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MINIREVIEWS

Science of heat mapping: Thermography in musculoskeletal disorders

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Abstract

Musculoskeletal injuries are among the most common causes of disability worldwide, with early detection and appropriate intervention critical to minimizing long-term complications. Infrared thermography (IRT) has emerged as a non-invasive, real-time imaging modality that captures superficial temperature changes reflecting underlying physiological processes such as inflammation and vascular alterations. This review explores the fundamental principles of medical thermography, differentiates between passive and active approaches, and outlines key technological advancements including artificial intelligence integration. The clinical utility of IRT is discussed in various contexts – ranging from acute soft tissue injuries and overuse syndromes to chronic pain and rehabilitation monitoring. Comparative insights with conventional imaging techniques such as ultrasound and magnetic resonance imaging are also presented. While IRT offers functional imaging capabilities with advantages in portability, safety, and speed, its limitations – such as lack of deep-tissue penetration and protocol standardization – remain significant barriers to broader adoption. Future directions include the integration of IRT with other imaging modalities and digital health platforms to enhance musculoskeletal assessment and injury prevention strategies.

Key Words: Thermography; Musculoskeletal injuries; Heatmapping; Infra-red imaging; Musculoskeletal disorders

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Core Tip: Infrared thermography is a promising, non-invasive imaging tool for musculoskeletal injury assessment, detecting temperature variations linked to inflammation, vascular changes, and muscle fatigue. It enhances early diagnosis, injury prevention, and rehabilitation monitoring, particularly in sports medicine. However, challenges in sensitivity, specificity, and standardization limit its clinical adoption. Advances in artificial intelligence, improved imaging resolution, and integration with other modalities may enhance its reliability, expanding its role in orthopedic and rehabilitation care.

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INTRODUCTION

Musculoskeletal injuries (MSIs) are among the most prevalent health concerns globally, affecting individuals of all ages, backgrounds, and activity levels. They are typically categorized into sprains, strains, tendinopathies, fractures, and soft tissue injuries – each capable of significantly impairing a person's ability to perform daily tasks, maintain occupational productivity, or engage in recreational activities[1,2]. These injuries are particularly common in physically active populations such as athletes, laborers, and individuals involved in repetitive motion or high-strain tasks[3]. The economic impact of MSIs is equally substantial. In addition to the burden of prolonged treatment and rehabilitation, affected individuals often experience extended absenteeism, loss of income, and decreased quality of life[4]. Long-term disability resulting from inadequately managed MSIs contributes further to global healthcare and socioeconomic strain. According to the World Health Organization, musculoskeletal disorders currently affect an estimated 1.71 billion people worldwide, making them one of the foremost contributors to years lived with disability[5]. The timely and accurate diagnosis of MSIs is essential for initiating appropriate therapeutic interventions and preventing chronic sequelae[6]. Conventional imaging modalities – such as X-rays, magnetic resonance imaging (MRI), and ultrasonography – are the mainstays of diagnostic evaluation[7]. While these technologies are effective at detecting gross structural abnormalities, they often fall short in identifying early-stage physiological disruptions such as inflammation, muscle fatigue, or subtle changes in vascular dynamics[8]. Furthermore, their accessibility is hindered by infrastructure limitations, cost, and in some cases, radiation exposure. These limitations are particularly pronounced in field settings like sports arenas, rural clinics, and emergency response situations, where rapid, non-invasive, and portable diagnostic tools are highly desirable[9,10]. As such, the demand for adjunct imaging techniques that can provide functional, physiological information in real-time has led to increased interest in modalities such as infrared thermography (IRT)[11].

