143	Patients with proximal plantar heel pain	53 (range 16–79)	62/81	Conventional
Khan <i>et al.</i> ²³	Pakistan	Case series	38	Symptomatic and asymptomatic heels	25–59	Not reported	Conventional
Gatz <i>et al.</i> ²⁴	Germany	Diagnostic case-control	82	Symptomatic and asymptomatic PF	Group 1: 48.9±9.6, Group 2: 50±9.5, Group 3: 30.4±11.1	21/43	SWE
Butt <i>et al.</i> ²⁵	Pakistan	Comparative analytical study	50	Clinically suspected PF patients with heel pain for > 3 months	40 (range 30–55)	22/28	Conventional HRUS
Wu <i>et al.</i> ²⁶	Taiwan	Prospective cross-sectional comparative study	50	20 clinically diagnosed PF (10 unilateral, 10 bilateral) + 30 healthy volunteers	Healthy: 41.6±13.9, unilateral PF: 45.1±12.5, bilateral PF: 46.5±10.8	PF: 8/12, controls: 11/19	SE
Cushman <i>et al.</i> ²⁷	USA	Prospective cohort, multi-institutional	242	NCAA Division I collegiate athletes	20.2±1.6	102/140	Conventional B-mode+Power Doppler
Gurun <i>et al.</i> ²⁸	Turkey	Prospective study	66	Patients with unilateral PF	49.5±10.9 (27–67)	17/49	SWE
Daskareh <i>et al.</i> ²⁹	Iran	Cross-sectional comparative	96	AS and non-AS patients, with and without PF	AS+PF: 39±11, non-AS+PF: 47±11	AS+PF: 54% M, non-AS+PF: 53% M	SWE
Pan <i>et al.</i> ³⁰	China	Cross-sectional (comparative)	40	Individuals with and without PF	51±13	10/10 (each group)	SWE
Jiang <i>et al.</i> ³¹	China	Observational case control	81	Early-stage plantar fasciopathy vs. healthy volunteers	Median: 56 (IQR 25.25)	60.3% F	SWE
Baur <i>et al.</i> ³²	Austria	Observational, prospective	108	Patients with unilateral PF and healthy controls	PF: 51.7± (29–82) control: 47.3± (32–58)	PF: 66/21, control: 15/6	SWE
Wang <i>et al.</i> ³³	China	Prospective single-center diagnostic accuracy study	124	Patients with unilateral heel pain	PF: 43.6±10.1, non-PF: 41.5±15.1	PF: 36/24, non-PF: 36/28	SWE
Harish <i>et al.</i> ³⁴	India	Cross-sectional	81	Type 2 DM patients and healthy controls	53.78±10.35	61/52	SE
Saroja <i>et al.</i> ³⁵	India	Cross-sectional observational study	60	Adults with and without Type 2 DM	DM Group: 49.5±8.2, control: 46.2±7.4	35/25	SWE
Schillizzi <i>et al.</i> ³⁶	Italy	Cross-sectional observational comparative study	19	Symptomatic PF vs. healthy subjects	Symptomatic: 50.5±12.6 controls: 47.5±7.4	Not specified	SWE

Abbreviations: AS: Ankylosing spondylitis; DM: Diabetes mellitus; IQR: Interquartile range; NCAA: National Collegiate Athletic Association; PF: Plantar fasciitis; SE: Strain elastography; SWE: Shear wave elastography.

the same trend (55.9 kPa vs. 100.3 kPa). It is worth noting that the integration of SWE parameters and B-mode measurements significantly increased diagnostic accuracy, as Gatz *et al.*²⁴ (100% sensitivity, 90% accuracy) and Jiang *et al.*³¹ (92% sensitivity and 93.6% accuracy) demonstrated when relying on integrated SWE and B-mode evaluation.

In addition to diagnostic performance, studies have examined the therapeutic and prognostic uses of elastography. Gurun *et al.*²⁸ found that corticosteroid

injection of the plantar fascia resulted in a significant increase in plantar fascia stiffness in the post-treatment period, which was associated with the improvement in pain and functional scores, thus implying the potential of SWE in monitoring treatment. Moreover, Cushman *et al.*²⁷ found that preseason ultrasound abnormalities in collegiate athletes predicted subsequent tendon or fascial injury, suggesting potential utility for preparticipation screening.

