Thermography Applied in Health: Clinical Case of Physical Rehabilitation

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Abstract:

Infrared thermography is a non-invasive tool that allows taking real-time images in a safe and cost-effectively way. This paper aims to describe the infrared thermography applied in health as a tool for monitoring and evaluation of physical rehabilitation. The techniques, instrumentation, and exercises used in polytraumatized patient rehabilitation are presented. The main materials employed are two thermal-imaging cameras, ultrasound and electro-stimulator. The methods employed are infrared thermography and physiotherapy. Assessment of thermograms allows proposal performance indicators useful to identify the effectiveness of the physical therapy. Is concluded that infrared thermography is great technical support to monitoring and evaluation of physiotherapy patients for physical rehabilitation.

Keywords: Infrared Thermography, Health, Physical Rehabilitation.

1. Introduction

Since the discovery of infrared rays, its evolution to infrared thermography, and its various applications, it has been observed that this tool has been very useful in different areas of research and application, nowadays and with scientific progress we can see the incursion of this type of technology in sectors such as industrial, military, environmental and medical among others; It is precisely this last sector that is distinguished by the benefits that infrared thermography represents, specifically in the area of Rehabilitation and Physical Medicine, offering a tool in the diagnosis and monitoring of various diseases including injuries of the skeletal muscle system providing an evaluation of the painful processes, allowing to identify pathophysiological alterations of the internal environment that justify the painful clinic manifested by the patients [1].

Infrared thermography (IRT) is a simple, non-invasive tool that represents a low cost in its use, by providing data that is of great importance to determine whether or not to continue with specialized studies, it is currently possible to obtain Real-time a thermal imaging, which represents in color the temperature distribution in the objects of study [2]. Since no radiation is emitted, it can be used in patients who would not normally recommend other diagnostic imaging tools, that is pediatric patients and pregnant patients.

The taking of thermograms can be repeated as many times as necessary, of course, the use of this technique does not mean the replacement or displacement of other diagnostic tests, on the contrary, it complements them and provides the health professional with more accurate information whit relation to the pathology or injuries suffered by patients, when using infrared thermography, it can be detected that a small increase in temperature translates into an increase in the brightness of the study area [3].

Background

Applied Thermography in Health

It is in the early 80's when thermal cameras are used in the clinical area, becoming a procedure that is used to detect and record an image called a thermogram that measures the surface temperature of a patient's skin. This procedure uses equipment that can offer both qualitative and quantitative representations of these temperature patterns [4].

Thermoregulation

Or temperature regulation is the mechanism by which a biological organism can modify its temperature within certain limits and describes the processes that maintain the balance between thermogenesis gain and thermolysis heat loss, the human thermoregulatory model can be divided, with the purpose to better understand this concept, in a central or nuclear part and a superficial part that has direct contact with the external environment [5].

Starting from this, the center or nucleus would be formed by the thoracic and abdominal head and cavities, the superficial part would then integrate it, the skin, the subcutaneous cellular tissue and the muscle mass. The blood is distributed in the body by the cardiovascular system who is the means by which heat is conveyed by convection of the nucleus to the cutaneous region. The temperature of the nucleus, brain, is regulated at approximately 37 °C, while the skin temperature ranges from 33.5 ℃ [6].

Physiotherapy

Physical therapy is a discipline of the health sciences that intervenes in the recovery of a patient to provide therapeutic and rehabilitation treatment, useful to diagnose, prevent and treat multiple diagnoses, acute or chronic processes through the use of scientifically proven techniques, including the use of Physical Agents, Manipulation Techniques and Therapeutic Exercise among many others [7].

Thermography applications:

Table 1 Below presents some of the main applications of infrared thermography**.**

Table 1.
Thermography applications

• Foods	• Sports	• Study of energy losses in facilities	Predictive Maintenance
• Farming	• Gas detection	• Applied research	• Manufacture
Search and rescue	• Temperature loss detection	• Building Inspection	• Medicine
• Military tasks	• Meteorology	• Space observation	Border and airport security

Source: own elaboration.