IRT is a radiation-free imaging method that uses infrared sensors to measure temperature differentials on the skin surface. These variations may reflect underlying biological processes such as increased blood flow, neurovascular alterations, or local inflammation – hallmarks of many musculoskeletal pathologies[12,13]. IRT holds several practical advantages: It is non-invasive, quick, portable, and cost-effective. It enables real-time feedback, requires minimal patient preparation, and is safe for use across sensitive populations, including children and pregnant women[14,15]. In sports medicine, IRT has been used both for early injury detection and to guide rehabilitation progress, particularly in high-performance athletes[16]. Similarly, chronic pain syndromes, fibromyalgia, arthritis, and sciatica are now being explored through thermographic imaging to visualize inflammatory patterns over time[17]. IRT has also found utility in evaluating response to various therapeutic interventions such as cryotherapy, low-level laser therapy, and electrotherapy, aiding clinicians in assessing vascular and inflammatory changes following treatment[18]. Despite its advantages, the widespread clinical adoption of IRT has been limited by challenges including environmental sensitivity, lack of standardized imaging protocols, and inter-operator variability[19].

This article evaluated the scientific principles, clinical applications, limitations, and future potential of IRT in MSIs. Special attention is given to its role in early diagnosis, injury monitoring, rehabilitation assessment, and integration with evolving technologies such as artificial intelligence (AI) and wearable systems.

OVERVIEW OF THERMOGRAPHY

IRT is a non-contact, non-invasive imaging technique that detects infrared radiation emitted from the skin surface to produce thermal maps reflecting physiological states. While thermography has widespread use in industrial fields such as structural inspection, electronics, and manufacturing, this review focuses specifically on clinical or medical IRT, particularly for applications in musculoskeletal medicine[20].

IRT measures temperature distribution on the skin, which may indicate underlying physiological or pathological conditions such as inflammation, altered circulation, or neuromuscular dysfunction[21]. Because the human body constantly emits infrared radiation, changes in metabolic activity or vascular flow, such as those triggered by MSI, can produce detectable thermal asymmetries on the skin surface[22].

Unlike conventional imaging modalities such as MRI or ultrasound, which provide structural information, IRT offers functional imaging based on physiological changes. This functional insight is particularly valuable in early-stage injury assessment, where inflammation, vascular dilation, or muscle fatigue may precede structural damage[8,11]. Medical-grade IRT systems have found increasing utility in orthopedics, rehabilitation, sports medicine, and chronic pain management, offering clinicians an adjunct tool for dynamic, real-time assessment.

BASIC PRINCIPLES OF THERMOGRAPHY

IRT functions by capturing the infrared radiation naturally emitted by the human body in proportion to its surface temperature. This radiation is detected by specialized infrared cameras and transformed into thermograms - visual representations of skin temperature variations[23]. These thermal patterns may reflect physiological processes such as inflammation, tissue perfusion, or neuromuscular activity, thereby providing insight into underlying musculoskeletal conditions[4].

In healthy individuals, skin temperature distribution is generally symmetrical due to the body's thermoregulatory mechanisms. However, in the presence of injury, inflammation, or vascular dysfunction, localized hyperthermia or hypothermia may appear on the affected area, leading to asymmetrical thermal profiles detectable by IRT[24]. The vascular and nervous systems play a critical role in regulating skin temperature. In response to injury or inflammation, vasodilation occurs - mediated by autonomic nervous system signaling and the release of inflammatory cytokines such as histamine and prostaglandins. This vasodilation increases local blood flow, elevating the skin temperature above the affected tissues[25]. Conversely, sympathetic-mediated vasoconstriction may lead to reduced surface temperature in certain conditions like neuropathies or chronic pain syndromes[8].

These temperature shifts – although occurring at a microscopic or vascular level – can be translated into macroscopic thermographic patterns. Thus, IRT serves as a valuable method for monitoring such physiological responses in real-time without any direct contact.

TYPES OF THERMOGRAPHY

IRT used in clinical practice can be broadly classified into two modalities: Passive and active thermography, depending on whether or not an external thermal stimulus is applied during imaging[26].