Table 2. Ultrasound machine and findings from selected studies

References	Ultrasound system	ROI	Reference standard	PF thickness (mm)	Elasticity measure (m/s or kPa)	Cutoff value
Argerakis <i>et al.</i> ²²	Philips iU22, L12-5 linear probe	Proximal medial band of plantar fascia	Ultrasound evaluation by a musculoskeletal radiologist	PF: 6.2, without PF: 3.5	NR	>4 mm
Khan <i>et al.</i> ²³	Aplio 500 linear 5–17 MHz	Plantar fascia (longitudinal and transverse views)	MRI	Study group: 2.9–6.9 (4.9±1.4), control group: 1.1–2.4 (1.7±0.06)	NR	>4 mm
Gatz <i>et al.</i> ²⁴	Aixplorer, Supersonic Imagine, Aix-en-Provence, France	2 mm-diameter ROI at PF insertion and 2 cm ² window	B-US (PF thickness >4 mm)	Symptomatic: 4.2±1.2, asymptomatic: 3.0±0.6	Symptomatic: 31.9 kPa (3.26 m/s), Asymptomatic at L1: 93.3 kPa (5.56 m/s)	51.5 kPa (4.14 m/s)
Butt <i>et al.</i> ²⁵	Toshiba Aplio 300, 7 MHz linear array transducer	Proximal end of plantar fascia near calcaneal insertion (within 1 cm)	Clinical diagnosis (history+heel tenderness)	5.3 (normal<2.9)	Not measured	>4 mm
Wu <i>et al.</i> ²⁶	Siemens ACUSON S2000, linear transducer 14L5 (6–12 MHz)	Proximal plantar fascia (2 mm proximal to calcaneal insertion, 1 cm distal along fascia)	Clinical diagnosis (heel pain >3 months, VAS >4, PF<4 mm)	Healthy: 2.6±0.4, PF (uni/bilat): 2.8±0.5	Red pixel intensity (0–255 scale): healthy: 146.9±9.1, asymptomatic PF side: 140.4±7.3 (<i>p</i> =0.01), symptomatic PF side: 127.1±7.4 (<i>p</i> <0.001), bilateral PF: 129.4±7.5 (<i>p</i> <0.001)	NR
Cushman <i>et al.</i> ²⁷	GE Logiq E9 R7; Sonosite PX, X-Porte; Konica Minolta HS-1	Achilles tendon, patellar tendon, plantar fascia	Clinical diagnosis of pain with time-loss injury	Not reported	Not reported	NR
Gurun <i>et al.</i> ²⁸	Mindray Resona R9 (China), 15–3 MHz linear probe	1 cm distal to calcaneal insertion (3 ROIs, 2 mm each)	Clinical evaluation (VAS, AOFAS scores)	Pre: 5.02±0.66, post: 3.53±0.39	Pre: 2.37±0.22, post: 3.39±0.32 (m/s); Pre: 18.64±3.28, post: 35.49±7.25 (kPa)	Not specified
Daskareh <i>et al.</i> ²⁹	Aixplorer Ultimate, Supersonic Imagine, France	Plantar fascia origin (longitudinal view)	Clinical PF confirmed by rheumatologist and orthopedic surgeon (blinded)	Not specified	Mean stiffness (kPa)	NR
Pan <i>et al.</i> ³⁰	SuperSonic Imagine, Aix-en-Provence, France (SL10-2 probe, 2–10 MHz)	Achilles tendon at 0 cm, 3 cm, and 6 cm above the calcaneal tuberosity	Clinical diagnosis and ultrasound findings	PF group: 5±0.8; Healthy: 3±0.1	AT ₀ cm: 497±66 kPa, AT ₃ cm: 449±36 kPa, AT ₆ cm: 444±42 kPa	452 kPa (AT ₀ cm), 417 kPa (AT ₃ cm)
Jiang <i>et al.</i> ³¹	Logiq E9, GE Medical Systems, USA	Single-point and multipoint ROI from calcaneal origin to ~2 cm distal	Clinical diagnosis (orthopedic specialist)	PF group: 3.95±1.37, control: 2.40±0.60	SWE single-point: 65.76 (58.58) kPa, SWE multipoint: 57.42 (35.52) kPa	Not specified (ROC analysis used)
Baur <i>et al.</i> ³²	SuperSonic Imagine Aixplorer®, SL12-7 MHz transducer	Plantar fascia insertion at calcaneus (longitudinal plane)	Clinical diagnosis (history+physical exam)	PF: 6.07±2.37, control: 3.28±0.41	SWV: PF: 4.98, control: 6.94 m/s, stiffness: PF: 93.54, control: 152.88 kPa	SWV: 6.16 m/s, stiffness: 125.57 kPa, thickness: 4.0 mm
Wang <i>et al.</i> ³³	GE LOGIQ E9 (7–15 MHz linear probe)	Insertion of the plantar fascia at the calcaneus	Clinical criteria per APTA Orthopedic Branch Guidelines (2014)	PF: 4.05±0.74, non-PF: 2.61±0.64	PF: 55.92±11.13 kPa, non-PF: 100.29±58.44 kPa	Thickness: 3.15 mm, Young's modulus: 63.24 kPa