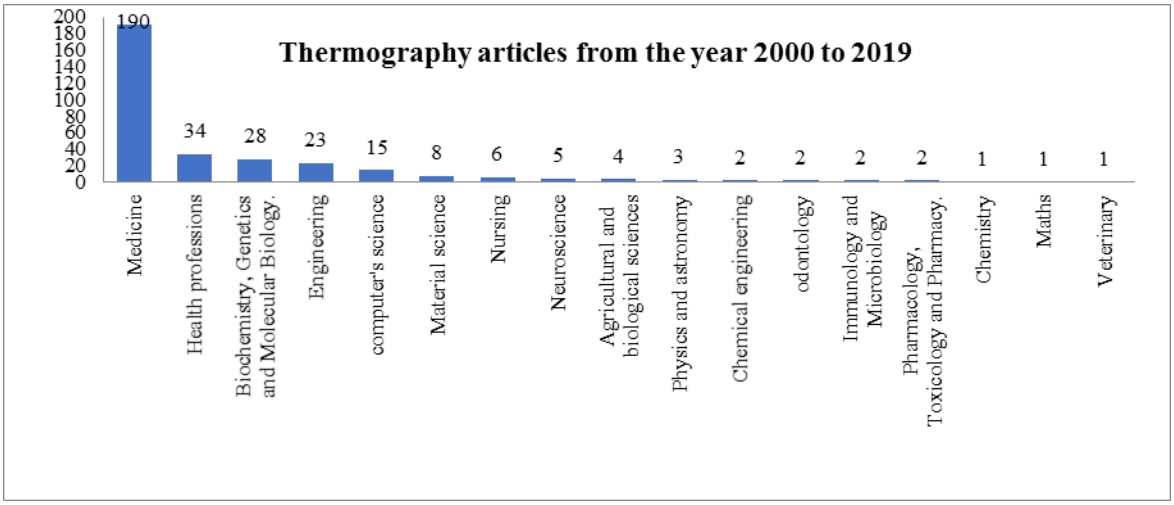
Thermography: Thermography applied in medicine is a non-invasive technique, which allows the doctor to visualize and quantify changes in the surface temperature of the skin. An infrared scanning device is used to convert infrared radiation emitted from the skin surface into a thermographic image or thermogram. The color spectrum indicates the increase or decrease in the amount of infrared radiation that is emitted from the body surface. Since there is a high degree of thermal symmetry in the body, the abnormal and antisymmetric temperature can be easily detected [4].

What it consists of: Clinical Thermography is based on the measurement and quantification of the skin's surface temperature. This temperature depends on the blood circulation in the outermost millimeters located inside the skin. This blood flow is subject to complex regulation by the nervous system and local factors [4].

State of the art

The 24 most frequent conditions in the human being and the evidence of application of thermography in them were reviewed under the criteria of research articles, in all cases the review was favorable, so work will continue to develop a Review, as can be seen in **graph 1**.

Graph 1.
Articles on thermography from 2000 to 2019, own elaboration with data from Scopus 2019



Source: own elaboration with data from Scopus.

Table 2.
Presence of thermography in the medical sector, own elaboration 2019

Area in medicine	Presence of thermography	Area in medicine	Presence of thermography
Central Nervous System	✓	Gynecology	✓
Eyes	✓	Urinary system	✓
Ear, nose, pharynx	✓	Skin disorders	✓
Respiratory system	✓	Endocrine problems	✓
Cardiovascular system	✓	Infections	✓
Digestive system	✓	Allergies	✓
Reproductive system	✓	Pain	✓
Musculoskeletal disorders	✓	Diagnostics	✓
Euthanasia	✓	Nutrition	✓
Immune system	✓	Fractures	✓
Cancer	✓	Stress	✓
Physical injuries	✓		
Odontology	✓		
Non-invasive tests and methods	✓		

Source: own elaboration.