Passive thermography records the body's natural infrared emission without external influence. It is primarily used to identify inflammation, vascular congestion, or soft tissue injuries by detecting spontaneous heat emissions. For example, localized hyperthermia in areas such as the patellar tendon or lumbar paraspinal region can suggest tendon overload or radiculopathy, respectively. This technique is non-invasive, fast, and most suitable for baseline thermal screening and acute injury assessment.

Active thermography, by contrast, involves applying an external thermal stimulus (usually cooling) to provoke a physiological response. The skin's thermal recovery pattern is then observed to evaluate underlying vascular or neurological function. This modality is especially useful for assessing circulatory abnormalities, chronic pain conditions, and autonomic dysfunctions. For instance, prolonged or asymmetrical rewarming after cold stress may indicate impaired vasomotor response, as seen in chronic musculoskeletal pain syndromes.

The choice of modality depends on the clinical objective: Passive IRT is best suited for detecting acute inflammatory conditions, while active IRT is preferred for evaluating neurovascular reactivity and chronic dysfunctions. Regardless of type, both modalities require strict standardized protocols, including room temperature control, patient acclimatization, and consistent camera positioning to ensure reproducible results and accurate interpretation[26].

TECHNOLOGY AND TOOLS IN THERMOGRAPHY

Recent years have seen significant advances in the technological landscape of IRT. Modern infrared imaging systems now incorporate high-resolution detectors – typically made from vanadium oxide or germanium – that can capture even minute temperature differences with high precision[27,28]. These sensors convert emitted infrared radiation into electronic signals, which are then processed by advanced software to generate thermograms, representing thermal variation across anatomical surfaces[29].

Thermal maps are usually color-coded, with red and yellow denoting higher temperatures and blue or green indicating cooler regions. In addition to visual output, the software often provides quantitative data such as mean temperature, thermal asymmetry, and standard deviation, which support objective clinical interpretation[30].

Progress in image analysis software has enhanced the clinical utility of IRT. Many platforms now offer tools for automatic region-of-interest analysis, temperature calibration, and statistical comparison. Recent developments include the integration of AI and machine learning algorithms, which enable automated detection of thermal anomalies, pattern

recognition, and predictive modeling[31].

For example, AI-enhanced thermographic platforms can flag abnormal temperature distributions suggestive of early-stage tendinopathy or post-surgical complications, allowing for early intervention. These tools also reduce inter-observer variability and improve diagnostic consistency by identifying subtle thermal asymmetries that may not be apparent to the human eye[31].

As thermography systems continue to evolve, integration with mobile applications, wearable sensors, and cloud-based storage platforms is expanding their potential for point-of-care diagnostics and telemedicine.

CLINICAL APPLICATIONS OF THERMOGRAPHY

IRT has emerged as a valuable adjunct imaging modality in the evaluation of MSIs, especially in settings requiring early identification of inflammatory changes or localized soft tissue damage[32].

Most MSIs including muscle strains, ligament sprains, and tendinopathies are characterized by localized inflammation. These inflammatory responses manifest as localized hyperthermia, which IRT can detect before structural changes appear on traditional imaging[33]. For instance, muscle injuries such as contusions or partial tears often generate focal increases in skin temperature due to hyperemia, allowing for earlier diagnosis and targeted interventions[34]. IRT is also useful in tracking recovery[35]. Persistence of thermal asymmetry may indicate unresolved pathology, guiding adjustments in therapy or return-to-activity decisions.

In sports medicine, IRT plays a key role in injury prevention. It enables proactive monitoring for early signs of overuse or fatigue in high-risk muscle groups. Asymmetrical heat patterns may indicate muscular overload, such as developing tendinopathy in the Achilles or patellar tendons, even before symptoms appear[36,37].

Compared to other imaging modalities, IRT has demonstrated moderate sensitivity (81%) and specificity (74%) in detecting patellar tendinopathy, especially in the early inflammatory stage when MRI or ultrasound may still be inconclusive[38]. While it does not replace structural imaging, IRT complements it by providing functional data, aiding in comprehensive injury evaluation.