(Cont'd...)

Table 2. (Continued)

References	Ultrasound system	ROI	Reference standard	PF thickness (mm)	Elasticity measure (m/s or kPa)	Cutoff value
Harish <i>et al.</i> ³⁴	Philips IU22, Siemens ACUSON S2000	Near calcaneal insertion	Clinical and US evaluation	Patients: 3.65±0.88, controls: 2.68±0.59	Qualitative: Grade 1/2/3 (hard/intermediate/soft)	3.03 mm
Sarooha <i>et al.</i> ³⁵	GE LOGIQ S8 ultrasound system with 9L linear probe (6–9 MHz)	Plantar fascia (central portion, near calcaneal insertion)	Clinical grouping (Type 2 DM vs. healthy)	DM: 3.22±0.62, control: 2.69±0.38	Elasticity (kPa): DM: 110.3±24.8, control: 145.8±28.6	NR
Schillizzi <i>et al.</i> ³⁶	Toshiba Aplio i800 (Canon Medical Systems Europe BV), 5–18 MHz linear probe	Plantar fascia, 1 cm distal to calcaneal insertion	Clinical diagnosis+US (PF >4 mm, VAS > 4, >3 months pain)	Symptomatic: 5 (4.0–6.9), controls: 3.1 (2.0–4.0)	SWV: PF: 3.8 m/s (1.8–4.35), controls: 5.12 m/s (3.49–6.9)	NR

Abbreviations: AOFAS: American Orthopedic Foot and Ankle Society Score; APTA: American Physical Therapy Association; B-US: B-mode ultrasonography; DM: Diabetes mellitus; MRI: Magnetic resonance imaging; NR: Not reported; PF: Plantar fasciitis; ROC: Receiver operating characteristic; ROI: Region of interest; SWE: Shear wave elastography; SWV: Shear wave velocity; US: Ultrasonography; VAS: Visual Analog Scale.

Elastographic analysis was included in a systematic disease in further research. As an example, according to Saroha *et al.*³⁵ and Harish *et al.*,³⁴ the thickness and softness of plantar fasciae in diabetic patients were greater than in healthy people, suggesting that the soft tissue is first subject to changes due to diabetes by the time of elastography.

Altogether, the evidence reviewed indicates that both B-mode ultrasonography and elastography modalities, in particular, SWE, have high diagnostic accuracy in PF. SWE provides more quantitative data on fascial biomechanics, improving early detection, differentiation, and subsequent treatment. The combination of SWE and traditional B-mode imaging appears to provide the highest diagnostic accuracy and should therefore be considered an integral component of a comprehensive ultrasound-based assessment of PF.