2. Materials and methods

Electrostimulation: Technique used in Physiotherapy in which electric current is used as a treatment in painful processes, inflammatory processes, nerve stimulation and muscle stimulation. An electro-stimulator is a current generator, which produces electrical impulses with enough energy to generate an action potential (AP) in excitable cells: muscular or nervous (with analgesic and efferent results with motor results), and thus modify its state [8].

Therapeutic ultrasound generates deep ultrasonic waves within the body's tissues, it works through two main effects: The thermal effect and the mechanical effect being useful to treat pain, muscle spasms and joint stiffness [9].

Table 3 shows the values by which the electro stimulator device and therapeutic ultrasound operate, classified as non-invasive techniques.

Table 3.
Currents of the Care Tec IV electrostimulation device / Therapeutic Ultrasound Great Sonic

Current (s)	Waveform	Frequency	Pulse width	Intensity	Technique Type
TENS/EMS	Square single phase	1Hz-50 Hz	50-300µs	0-150mA	Non-invasive
IF	Square biphasic	1Hz-150 Hz	125 µs	0-70mA	Non-invasive
Russian	Square biphasic	2500 Hz	50-300µs	0-60mA	Non-invasive
U.S (Therapeutic)	Longitudinal / ultrasonic waves	1/ 3 MHz	8%, 14%, 29% , 0.5, 1.0, 2.0 mS	1.6W / cm² (low) 2.6W /cm² (medium) 4.6W / cm² (high)	Non-invasive

Source: own elaboration.

Instrumental Techniques: There is a wide range of techniques that are used in Physical rehabilitation and involve a tool in its use, then the concepts and material of instrumental techniques are mostly explained.

"The Scout": Instrument and technique created in the USA cataloged within the Myofascial Instrumental Fibrolysis elaborated in Surgical Steel, certification is required for the application of the technique, the treatment method is based on the release of adhesions and polishing of the corpuscles located in the fascias muscle, with the aim of returning to the myofascial tissue the range and normal route of mobility. (Non-invasive technique) [10].

Floss Band: Elastic band made of latex rubber, has as a mechanism of action the reactive hyperemia on the treatment area, the method consists of performing a compression bandage and starting the mobilization for a period of exclusively 2 minutes, resulting in an increase Visible and immediate range of mobility over the area to be treated, decrease of pain and local inflammation when triggering a proprioceptive-sensomotor reintegration, certification is required for the application of the non-invasive technique [11].

Kinesiotape: The tape has a texture and elasticity similar to human skin, made of cotton (96%) and polyurethane (4%), offers the application correct perspiration, placed correctly, improves local circulation and tissue drainage, the tension of the area is reduced, and the pain decreases, a non-invasive technique [12].

Rood technique: Stimulates the different sensory receptors, mainly the cutaneous ones. It is a method of facilitation and inhibition of movement. Through the following stimuli: Rapid Brushing, Knocking, Vibration, when applying the same stimulus repeatedly, an excitation of the nervous system is achieved which will lead to the contraction of striated or smooth muscles Non-invasive technique [13].

Dry puncture: Insert a needle without introducing or extracting any substance in the area to be treated, the technique is based on myofascial analysis when introducing the needle and working on the muscular fascia a mechanical change occurs that stimulates the sensitive nerve fibers causing an increase of neurotransmitters that results in a decrease in pain in the area to be treated. The needles used are made of tempered surgical steel, with a rigid handle for handling is listed as an invasive technique and certification is required for the application of the technique [14]. In recent years, the popularity of percutaneous needle electrolysis (PNE) has increased for the application of invasive physical therapy treatments. The theoretical model of the biological effects of PNE states that a galvanic current (GC) applied through a solid metal needle causes an inflammatory response in the treated tissue, favoring its repair [15].

Table 4.