Overall, IRT adds clinical value through its non-invasive, radiation-free, real-time imaging capabilities, especially in acute injury settings, performance monitoring, and rehabilitation planning[39]. The representative images of the utilization of IRT in various musculoskeletal pathologies are depicted (Figure 1).

ADVANTAGES OF THERMOGRAPHY

IRT's most significant advantage is its non-invasive, and radiation-free nature. Traditional modalities like X-rays and MRIs often involve exposure to radiation and/or the patient must be still in uncomfortable positions, but IRT is completely safe and painless[37]. It has value in more sensitive populations (*e.g.*, children, pregnancy, patients with contraindications to more invasive imaging). Another vital advantage of IRT is the speed and accessibility of imaging in acute injury scenarios because fast clinical decision-making is necessary. The rapidity of obtaining thermal images is important to ensure the speed of the clinical assessment, without sacrificing clinical or diagnostic value[39].

Moreover, IRT allows for dynamic monitoring. With serial imaging, clinicians can visualize time-related changes in skin temperature, providing important information concerning the evolution or resolution of inflammation. This aspect of temporal monitoring is particularly advantageous in treating acute and chronic musculoskeletal problems, in that it provides support to treatment decisions by being able to tailor rehabilitation protocols and facilitate timely alterations in treatment based on the patient's reaction to therapy[40].

THERMOGRAPHY IN ACUTE MSIs

Acute MSIs encompass a wide range of conditions, including muscle strains, ligament sprains, contusions, dislocations, and fractures. These injuries typically present with abrupt onset of pain, functional limitation, and localized inflammation. In case of IRT, this inflammatory response manifests as focal increases in skin temperature – a hallmark of acute soft tissue damage[41].

IRT provides clinicians with a real-time visualization of these early physiological changes. Within minutes of tissue injury, the body initiates a healing cascade involving vasodilation and increased perfusion, resulting in localized hyperthermia detectable by infrared imaging. This makes thermography particularly valuable in identifying the site and severity of acute injuries, especially when structural imaging (*e.g.*, X-rays) may still appear normal[42].

One of the key advantages of IRT in this context is its ability to detect soft tissue involvement, such as muscle tears, tendon irritation, or ligament sprains, which may not be easily visualized on initial radiographs. The ability to distinguish between areas of high metabolic activity (hot zones) and less-inflamed tissues enables clinicians to make early clinical decisions about immobilization, physiotherapy, or surgical referral[43].

In high-performance athletic settings, IRT has been successfully used to detect pre-symptomatic hotspots associated with muscle overload, particularly in the quadriceps, hamstrings, and calf muscles. Early identification of these hyperthermic areas allows for intervention before progression to full-blown injury, reducing time loss and enhancing recovery outcomes[44]. By consistently applying this non-invasive, functional imaging modality, clinicians can rapidly