3.1. Meta-analysis results

A total of nine studies were included in the quantitative synthesis, comprising 913 participants—419 diagnosed with PF and 494 healthy controls. Across the included datasets, 46% of observations were PF cases, reflecting a nearly balanced distribution of diseased and healthy individuals.

The pooled diagnostic performance of UE for detecting PF demonstrated a high sensitivity of 0.908 (95% confidence interval [CI]: 0.786–0.964) and a moderate specificity of 0.760 (95% CI: 0.664–0.835), indicating that elastography correctly identified most PF cases while maintaining acceptable specificity in excluding healthy individuals. The DOR was 31.38 (95% CI: 10.06–97.91), reflecting strong discriminative power between PF and non-PF cases. Correspondingly, the positive likelihood ratio was 3.78 (95% CI: 2.60–5.51), suggesting that individuals with PF were nearly four times more likely to test positive than those without the condition. Meanwhile, the negative likelihood ratio was 0.12 (95% CI: 0.05–0.30), signifying a low probability of false-negative results. The false-positive rate was 0.24 (95% CI: 0.17–0.34). Collectively, these results support a high overall diagnostic accuracy for UE in identifying PF (Figures 2 and 3).

In terms of heterogeneity, the I^2 statistic for sensitivity was 0.076, indicating low between-study variability, while the I^2 for specificity was 0.697, representing moderate heterogeneity across studies. The bivariate I^2 value of 0.43 further confirmed moderate heterogeneity in the combined sensitivity–specificity model. The variances of logit-transformed sensitivity and specificity were 1.53 and 0.30, respectively, with corresponding standard errors of 0.51 and 0.24. The covariance between sensitivity and specificity was 0.012, and their correlation coefficient was

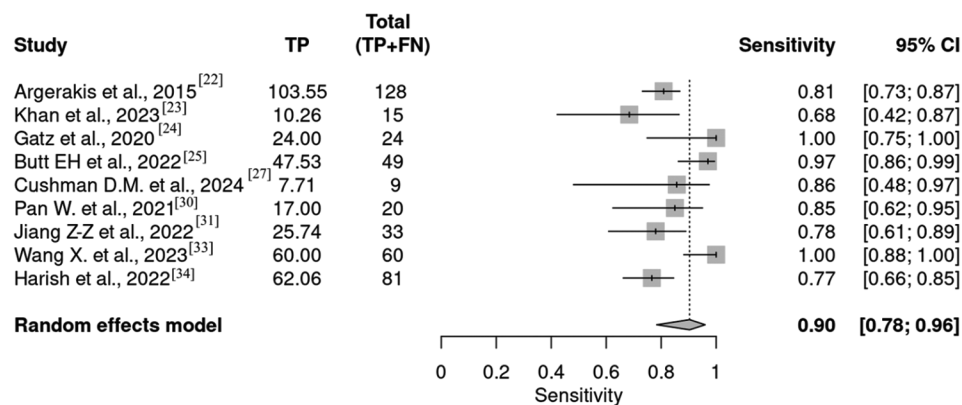


Figure 2. Pooled sensitivity of the included studies. Image created by the author.
Abbreviations: CI: Confidence interval; FN: False negative; TP: True positive.

