



Thermographic and sonographic findings in patients with ankle joint and foot pain: a retrospective study for the period from january 2010 to july 2025.

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SUMMARY

Starting point: This retrospective study evaluated all patients who were admitted to our institution with ankle or foot pain between January 2010 and July 2025, from which we included only those who presented a positive sonographic finding and also underwent thermographic examination.

Group: A total of 579 patients met the inclusion criteria, comprising 253 women aged 3–86 years (mean age 48.5 years) and 326 men aged 5–86 years (mean age 44.3 years).

Methods: Across this cohort, 803 positive sonographic findings were identified. Based on their morphological characteristics, these findings were categorized into solid-structure abnormalities, which accounted for 56% of all findings and included osteophytes, calcifications, ossifications and tophi; fluid-containing lesions, representing 19% and encompassing bursae, cysts, ganglia, joint effusion and oedema; tendinopathies, enthesopathies and ligamentous abnormalities, which constituted 15%; traumatic lesions such as ruptures, fractures, avulsions and TEP, representing 6%; defects and aseptic osteonecrosis, accounting for 2%; and growing pains, also accounting for 2%.

Results: Among the 579 patients with documented sonographic abnormalities, 81% exhibited an altered thermographic temperature distribution. Hyperthermia on the symptomatic side was recorded in 74% of these patients, whereas hypothermia was present in 7%, and 19% demonstrated a normal thermal pattern on the symptomatic side when compared with the contralateral ankle and foot.

Conclusions: The combined use of physical and thermographic assessment together with sonographic examination provides greater diagnostic accuracy than thermography or sonography alone. This integrated approach enables the selection of more targeted and individualized treatment strategies.

KEYWORDS

thermography, sonography, ankle, foot, bursa, calcification.

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1 INTRODUCTION

The ankle joint (AJ) and foot constitute a highly integrated functional complex composed of numerous bones, joints, ligaments, tendons, and neurovascular structures that collectively provide stability and mobility during locomotion. The osseous framework comprises 14 ankle and tarsal bones, five metatarsals, two sesamoid bones, and 14 phalanges, creating 25 articulations supported by 26 ligaments that maintain joint integrity. Motion is generated by nine extrinsic tendons and 22 intrinsic foot muscles, whose friction-free function is facilitated by 26 bursae. Vascular supply is derived from branches of the anterior tibial, dorsalis pedis, and posterior tibial arteries, whereas sensory and motor innervation originates from the tibial, deep peroneal, and superficial peroneal nerves (6,33).

Ankle sprains account for 15–25% of all joint injuries, with 10–20% progressing to chronic instability (21,4). They represent 14% of acute sports-related orthopedic consultations (28). Systematic reviews indicate that ankle sprains constitute up to 30% of sports injuries, with the anterior talofibular ligament (ATFL) being the most frequently affected structure, followed by the calcaneofibular ligament (CFL). Syndesmotic injuries involving the anterior inferior tibiofibular ligament (AITFL) occur in 18% of the general population and up to 74% of athletes, whereas deltoid ligament damage typically results from forced eversion mechanisms. Additional findings include injuries to the spring ligament, tibialis posterior tendinosis, and lesions of the tarsometatarsal and calcaneocuboid ligaments in approximately 7.3% of cases (15).

Epidemiological data underscore the substantial clinical burden of lateral ankle sprains, with approximately 302,000 new cases reported annually in the United Kingdom, 14% of which are classified as severe (1). Up to 75% of sports-related ankle injuries involve lateral ligament structures (31). Incidence rates are particularly high during preseason training, with rupture of lateral ligaments—especially the AITFL—being the predominant pathology. Recovery trajectories vary considerably, and residual symptoms such as pain, swelling, instability, and stiffness may persist for months or years, with prevalence estimates ranging from 21% to 74% (22). Persistent pain frequently reflects underlying degenerative or inflammatory alterations within tendinous or ligamentous tissues.

Recent histochemical investigations demonstrate that tendinopathies previously regarded as primarily degenerative are instead driven by inflammatory mechanisms involving cytokines, complement components, immune cells, TNF- α , interleukins, and tendon stem/progenitor cells (32). These processes may give rise to neurogenic inflammation, tenocyte hypertrophy, and in some cases heterotopic ossification or fatty infiltration. Local inflammatory activity can elevate superficial skin temperature, whereas autonomic dysregulation may paradoxically decrease temperature in symptomatic regions. Accordingly, thermography offers valuable insights into pathophysiological processes; however, it lacks the resolution necessary to precisely localize discrete structural lesions.