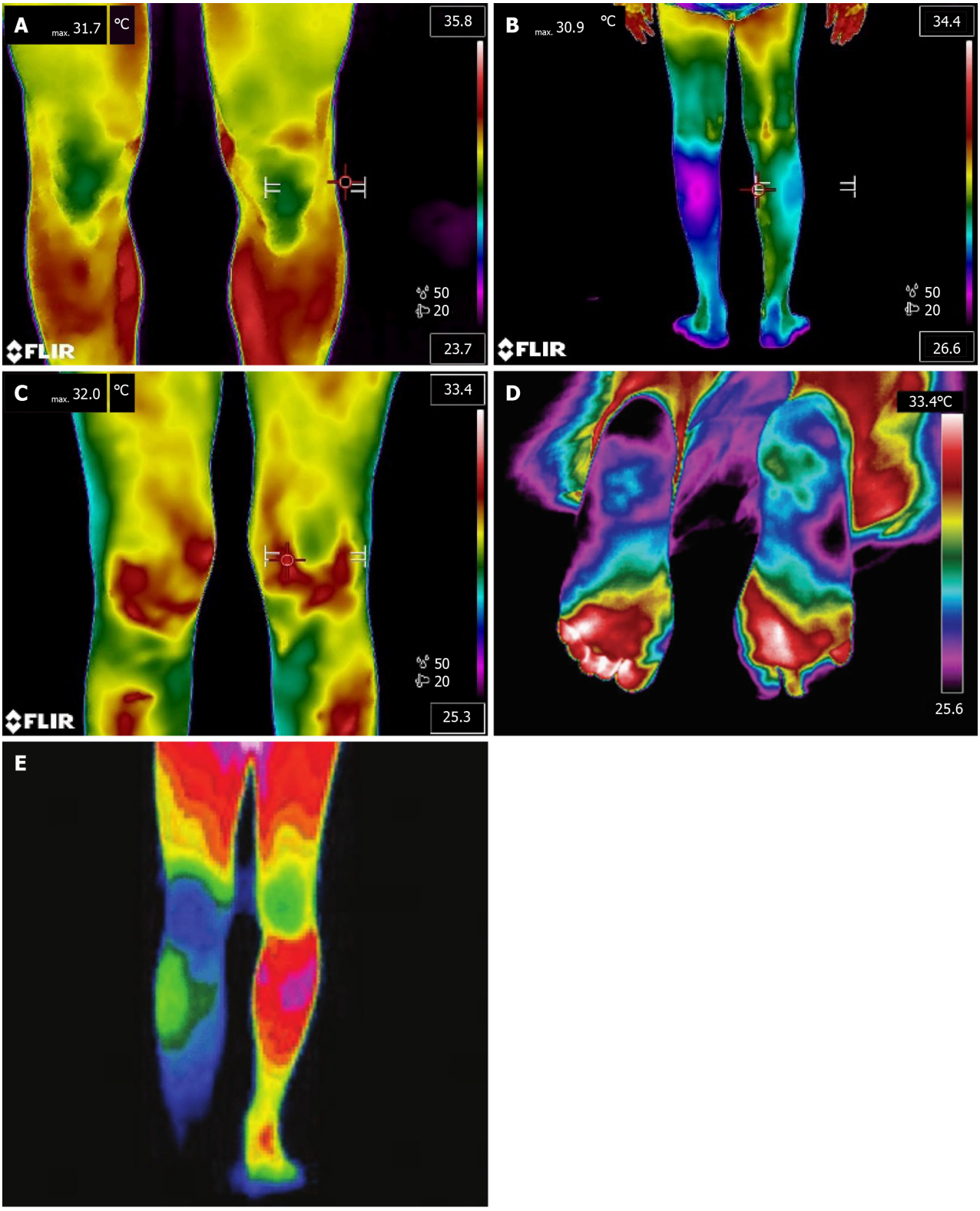


Figure 1 Representative images of the utilization of infrared thermography in various musculoskeletal pathologies are depicted. A: Infrared imaging of bilateral knees with localized hyper-radiation in the superolateral region of the left patella suggestive of quadriceps tendinopathy; B: Infrared imaging of bilateral lower limbs showing hyporadiant area on the lateral side of the thigh and posterolateral side of the right leg suggestive of lumbar radiculopathy; C: Infrared imaging of left knee showing hyper-radiant area embracing the inferior aspect of the patella with localized area of hyper-radiation on the medial aspect of the knee suggestive of knee synovitis (horseshoe sign) with overloading of medial collateral ligament; D: Infrared imaging of bilateral feet showing the breaking of the transverse lines of the feet distal thermal gradient with digital anisothermy, and the average temperature of feet sole > 33 °C suggestive of diabetic neuropathy; E: Infrared imaging of the right lower limb showing the area of diffuse hyporadiation throughout the leg and especially the foot suggestive of chronic complex regional pain syndrome.

evaluate acute injuries, initiate timely interventions, and monitor the initial phase of the healing process with improved clinical insight.