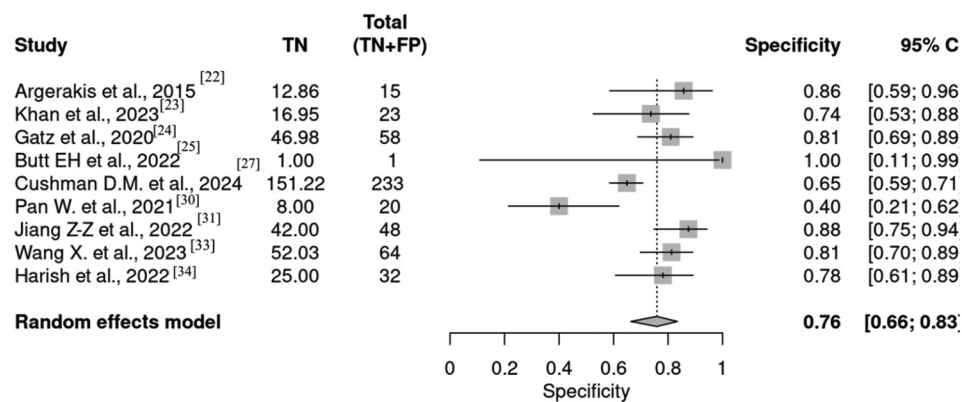


Figure 3. Pooled specificity of the included studies. Image created by the author.
Abbreviations: CI: Confidence interval; FP: False positive; TN: True negative.

0.164, indicating a weak positive relationship between the two diagnostic measures across studies.

The median odds ratio, which quantifies heterogeneity across studies, was 3.26 for sensitivity and 1.69 for specificity, further suggesting that variability in test performance across studies was modest for sensitivity but higher for specificity. The area of the 95% prediction ellipse was 0.448, denoting moderate dispersion of study estimates in the SROC space (Figure 4).

For risk of bias, most included studies have a low risk of bias across D1 (patient selection) to D4 (flow and timing). Only a few studies have some concerns due to limited data reported, including diagnostic outcomes (Figure 5).

Overall, these findings demonstrate that UE—encompassing both strain and shear wave modalities—provides high sensitivity and satisfactory specificity for detecting PF. The relatively high DOR and low likelihood ratio values indicate that elastography is a reliable

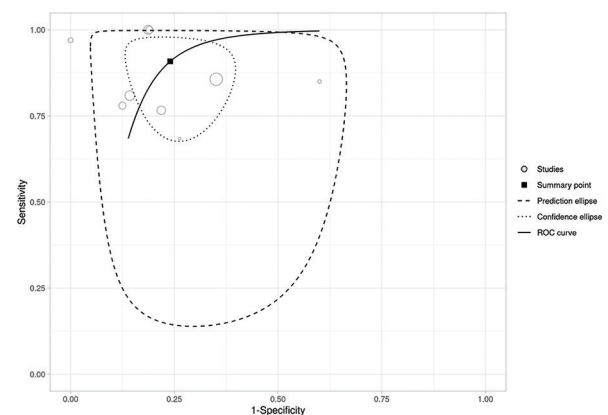


Figure 4. Summary receiver operating characteristic (ROC) curve results shown from the meta-analysis. Image created by the author.

diagnostic adjunct to conventional imaging methods, such as B-mode ultrasonography or MRI. The observed heterogeneity underscores potential variability related to