Description of Non-Instrumented Therapeutic Tools in Physiotherapy (Non-invasive)

Therapeutic Tool	Description	Benefits	Contraindications
Orthopedic Manual Therapy	It covers a wide range of techniques that are mostly manipulations performed by the Physiotherapist in the different articular areas of the patient.	Decreases pain and stiffness in joint and muscle areas, favors increased ranges of motion.	Bone fragility Tumor or infection Inexperienced Manipulator
Progressive resistance exercises	It consists of muscular training with some type of resistance that increases progressively as the patient's strength improves. It can be done with leggings, weight-bearing therapeutic balls or resistance bands.	Visible and accelerated improvement of the increase in muscle strength due to fibrillation recruitment. Reduced risk of overload injury.	Acute injuries involving a rupture or suspected fibrillar rupture (sprains, tears). Patients with cardiac or respiratory pathology.
Training CORE	Exercises and Techniques focused on strengthening the area that corresponds to the abdominal region and lumbar area.	Decreases the load on the lumbar spine by strengthening the abdomen, improves respiratory capacity and helps improve posture.	Surgical intervention involving a recent abdominal incision.
Standing and Walking Exercises	Set of various techniques including working balance, posture, control of the center of gravity and base of lift.	Improvement in the phases of the march, greater independence with respect to attachments.	Patients with poor bone consolidation or possible changes in its mineralization.

Source: own elaboration.

Among the most representative materials and equipment used for this research work were: two thermal imaging cameras Flir system E5 and E6 model E6390,Great Sonic Ultrasound, Caretec IV Electrostimulator Dual channel device, four waveforms (TENS, EMS, IF and Russian Stim) Oximeter (oxygen saturation and heart rate detector) Sonopulse brand, Beurer HK125, Extra Large Electric Pad, Stopwatch: 1-60 seconds, SUNBEAM 764 Heat Mat, 0.16x Dry Puncture Needle 25 Agupunt Surgical Steel, Floss Band Elitefts Pro Brand Strong and Medium Compression, Bodyfit 65 cm Diameter Therapeutic Balancing Balloon, Stethoscope and Baumanometer Microlife Brand Aneroid, Mach Medical Brand Resistance Bands, different intensities made in Latex, Naturaness brand seed compress, Antiseptic for healthy skin Colorless spray brand Clorox Anywhere, Kettler Brand 2 kg Therapeutic Ball, GSport 1.5 kg Leggings, "The Scout" Patent: D624,193, Electric Brushes, Hot Thermal Compresses, McDavid Brand Silica Sand Compress 50 x 18 cm, gym floor, parallel bars, examination table and / or treatment, for a better interpretation see **Figure. 1** Materials and equipment used.

Figure 1. *Materials and equipment used for therapies.*

Source: own elaboration.

Variables

Table 5. *The identified variables were compiled and studied for possible approach in the research work*

Controllable Variables:			
Distance: Distance between the camera and the object to be analyzed	**Illumination:** Lighting in the study area that can affect thermography	**Hotspot:** Look for the highest temperature point or the coldest	**Reflected temperature:** Temperatures that can be seen on the thermogram from other sources
Emissivity: Is the thermal radiation emitted by a surface or object due to its temperature	**Period between sessions for thermography:** Time between sessions reserved with the patient to take thermograms.	**Test room temperature** is the ambient temperature inside the thermography test room	
Humidity: Environment humidity	**Time period between thermograms:** is the time that elapses between each thermogram	**Patient waiting time:** is the time in which the patient must rest before thermography session	
Uncontrollable variables:			
Equipment miss calibration: Loss of accuracy of the thermographic equipment	**Vibration from patient breathing:** Vibration from the breathing that affects accuracy on thermogram	**Feeding Habits:** Foods that the patient usually take.	**Sedentary:** sedentary lifestyle of the patient
Patient movement: Involuntary movement affecting on thermography	**Sun radiation on the patient:** Is the sun radiation received for the patient	**Rest habits:** Patient rest periods.	

Source: own elaboration.

Developing

Description of the Clinical Case:

A 39-year-old male patient (at the time of intervention), referred to Rehabilitation by a specialist in Traumatology and Orthopedics after having undergone surgery in September 2017 at San Lucas Hospital in Oaxaca City after suffering a car accident from which it was derived: Exposed fracture of multifragmented left tibial plateau with bone loss, whose treatment consisted of open reduction and internal fixation with golf club type plate, Bimaleolar fracture of left ankle, tibia fracture and left fibula, right wrist fracture. Upon review by a medical specialist, it is determined that tibia and fibula fractures are consolidated, as well as a consolidated right wrist fracture.