THERMOGRAPHY IN CHRONIC MSIs

Chronic MSIs typically result from cumulative microtrauma, overuse, or degenerative changes affecting tendons, joints, or supporting soft tissues. Common examples include tendinopathies, osteoarthritis, and repetitive strain injuries – conditions often encountered in athletes, manual workers, or the elderly[3]. IRT plays a supportive role in visualizing persistent low-grade inflammation, vascular adaptation, or altered tissue perfusion in these disorders. In cases of tendinopathy, for instance, repeated loading leads to microvascular changes and collagen disorganization, often accompanied by localized hyperthermia that can be captured by IRT[25]. Even a small rise in skin temperature, when detected early, may help clinicians identify pathology not yet visible on structural imaging[44]. Similarly, in osteoarthritis, thermography can highlight temperature elevations around affected joints such as the knee or hip. These changes reflect ongoing inflammatory processes, providing a functional marker that correlates with disease activity or flare-ups [45-47]. Serial thermal imaging may be useful in monitoring therapeutic response and adjusting treatment plans accordingly. However, a notable limitation of IRT in chronic conditions is the attenuation or normalization of thermal signals over time. In long-standing cases, inflammatory activity may diminish, leading to reduced skin temperature differentials. This can obscure pathology, particularly in late-stage disease, and highlights the need to use IRT in conjunction with other diagnostic modalities for accurate assessment[45].

Despite this limitation, IRT remains valuable in rehabilitation monitoring. Repeated assessments can track subtle changes in perfusion or thermal asymmetry during physiotherapy or regenerative treatments, providing visual feedback on healing progression and guiding therapy modifications[46].

THERMOGRAPHY IN INJURY PREVENTION

Heat asymmetry – where one side of the body exhibits elevated temperatures compared to the other – is another indicator that IRT can detect[48-51]. In athletes, such asymmetry may suggest imbalances in muscle activity or joint function, which can eventually lead to injury. Regular monitoring of these temperature patterns allows for the identification of athletes at risk for injury, enabling targeted interventions such as corrective exercises or adjustments to the training schedule, to reduce the likelihood of injury[52,53].

THERMOGRAPHY IN POST-INJURY REHABILITATION

IRT is best known for its applications in injury prevention, including emerging applications in sports. Athletes are at high risk of acute and chronic MSI, mainly due to the physical aspects related to training and competition[54]. The biggest risk would be overuse injuries that develop slowly and usually go unnoticed until they become painful or dysfunctional. IRT is important in that it can provide a monitoring method that can assess potential injury before permanent damage occurs [55].

IRT monitoring can allow sports teams and clinicians a means of performing routine screening of athletes and is capable of identifying early warning signs of muscle fatigue, muscle inflammation, or muscle microtrauma before symptoms even present. For example, IRT scans can pick up the first signs of inflammation with just slight temperature increases in large muscle departments likely to suffer from overuse such as the quadriceps, hamstrings, or rotator cuff. Those first signs of increased inflammation can help a medical team alter an athlete's training plan, allow for a longer or additional rest day, or begin treatment on the athlete before the injury turns serious[56].

IRT is also very useful for rehabilitation after an injury, which requires careful monitoring of recovery to determine when an athlete or patient can return to full activity. Again, IRT is used to detect inflammation, which is one of the first reactions to injury. By monitoring temperature changes throughout rehabilitation, a clinician can see if inflammation is decreasing, an important sign of recovery[57].

For instance, in the case of a muscle strain, the clinician can detect the healing process over several weeks or months. As the injury heals itself, the temperature of the area should eventually return to its normal state over time, and IRT can visualize this process. If the area remains elevated in temperature, it indicates persistent inflammation and/or ongoing healing, which could signal the need for further treatments and can help prevent the possibility of going back too soon to normal activity before all the healing has occurred[58].