Accurate identification of morphological abnormalities therefore requires imaging modalities such as radiography, MRI, CT, and particularly high-resolution musculoskeletal ultrasound. Given the widespread clinical use of thermographic and sonographic assessment, the present study aims to classify ankle and foot pain based on thermographic patterns and to evaluate the sensitivity of thermography in comparison with sonographic morphological findings. Elucidating these relationships may support more targeted diagnostic strategies and facilitate individualized treatment planning (16,9,20,31).

2 GROUP AND METHODS

From our institutional archives, we identified patients admitted for ankle and foot pain between January 2010 and July 2025. Inclusion criteria comprised (6) the presence of ankle or foot pain, (33) abnormal

sonographic findings of the ankle joint or foot, and (25) available thermographic recordings of the corresponding region. Following a standardized medical history assessment, all patients underwent a comprehensive musculoskeletal examination. The clinical evaluation was further supplemented by thermographic imaging of the ankle and foot, as well as diagnostic musculoskeletal ultrasound. In most cases, additional imaging modalities were employed to refine the diagnostic work-up.

Physical examination

The clinical examination includes recording of the patient's medical history, with a particular focus on the characteristics of the pain: where and at what point the pain begins, the direction in which the pain spreads, what conditions intensify or reduce the pain, such as rest, movement, work, stress, relaxation, etc. Palpation examination of the ankle joint and foot includes testing of ligament and tendon sensitivity, evaluation of swelling and effusion. Functional tests were performed, including range of motion (ROM) examination, evaluation of joint play, joint stability, and joint stiffness. Muscle strength and muscle tone were also tested.

Thermographic examination

For the thermographic assessment, we employed a Fluke Ti32 thermal imaging camera equipped with a 320×240 focal plane array and an uncooled microbolometer, offering a thermal sensitivity (NETD) of 0.05°C at a target temperature of 30°C . Prior to imaging, the patient—with the relevant anatomical region exposed—underwent thermal acclimatization for 20 minutes in a darkened room maintained at $25^\circ\text{C} \pm 1.0^\circ\text{C}$. Thermograms were subsequently acquired in standard positions and views as recommended by the Glamorgan protocol (2).

Temperature parameters including T_{max} , T_{mean} , and T_{min} were evaluated within predefined regions of interest following the Glamorgan guidelines. Normal thermal distribution is determined based on temperature symmetry, defined as the similarity of mean temperature between anatomically corresponding regions mirrored across the body's midline (4,29). Temperature differences of less than 0.5°C between contralateral regions are considered physiologically symmetrical. A reduction of 0.5°C or more relative to the reference region is classified as a hypothermic pattern, whereas an equivalent increase is defined as a hyperthermic pattern. In the presence of symmetrical distribution, a localized temperature deviation of at least 0.5°C from the surrounding tissue is interpreted as local hyperthermia or local hypothermia. Thermographic evaluation was conducted across the anterior, medial, lateral, and posterior aspects of the ankle joint, as well as the dorsal and plantar surfaces of the foot at a camera distance 1 m.

3 STARTING POINT, OBJECTIVE, TASKS

Normal thermographic findings

The thermographic pattern is characterized by symmetrical temperature distribution and consistent absolute temperature parameters (Tmax, Tmin, Tmean) across all projections—anterior, posterior, medial, and lateral.

Anteriorly, increased thermal activity is observed in the anterior region of the talocrural (ATC) joint, corresponding to the course of the a. tibialis anterior, as well as in the dorsal aspect of the foot along the a. dorsalis pedis. A characteristic proximodistal descending temperature gradient is present, extending from the forefoot toward the toes, which exhibit hypothermic values.

Posteriorly, a similar proximodistal temperature decrease is evident, ranging from the calf through the Achilles tendon to the dorsal aspect of the heel, which demonstrates hypothermia.