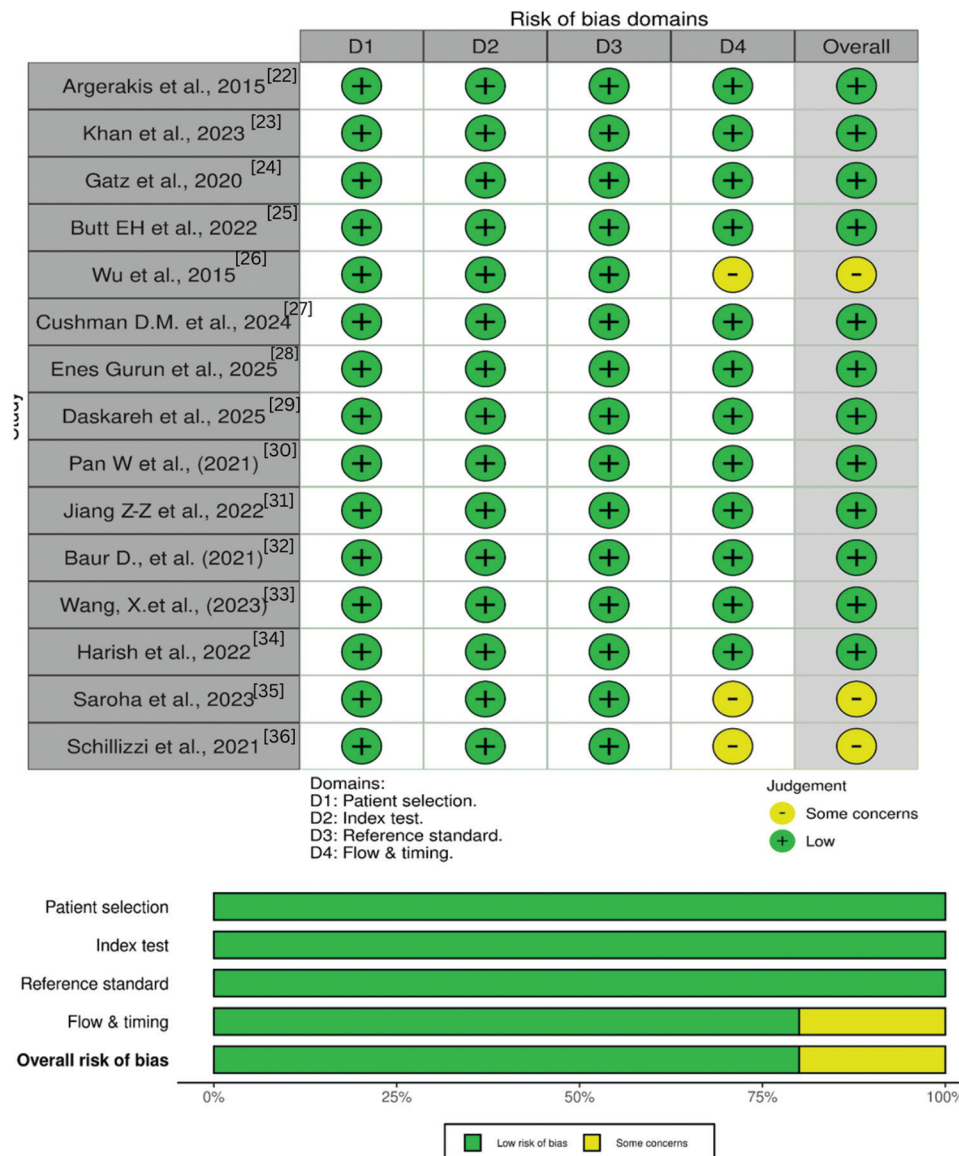


Figure 5. Quality assessment results from the selected studies. Image created by the author.

differences in elastography techniques, threshold settings, or study populations, and should be further explored in future large-scale standardized studies.

4. Discussion

This systematic review and meta-analysis provide a comprehensive synthesis of available evidence evaluating the diagnostic accuracy of UE for detecting PF. The pooled sensitivity and specificity were 90.8% (95% CI: 78.6–96.4%) and 76.0% (95% CI: 66.4–83.5%), respectively, with a DOR of 31.38 and a negative likelihood ratio of 0.12. These findings collectively indicate that UE—encompassing both strain and shear wave modalities—offers high diagnostic

reliability, accurately identifying most cases of PF while maintaining acceptable discrimination between diseased and healthy plantar fascia.

The high sensitivity suggests that UE can effectively identify early pathological changes within the plantar fascia, even before gross structural abnormalities appear on conventional ultrasound. This finding aligns with previous reports demonstrating that elastography detects subtle biomechanical alterations—such as reduced fascia stiffness and increased compliance—before morphological thickening. For example, Gatz *et al.*²⁴ reported that SWE could distinguish symptomatic PF patients from healthy controls with a sensitivity of 91% and specificity of 80%,

while Jiang *et al.*³¹ demonstrated that SWE outperformed conventional B-mode imaging in differentiating chronic degenerative changes. Similarly, Wu *et al.*³⁷ highlighted that reduced plantar fascia stiffness measured by SWE was strongly correlated with clinical pain scores and disease duration, suggesting a potential role of elastography in disease monitoring.