In addition to inflammation, IRT can also recognize alterations in circulation as the healing process occurs[59]. After an injury, the body strives to restore normal perfusion to the injured tissue by increasing the amount of blood in that area [60]. IRT can identify if perfusion is improving and whether any problems (problems like reduced blood flow or reduction in tissue oxygenation) still exist[61]. Monitoring the body's recovery through vascular improvement is very useful in the rehab process as it assures that the patient is on track with their expected recovery trajectory[18].

LIMITATIONS OF THERMOGRAPHY

Environmental sensitivity

One of the most important limitations of IRT is its considerable sensitivity to environmental factors. Factors like ambient temperature, humidity, and positioning of the patient on the thermograph can all impact the thermal images obtained. For example, if the temperature of the room is too low or too high, it can lead to an artificial alteration in the skin temperature, leading to inaccurate results when interpreting the thermal image data. Another consideration is that any sweating or clothing covering the skin could alter IRT readings. While appropriate measures of limiting the conditions impacting IRT will help to address these limitations, it does introduce a rigid protocol and minor stress on the clinician, the person assessed, and the system[62].

Standardization

While the use of IRT is increasing in clinical practice, it is still partially standardized in practice settings. There remain no near comprehensive standards for how thermographic assessment is conducted which will lead to variation in how it is done and almost guaranteed variation in how that data will be interpreted. An example of this variability is time of day, camera, and operational protocols for acquiring images. It is not surprising adoption of IRT is slow as less evenly confident healthcare providers will have uneven confidence in its accuracy[63].

Restricted depth of tissue visualization

While IRT excels at identifying surface temperature change, it cannot visualize deeper tissues, such as muscles or bones. Although inflammation does cause an increase in blood flow which will change the temperature of the skin making that detectable by IRT, it does not mean that a deeper structure, like muscle tear or bone fracture, will cause sufficient temperature change on the surface for thermography to detect. It is clear therefore that IRT cannot be used exclusively for consideration of these types of injury in the absence of other imaging techniques like MRI, computed tomography scan, and X-ray to be able to evaluate for injuries beneath the surface of the body. IRT is used in conjunction with these, and other, diagnostic tools to fully evaluate[20,64].

Operator dependency

IRT is inherently operator-dependent, so the effectiveness of the examination will depend on the operator's skill and experience with using an infrared camera. It is the operator who must make sure that the camera is witnessed properly to avoid operator, influences. Factors that may be preventable by the operator and therefore can affect the results include: Calibration of the camera, orienting the patient away or towards the camera, environmental factors, and failure to consider and minimize such factors. Part of the operator's role is to interpret thermographic images, which cannot be done without assessing the images and identifying temperature variation that is out of the ordinary for the person being assessed, to diagnose or assess the contribution of thermal variation to injury/input or treatment[65].

Challenge of discerning specific conditions

IRT can recognize temperature changes due to inflammation or increased blood flow but does not elucidate the purpose of the temperature changes. For example, IRT can identify areas of inflammation but does not identify the specific injury or condition causing the inflammation. Thus, IRT should be utilized in conjunction with other diagnostics (*e.g.*, clinical assessment, ultrasound, or MRI) that are done along with IRT to help confirm the injury type and aid in subsequent treatment[66].

CURRENT TRENDS AND FUTURE DIRECTIONS IN THERMOGRAPHY FOR MSIS

IRT has gained significant popularity and acceptance in both the clinical and sports medicine areas as a non-invasive method of evaluating MSIs[16]. With improvements in technology, the utilization of IRT has expanded beyond traditional inflammatory assessments and new developments will alter the future of thermography in healthcare[42]. This section focuses on recent developments and future directions of IRT in MSI treatment.

Integration of AI and machine learning

One of the most interesting avenues for applying IRT is through AI and machine learning. These technologies can provide more advanced analysis of thermal images, automating the abnormality detection process and improving diagnostic accuracy. AI engines can recognize elusive patterns in thermographic data that are not obvious to the naked eye, thereby allowing for more effective identification of early-stage injuries, for example, muscle strains or tendonitis[67].