Medially, increased thermal activity occurs posterior to the medial malleolus above the course of the a. tibialis posterior. The medial malleolus itself is slightly hypothermic, with more pronounced hypothermia in the calcaneal region. Distal to the ATC joint, a progressive temperature decline is present, culminating in hypothermia of the hallux and lesser toes.

Laterally, hypothermia is present over the lateral malleolus, with more substantial hypothermia in the calcaneal area. Increased thermal activity is again detectable in the dorsal region of the foot along the a. dorsalis pedis. The temperature gradient decreases distally toward the toes, which show marked hypothermia. Plantarly, increased thermal activity is present in the central medial aspect of the foot.

There is evident hypothermia in the plantar aspect of the calcaneus, with more pronounced hypothermic changes also observed in the toe region.

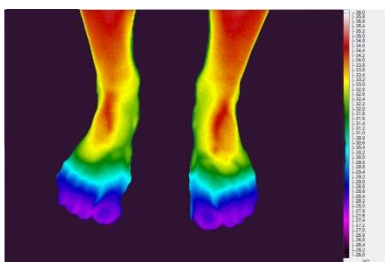


Fig. 4a. ATC and foot anteriorly

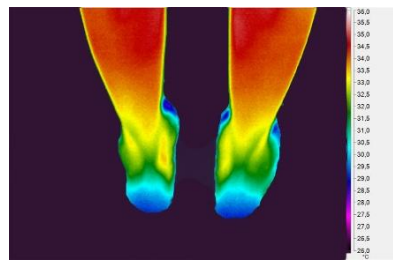


Fig. 4b. ATC and foot posteriorly

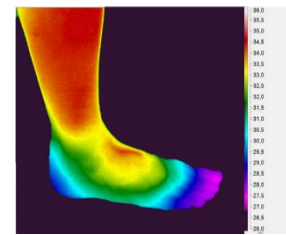


Fig. 4c. ATC and foot plantarly

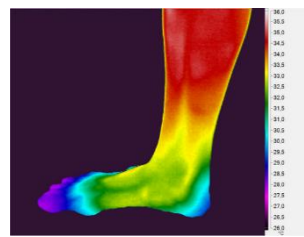
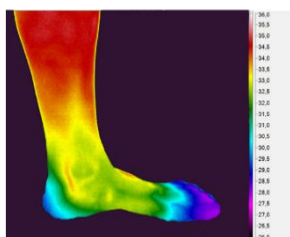


Fig. 4d.,e. ATC and foot medially on the left, on the right. **Fig. 4f.,g.** ATC and foot laterally on the right, on the left.