Physical assessment Conducted in February 2018 by Physiotherapy: Male patient using axillary support attachment for gait, limited mobility can be observed with respect to range, specifically to the knee flexion-extension in the supine position and in standing position, in the supine position. knee position is in semi-flexion, at the time of exploration the patient refers pain in 7 located on the VAS scale when performing knee movements, performs internal and external rotation of the same with difficulty and there is a decrease in the total range of movement, It is also observed a decrease in limb muscle mass affects, there is an important limitation to left ankle dorsiflexion attributable to retraction and lack of mobility in psoleo and twin muscles, decrease in Grade 3 strength in Daniels scale with respect to quadriceps , twins, tibialis anterior, tibialis posterior, probable popliteal muscle overload and / or femoral biceps tendinopathy.

The patient reports pain at the height of the medial epicondyle and medial tibial condyle when performing knee flexion, as well as the external lateral ligament and patellar tendon, an anti-allergic posture is observed, with probable pelvic tilt attributable to the patient's condition, discomfort to the shoulder height and scapular area due to the use of crutches, probable adhesion in the scar area that limits the anterior tibial muscle movement, decrease in exteroceptive and proprioceptive sensitivity in the scar area, pain of 8 (AVS) when performing muscle stretching Hamstring, notable angulation in the varus of the lower left limb, difficulty in completing total wrist flexion and when performing the movement, accompanied by pain, decreased strength on Daniel's 4/5 scale, there are slight alterations in the tactile sensitivity of the index finger with difficulty flexing the proximal and distal interphalangeal joints, see figure 2.

The surgical techniques that are most used today for tibial plateau fractures do not correctly consider multiplanar bone comminution or the presence of posterior bone fragments [16], therefore they represent a challenge for the rehabilitation of the patient and for the therapist.

The problem that occurs in cases of tibial plateau fractures begins with the understanding of the fracture and with the decision of the type of osteosynthesis to use. The most widely used classical classifications of tibial plateau fractures are based only on frontal radiographic projections, as are the AO / OTA and Schatzker classifications [17].

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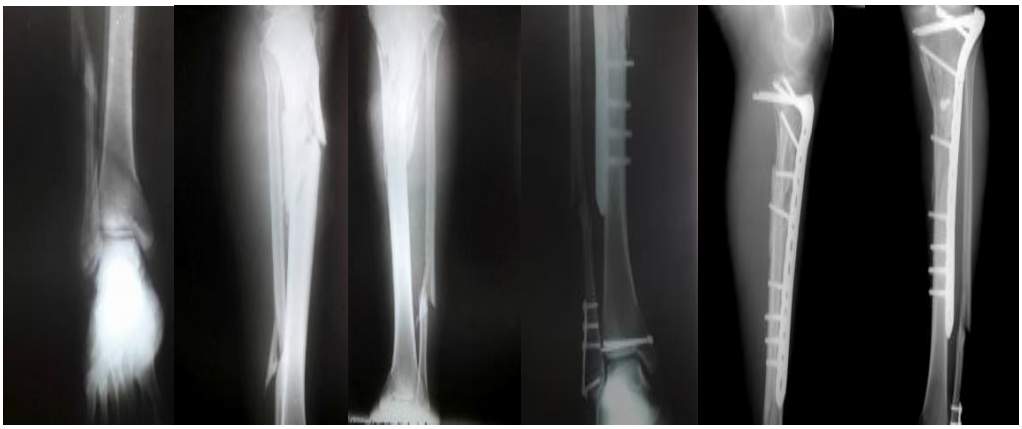
Figure2. *Radiographic Plates of the Lower Left Limb: a – before and b – after Surgical Intervention in Anteroposterior, Lateral and Posteroanterior Views. September 2017*

a b



Source: own elaboration.