Comparison with previously published systematic reviews further validates these results. Albano *et al.*¹⁵ performed a systematic review and meta-analysis on SWE of the plantar fascia, concluding that PF-affected fasciae show significantly lower stiffness values compared to healthy fasciae (standardized mean difference = -3.00 m/s; 95% CI: -4.95 to -1.06). Similarly, Khammas *et al.*³⁸ reported that UE consistently detected a reduction in stiffness in PF patients, suggesting strong diagnostic promise. However, both reviews focused on differences in elasticity rather than diagnostic accuracy parameters, such as sensitivity and specificity. Our study extends these findings by providing pooled diagnostic metrics that quantify the discriminative ability of UE, thereby filling an important knowledge gap.

The pooled specificity (76.0%) indicates that a subset of healthy individuals may yield false-positive results. This could be attributed to inter-operator variability, differences in equipment calibration, loading conditions, and anatomical variations in plantar fascia stiffness. The moderate heterogeneity for specificity ($I^2 = 69.7\%$) further supports this variability, whereas the low heterogeneity for sensitivity ($I^2 = 7.6\%$) reflects consistency in detecting positive cases across studies. Importantly, when SWE is combined with B-mode ultrasonography, diagnostic performance improves considerably—as shown by Wang *et al.*,³³ which reported sensitivity of 93.3%, specificity of 93.8%, and an AUC of 0.97 using a multimodal approach.

These findings reinforce that elastography is best used as a complementary modality rather than a standalone diagnostic tool. The integration of SWE or SE with B-mode ultrasonography provides a quantitative assessment of fascia stiffness alongside conventional morphological evaluation, thereby enhancing diagnostic precision, especially in early or equivocal cases. Furthermore, emerging evidence suggests that elastography may have prognostic and therapeutic applications. Albano *et al.*¹⁵ and Abacioğlu *et al.*³⁹ reported measurable post-treatment increases in fascia stiffness following successful therapy, highlighting its potential for treatment monitoring. From a clinical perspective, elastography offers practical utility in routine practice by allowing clinicians to quantify tissue stiffness at the point of care, aiding in differentiating early

inflammatory changes from chronic degenerative disease. UE can guide decision-making regarding conservative therapy, physical therapy targeting biomechanical deficits, and follow-up assessment to monitor treatment response.

Despite its strong diagnostic performance, several limitations must be acknowledged. Most included studies had relatively small sample sizes and were conducted in single-center settings, which may affect generalizability. The absence of standardized stiffness cutoff values and the diversity of ultrasound systems (e.g., GE, Siemens, and Philips) also contribute to between-study heterogeneity. In addition, publication bias may arise from the selective reporting of positive findings. These factors underscore the need for large, multicenter trials with harmonized elastography protocols to establish universal diagnostic thresholds for PF detection. Another important consideration is the presence of comorbid conditions, such as pes planus (flat foot), obesity, Achilles tendon tightness, and prolonged standing, all of which alter foot biomechanics and may influence elastography measurements. Understanding these factors is crucial for accurate interpretation, as reduced fascia stiffness may partially reflect underlying structural or mechanical abnormalities rather than isolated PF alone.

Future research should prioritize large-scale, multicenter studies employing standardized elastography protocols and clearly defined diagnostic criteria. Comparative studies exploring the relative performance of strain and SWE, as well as their integration with artificial intelligence-based image analysis, could further refine diagnostic precision. In addition, longitudinal studies investigating the role of elastography in monitoring treatment response and predicting recurrence would expand its clinical applicability. Given the growing availability of handheld and smartphone-based ultrasound devices, future studies should also evaluate whether portable systems can provide reliable elastography measurements. If validated, such portability could greatly enhance accessibility for primary care and sports medicine settings.

5. Conclusion

This meta-analysis demonstrates that UE exhibits high sensitivity (90.8%) and satisfactory specificity (76.0%) in detecting PF, with strong overall diagnostic accuracy. By quantifying tissue stiffness and elasticity, elastography provides valuable biomechanical insights that complement conventional B-mode ultrasonography. Given its noninvasive nature, accessibility, and reproducibility, UE represents a reliable, adjunctive imaging modality for the early diagnosis, management, and follow-up of patients with PF. Standardization of acquisition protocols and

diagnostic cutoffs will be essential to further consolidate its role in routine clinical practice.

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