Pathological sonographic and thermographic findings – examples

Ankle joint anteriorly

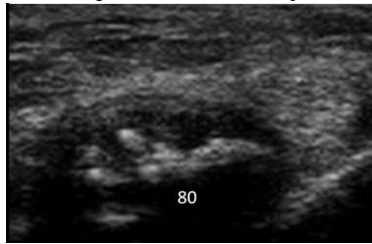


Fig. 5a. Ultrasound
80.calcification

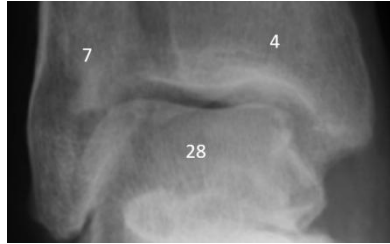


Fig. 5b. X-ray
4.tibia, 7.fibula, 28.talus

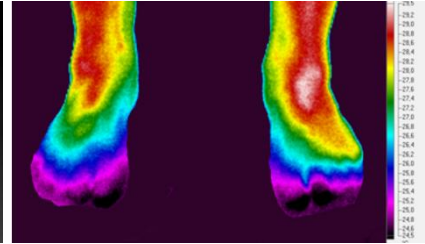


Fig. 5c. TMV
↑temperature on the left

Ankle joint medially

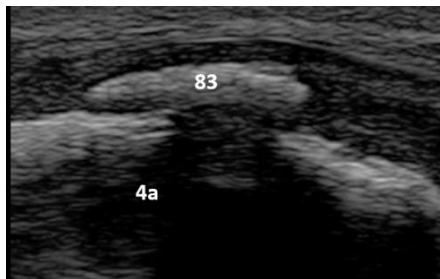


Fig. 6a. Sono
4a.maleolus medialis , 28. talus,83. abrasion

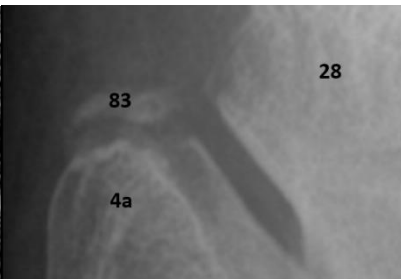


Fig. 6b. X-ray

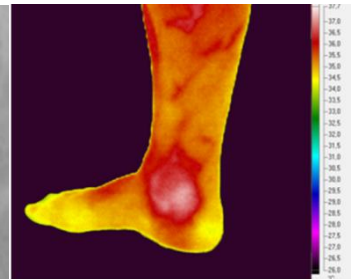


Fig. 6c. TMV
↑temperature on the right medially

Ankle joint laterally

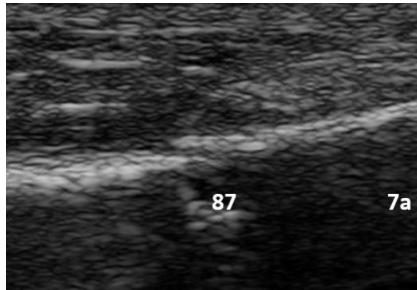


Fig. 7a. Sono
maleolus lateralis, 87. fracture

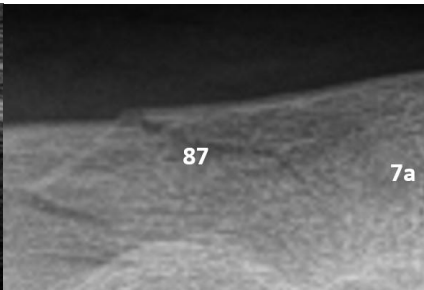


Fig. 7b. X-ray

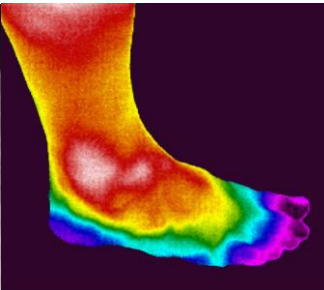


Fig. 7c. TMV
↑temperature on the right laterally

Ankle joint posteriorly



Fig. 8a. Sono

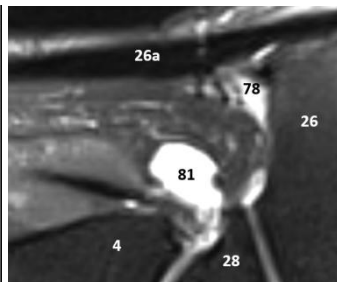
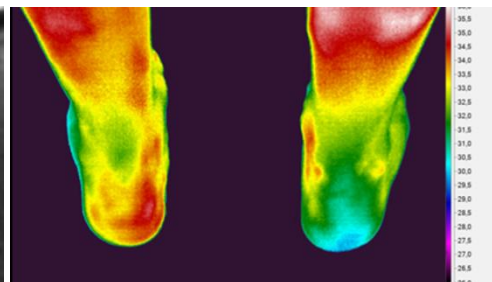


Fig. 8b. MRI



8c. TMV ↑temperature on the left posteriorly

4.tibia, 26a.tendo Achilei, 26.calcaneum, 28.talus, 78.bursa subachilea, 81.hydrops in recessus articularis posterior