In 2019 Rothberg et. al presented a randomized comparative study on postoperative knee pain with the lateral parapatellar technique in semi-extension and with the classic infrapatellar technique. The results revealed less knee pain in the group of patients who operated with the parapatellar technique [18].

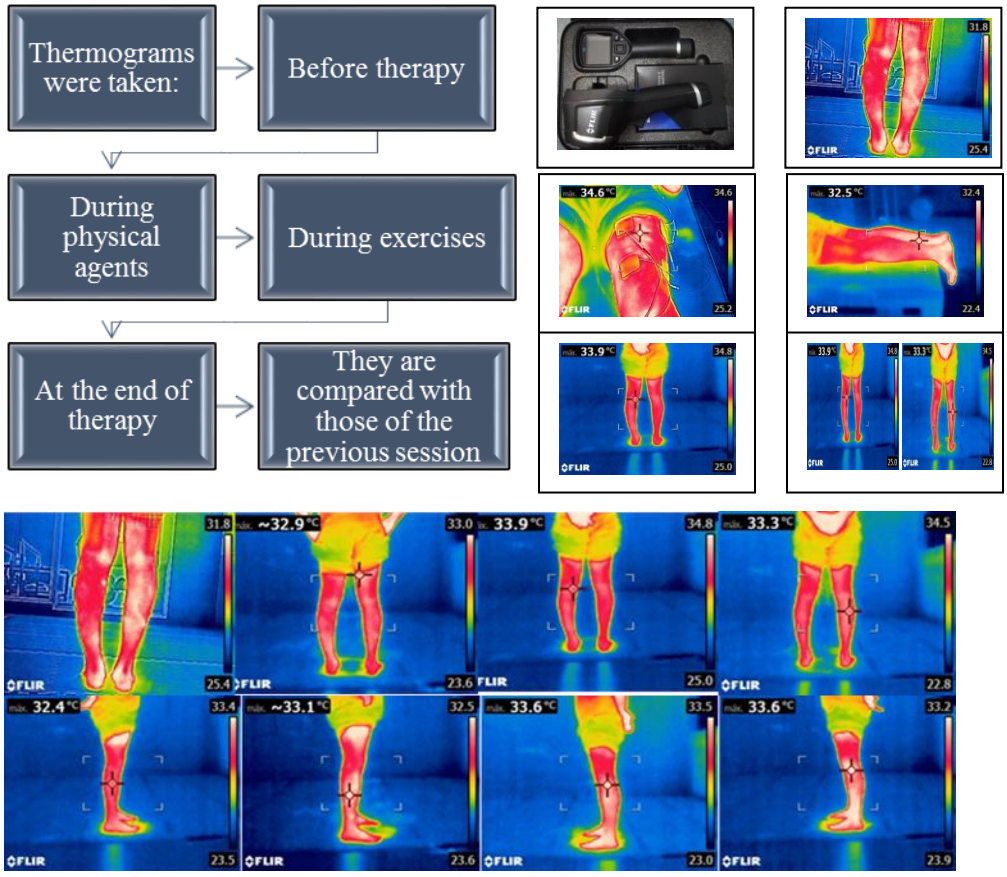
Ibrahim et al. published a literature review, in which they mainly included comparative studies between the semi-extension technique and the traditional infrapatellar technique, and concluded that the results of postoperative pain and knee function are better with the semi-extension technique [19].

Chronic patellar tendon injuries are rare in young patients and there is no consensus in the literature on the appropriate surgical treatment. There are only case reports. Savyasachi et al. described the successful use of allograft for extensor repair and highlight the benefit of this procedure to restore adequate extension in young and active patients [20].

According to Pesciallo et. al (2021) a stable knee to varus-valgus was also observed, with passive mobility of 0-100º and active mobility of 10-100º, and a clear weakness in the muscle strength of the quadriceps [21]. The left limb can be seen to be overheated or fatigued in the thermograms of the left limb figure3, which is benefited at the end of the therapy, ruling out some techniques that work or have better results in terms of reducing pain and mobility.

Part of the procedure for the taking of thermograms are presented below, it should be noted that many authors have to consider many variables, to reduce errors in the taking of thermograms, it is common that some of these variables affect the results, in some cases those variables are controllable and in other cases not figure 3.