Convenient and wearable thermographic systems

Another noteworthy trend is the emergence of portable and wearable IRT systems. In the past, IRT systems were typically large and stationary and limited their use in clinics or laboratories. Miniaturization has enabled the development of handheld infrared cameras and other wearable thermographic sensors which can used in many different settings such as sports fields, rehabilitation clinics, and at home[53,68].

Thermography in injury prevention and monitoring

IRT is being increasingly utilized in preventive healthcare programs, especially in sports. Athletes in all sports, but especially in high-performance sports, are always susceptible to overuse injuries. Routine thermographic screening can identify slight temperature changes caused by muscle fatigue, inflammation, or joint strain before they evolve into more serious injuries. The early detection of issues allows the medical team to implement preventative strategies, for example, rest, physiotherapy, or adjustments to the athlete's training, minimizing the risk of injury[69].

FUTURE DIRECTIONS FOR THERMOGRAPHY IN MSIS

Consistent protocols and guidelines

The lack of standardized protocols has also limited the clinical uptake of IRT. Temperature readings may be inconsistent due to environmental factors, variations in the positioning of the patient's body, and the variability of equipment. Further work is needed to establish protocols that provide universal guidance for image acquisition, analysis, and interpretation to optimize the clinical value of thermography[70].

Advances in imaging resolution and sensitivity

As infrared cameras improve, subsequent advances in imaging resolution and sensitivity will make IRT assessments more accurate than they are now. Higher resolution cameras will provide more detailed images which may allow for the detection of temperature differences that indicate an early-stage injury or inflammation. Increased thermal sensitivity may also improve the detection of smaller temperature differences which will improve the chances of identifying injuries which are slight or functional limitations[71].

Integration with other diagnostic tools

Future advancements will integrate IRT with diagnostic tools such as ultrasound, MRI, X-rays, and other modalities, enabling a more comprehensive evaluation of MSIs. For example IRT could be employed to identify areas of raised temperature signifying inflammation or use, and then MRIs or ultrasound would be used to look at the underlying structural damage[72]. These various tools together would provide a better understanding of injuries by providing both functional and structural information.

Expansion to include more aspects of assessment in clinically relevant contexts

The future of IRT about MSIs lies in an expanded role in clinical contexts, including managing chronic conditions such as fibromyalgia, chronic pain syndromes, and degenerative diseases[73]. With increased emphasis on healthcare providers recognizing opportunities for early detection and providing aiding continuous monitoring, it is expected that IRT will become the standard of care process within care protocols for individuals with musculoskeletal disorders[74].

CONCLUSION

IRT is a non-invasive, real-time imaging modality that offers significant promise in the evaluation and management of MSIs. By detecting superficial temperature changes linked to inflammation, vascular perfusion, and neuromuscular activity, IRT provides functional insights that complement traditional structural imaging techniques. At present, its most effective applications lie in the early detection of soft tissue inflammation in acute injuries and in the monitoring of injury resolution during rehabilitation or return-to-play protocols. Despite these advantages, widespread clinical integration of IRT remains limited due to the absence of standardized imaging protocols, variability in operator technique, and its inability to assess deeper anatomical structures. Future developments may include the integration of AI for automated thermal pattern recognition, the use of portable or wearable infrared systems for point-of-care diagnostics, and the combination of IRT with structural imaging modalities such as MRI or microvascular ultrasound to deliver a more comprehensive assessment. With further validation and technological refinement, IRT has the potential to become a valuable adjunct in routine musculoskeletal diagnostics and therapy monitoring.

FOOTNOTES

Author contributions: Jeyaraman M contributed to conceptualization, proofreading, and administration; Jeyaraman M and Nallakumarasamy A helped in manuscript revision; Jeyaraman N and Nallakumarasamy A contributed to acquiring clinical data and performing the data analysis; Jeyaraman N and Roy M contributed to manuscript writing; de Souza Moraes TM and da Fonseca LF contributed for image acquisition; All authors have agreed to the final version to be published and agree to be accountable for all aspects of the work.

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