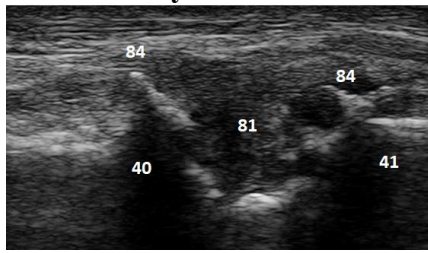
Foot dorsally

Fig. 9a. Sono
cuneiforme mediale, 41.os naviculare, 81.hydrops, 84.osteofyt

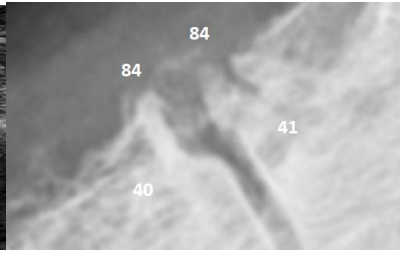


Fig. 9b. X-ray

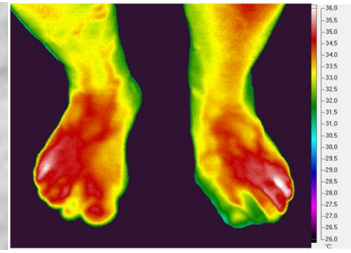


Fig. 9c. TMV ↑temperature on both sides 40.os

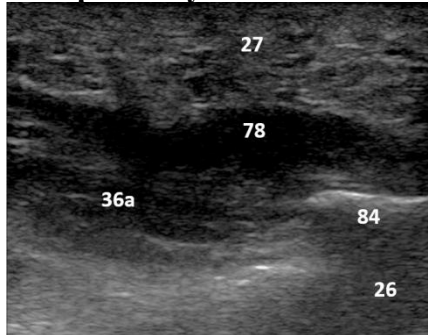
Foot plantarly

Fig. 10a. Sono
27.Kagers fat pad, 36a.aponeurosis plantaris, 78.bursa, 84.osteophyt

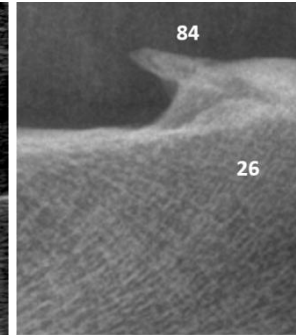


Fig. 10b. X-ray

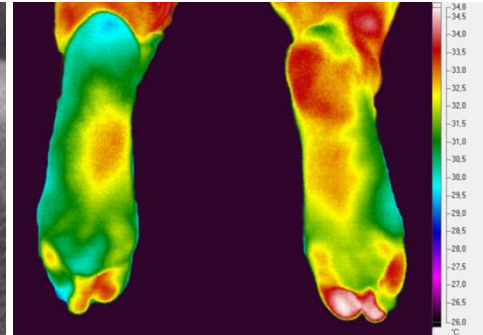


Fig. 10c. TMV ↑temperature on the right 26.calcaneum,

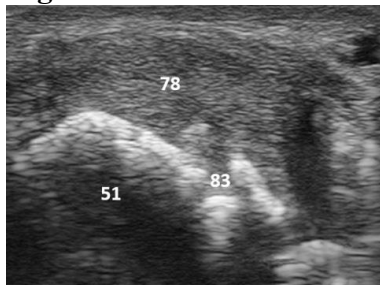
Big toe

Fig. 11a. Sono
51.MTI., 78.busza, 83.fragment

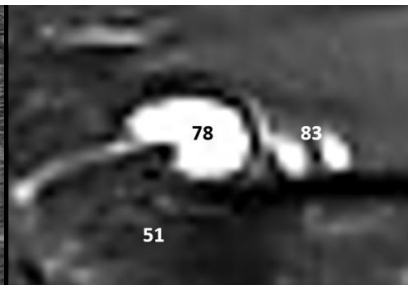


Fig. 11b. MRRI

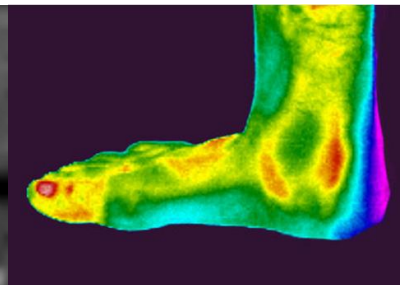


Fig. 11c. TMV↑MTI temperature

Toes

Fig. 12a. Sono
52.phalanx proximalis - luxation, 56.MTII., 81.hydrops

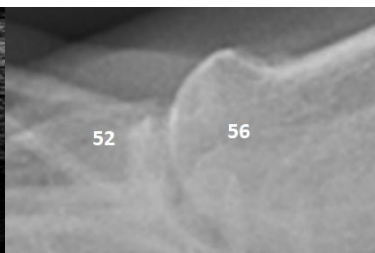


Fig. 12b. X-ray

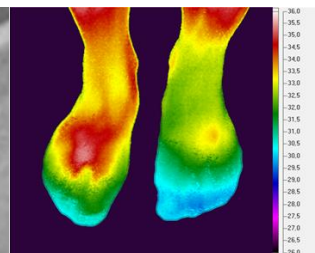


Fig. 12c. TMV↑temperature on the right

Sonography

For the sonographic examination, an Esaote MyLabSeven ultrasound system equipped with a 5–12 MHz linear transducer was used. The assessment was not limited solely to the region of reported pain; instead,

the entire ankle joint and foot were systematically examined in each patient. Dynamic sonographic tests were employed when clinically indicated.