Figure 3.
Procedure for taking thermograms, own elaboration



Source: own elaboration.

Thermogram comparisons were made before and after the therapies, different analyzes were performed such as: temperature distribution in affected limbs, distribution between affected and unaffected limbs, measurements and results of the different physical rehabilitation techniques were documented.
Fatigue was discovered in the limb without injury with the thermography, making it possible to adequately plan limb rehabilitation without injury, also avoiding its wear due to overload. Dynamic thermography diagnosis is very useful, as described [22] and [23] when it comes to better quality of life or even saving lives, research and its progress becomes crucial **(Table 6)**.

Table 6
Thermographic measurement parameters

Equipment	Distance	Material	Emissivity	Humidity	Temperature ambient	Reflected temperature	Temperature scale
Flir E5	1 meter	Human skin	0.98	35	28 Degrees °C	17 - 22 Degrees °C	22.0 – 37.5 Degrees °C
Flir E6	1meter	Human skin	0.98	35	28 Degrees °C	17 - 22 Degrees °C	22.0 – 37.5 Degrees °C

Source: own elaboration.

Results

The use of infrared thermography offers the health professional a non-invasive, painless and innocuous tool that allows a real-time evaluation of the skin temperature. These characteristics make thermography an ideal tool in physiotherapy, since through skin temperature it is possible to detect pathophysiological processes related to the symptoms of our patients and thus facilitate decision-making to the physiotherapist. In addition, a very interesting aspect is that knowledge about the cutaneous thermal effects that occur in pathologies that affect the peripheral nervous system, both autonomous and somatic, can improve the effects obtained with invasive physiotherapy techniques. Undoubtedly, it is a tool that provides valuable information in all phases of the process of care in physiotherapy, from the diagnosis of physiotherapy, planning, intervention and reevaluation, as well as everything related to prevention or reinstatement or sports.

The compensation mechanism, by raising the weight load of one limb with respect to the other can cause fatigue and even wear on the muscles and joint components causing injuries, inflammation and pain. By taking thermograms, the differences in skin temperature between right and left leg were observed, thus detecting fatigue, as shown in Figure 6 Inspection before, during and after therapy [24] High temperature points are located when there is presence of inflammatory processes such as tendinitis or fasciitis to be able to be treated with physiotherapy tools [25, 26]. Thermography can be a documented support to predict in a non-invasive way various types of conditions, as well as allow a follow-up in the evolution of the patient in a personalized way and in real time to obtain a support diagnosis for the physiotherapist and for the attending physician considering that each patient represents a different case. The early rehabilitation protocol included active isometric exercises and single-leg gait with the assistance of a four-point walker, as suggested in [27].

Objectives and methodology

- Know the principles of thermography as a tool in the process of attention in physiotherapy.
- To know the methodology of application of thermography within the clinical reasoning of the physiotherapist.
- Learn to apply thermography in the different anatomical regions of the neuromusculoskeletal system, integrating the available scientific evidence with clinical practice.

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There is a data set on progress to meet the objective of proposing performance indicators that help determine effectiveness and can modify the current indices used in physical medicine, the results obtained were analyzed by taking thermograms and parameter data of operation of the equipment used during the therapies. A documented support to be able to predict in a non-invasive way the evolution of the patient in a personalized way, considering that each patient represents a different case.

Study Limitation

The limitations of this research are mainly that the process of taking thermograms is slow, the conditions must be controlled and that implies a cost, the thermographic analysis software is very specialized, as are thermographic cameras.

Conclusions

The incorporation of thermography in Mexico is necessary, its presence is still scarce in hospitals and clinics, for now this is a first advance of the usefulness of medical thermography. It is preferable to use these types of technologies to monitor patients and reduce the case of x-rays that may compromise the patient's health. Thermography is a support tool for medicine that can help reduce errors when diagnosing a patient.

Conflict of interests

This research work does not present a conflict of interest, so all the participants in this research do not have any conflict of interest.

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