During the evaluation of the anterior, medial, and lateral aspects of the ankle joint, as well as the dorsal region of the foot, the patient was positioned supine. Examination of the posterior aspect of the ankle joint and the plantar surface of the foot was performed with the patient in the prone position.

4 RESULTS

A total of 579 patients met the inclusion criteria. Of these, 253 (43.69%) were women aged 3–86 years (mean age 48.5 years), and 326 (56.31%) were men aged 5–86 years (mean age 44.3 years).

Temperature distribution on the skin

Among the 579 patients with sonographic abnormalities (Table 1), 79.62% ($n = 461$) demonstrated disturbances in temperature distribution. Hyperthermia of the symptomatic ankle joint and foot was present in 72.71% ($n = 421$) of patients, while hypothermia was observed in 6.91% ($n = 40$). A normal thermographic pattern of the symptomatic ankle joint and foot, when compared with the contralateral side, was identified in 20.38% ($n = 118$) of patients.

Table 1. Temperature patterns and corresponding sonographic findings

Temperature pattern	Total number of patients	Total number of sonographic findings
Hyperthermia (temperature of the symptomatic ankle joint and foot at least 0.5°C higher than the temperature on the contralateral side)	421	594
Hypothermia (temperature of the symptomatic ankle joint and foot at least 0.5°C lower than the temperature on the contralateral side)	40	56
Normothermia (temperature difference between both ankle joints and feet less than 0.5°C)	118	153
Total (n)	579	803

Sonographic findings

The total number of positive sonographic findings was 803 (Table 2), indicating that several patients presented with two or more distinct pathological abnormalities. Findings involving solid structures—such as osteophytes, calcifications, ossifications, and gouty tophi—were the most common and accounted for 55.92% ($n = 449$). Fluid-containing abnormalities, including bursae, cysts, ganglia, hydrops, and edema, represented 19.18% ($n = 154$). Tendinopathies, enthesopathies, and ligamentous pathologies comprised 14.94% ($n = 120$). Injuries such as ruptures, fractures, abductions, and findings related to total

endoprostheses (TEP) constituted 5.98% (n = 48). Usurations, defects, and aseptic osteonecrosis accounted for 1.99% (n = 16), and growing pains were identified in 1.99% (n = 16).

Table 2. Sonographic findings and their temperature patterns.

Sonographic findings total n = 803	↑T n = 594	↓T n = 56	norm.T n = 153	Total findings
findings of solid structures - osteophytes, calcifications, ossifications, gouty tophi	332	31	86	n = 449
findings with fluid content - bursae, cysts, ganglions, hydrops, edema	113	12	29	n = 154
tendinopathies, enthesopathies, ligaments	89	8	23	n = 120
injuries: ruptures, fractures, abruptions, and TEP	36	3	9	n = 48
usurations, defects, aseptic osteonecrosis	12	1	3	n = 16
growing pains	12	1	3	n = 16

5 DISCUSSION

Ultrasonography (USG) represents one of the fundamental modalities in clinical diagnostic imaging, primarily due to its high level of safety, broad availability, and low economic demands. Comparative studies evaluating multiparametric ultrasound in relation to CT angiography and MR angiography for the assessment of carotid stenosis have demonstrated that USG is an equivalent, and in some cases a preferred, tool for both morphological and functional evaluation, as it enables dynamic visualization of structures that static imaging modalities cannot consistently capture (18). An additional advantage of USG is its ability to display anatomical structures in real time, which is particularly important in musculoskeletal and orthopedic indications, where CT and MRI do not allow for precise assessment of movement-related phenomena.

Ultrasonography is also not contraindicated in patients with pacemakers or metallic implants, which substantially broadens its applicability compared with MRI. In the context of evaluating ankle pain, it should serve as the preferred initial imaging modality. Park (2021) describe several diagnostic advantages of ultrasonography in the assessment of the ankle joint, particularly in the evaluation of tendons, ligaments, and peripheral nerves, emphasizing the importance of dynamic tests, stress maneuvers, and observation of muscle contraction or passive movement. In peroneal tendon injuries, USG achieves high diagnostic accuracy, with a sensitivity of 100%, specificity of 85%, and overall accuracy of 90% (27). However, early diagnosis of Achilles tendon rupture may be incorrect in approximately 20% of cases; the typical rupture site is located 2–6 cm proximal to the tuber calcanei. Ruptures of the TFL and CFL ligaments occur in roughly 20% of ATC injuries. Ganglia and talocalcaneal coalition account for 40–50% of tarsal

tunnel syndrome cases (28). Park further reported that the average MRI accuracy in assessing ATC instability is 85%, indicating that MRI cannot be considered the primary diagnostic modality for this indication (27).

According to Fessell et al., USG is a rapid and effective method for imaging the extensor tendons, anterior ligaments, and other soft-tissue structures of the ankle. It is capable of identifying a broad spectrum of pathologies, including aneurysms, ganglion cysts, bursitis, foreign bodies, tumors, edema, tenosynovitis, partial and complete tendon ruptures, loosened osteosynthesis material or screws, gouty tophi, giant-cell tumors, synovial sarcomas, neuromas, and other peripheral nerve sheath lesions (12).

Shalabya et al. (2017) compared sonographic findings with MRI results in 28 patients presenting with ankle pain. USG reliably identified synovitis, joint effusion, intra-articular loose bodies, arthritis, plantar fasciitis, and ligamentous or tendinous lesions, achieving a sensitivity of 95.4%, specificity of 83.3%, and overall accuracy of 92.8%. The limitations of ultrasonography include reduced ability to detect avascular necrosis, bone marrow edema, and fractures; therefore, MRI should be performed when sonographic findings are negative or inconclusive (31).

Artul and Habib (2014) analyzed 364 ultrasonographic examinations of the ATC region and foot, 93 of which focused on the ATC, 30 on the heel, and 241 on other foot regions. In the ATC region, the most frequent finding was tenosynovitis, occurring predominantly in women. In the heel region, Achilles tendon tendinitis was most common, again primarily in women. In other foot regions, the most frequent findings were fluid collections and foreign bodies, predominantly in men (4).

According to Ďurianová et al., thermography represents an appropriate tool for objectifying therapeutic interventions in peripheral pain associated with the axial system (10,11). Hornáček highlights that thermographic assessment still has untapped diagnostic potential in the early detection of diabetic foot and in monitoring its progression. This includes the postoperative period following partial amputations, evaluation of healing processes, and the identification of newly emerging at-risk lesions (17). He also emphasizes the differential-diagnostic utility of foot thermography in patients exhibiting “stiff gait,” where thermography can assist in determining whether the pain originates from overuse of soft tissues, early plantar fasciitis, enthesopathy (e.g., in the heel region), or early or advanced insertional Achilles tendinopathy (18).

Oliveira et al. documented a 2 °C decrease in temperature in a patient with recurrent ankle sprains (26), while hypothermia was also observed in six additional patients evaluated within 24–48 hours post-injury. The authors attribute this finding to reflex sympathetic vasomotor alterations (25). Similar observations were reported by Kozarski et al., who found reduced temperatures in painful ankle joints in dancers following repeated sprains; after ten consecutive rehabilitation sessions, temperature differences normalized

(3). Melgosa reported higher skin temperature in the limb with corrective adjustments compared with the contralateral limb, likely reflecting increased regional blood flow (23).

In our previous observations, we recorded more than a two-fold stronger correlation between thermographic, sonographic, and musculoskeletal findings in a cohort of 58 patients, compared with the correlation between radiographic and musculoskeletal findings. Distinct thermal patterns were associated with different types of pain (13). In this cohort, pathological findings were located in the heel region in 47% of cases, the Achilles tendon region in 16%, and other regions in 27%. Hyperthermia was present in 74% of cases, hypothermia in 19%, and normothermia in 7% (14).

Oliver et al. tested two thermal cameras (Flir One and Flir E8) in seven patients with Achilles tendon pain, and both devices demonstrated excellent intra- and inter-rater reliability at distances of both 1 m and 0.5 m (24). Oliveira et al. also compared thermograms of injured and uninjured ankle joints in 19 patients, observing an increase in thermal activity with progression from a mild to a severe condition (25).

Rodríguez-Portelles et al. (2025) reviewed 16 studies retrieved from Scopus, Science, and Springer over the past five years addressing plantar thermography and podography. Thermography effectively detects hyperthermia associated with inflammation and hypothermia associated with ischemia. It is utilized in the evaluation of diabetic foot ulcers, sports injuries, onychomycosis, vascular diseases, and tendinopathies and is often integrated with plantar pressure analysis and sonography (30). Bianchi and Martinoli describe increased thermal activity in the soft tissues of the retrotalar region due to inflammatory processes associated with os trigonum syndrome, Stieda process, and posterior ankle impingement during sports activities requiring excessive plantar flexion (5).

Vardasca documented a case of a rugby player with a grade III ankle sprain, in whom elevated temperature persisted 20 days after immobilization, with normalization occurring after 29 days of rehabilitation (34). Ioannou described a comparable pattern in a patient monitored after an ankle sprain, where a focal thermally active region began to diminish by day 21 and normalized by approximately day 42 (19).

6 CONCLUSIONS

The combined use of physical and thermographic assessment together with sonographic examination provides greater diagnostic accuracy than thermography or sonography alone. This integrated approach enables the selection of more targeted and individualized treatment strategies.

7 ZUSAMMENFASSUNG

Die Ausgangspunkte: diese retrospektive Studie untersuchte alle Patienten, die zwischen Januar 2010 und Juli 2025 mit Knöchel- oder Beinschmerzen in unsere Einrichtung aufgenommen wurden. Von diesen schlossen wir nur diejenigen ein, die einen positiven sonografischen Befund hatten, und unterzogen sich zudem einer thermographischen Untersuchung.

Die Datei: insgesamt erfüllten 579 Patienten die Einschlusskriterien, darunter 253 Frauen im Alter von 3–86 Jahren (Durchschnittsalter 48,5 Jahre) und 326 Männer im Alter von 5–86 Jahren (Durchschnittsalter 44,3 Jahre).

Die Methoden: innerhalb dieser Kohorte wurden 803 positive sonographische Befunde identifiziert. Basierend auf morphologischen Merkmalen wurden diese Ergebnisse wie folgt aufgeteilt: Auffälligkeiten starrer Strukturen, die 56 % aller Befunde ausmachten und Osteophyten, Verkalkungen, Ossifikationen und Tophi umfassten; flüssigkeitshaltige Läsionen, die 19 % ausmachten und Bursaen, Zysten, Ganglien, Gelenkerguss und Ödeme umfassten; Tendinopathien, Enthesopathien und Bandauffälligkeiten, die 15 % ausmachten; traumatische Läsionen wie Risse, Brüche, Avulsionen und TEP, die 6 % ausmachten; Defekte und aseptische Osteonekrose, die 2 % ausmachten; und Wachstumsschmerzen, die ebenfalls 2 % ausmachten;

Die Ergebnisse: von den 579 Patienten mit dokumentierten sonografischen Auffälligkeiten wiesen 81 % eine veränderte thermographische Temperaturverteilung auf. Bei 74 % dieser Patienten wurde Hyperthermie auf der symptomatischen Seite beobachtet, bei 7 % Unterkühlung. Bei 19 % wurde ein normales thermisches Bild auf der symptomatischen Seite im Vergleich zum kontralateralen Knöchel und Bein beobachtet.

Die Schlussfolgerung: die kombinierte Anwendung von physikalischer und thermographischer Beurteilung zusammen mit der sonografischen Untersuchung sorgt für eine höhere diagnostische Genauigkeit als die Thermographie oder die ausschließliche Sonographie. Dieser integrierte Ansatz ermöglicht die Auswahl gezielterer und individueller angepasster Behandlungsstrategien

Die Schlüsselwörter: Thermographie, Sonographie, Knöchel, Bein, Bursa, Verkalkung

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