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# THERMOLOGY INTERNATIONAL

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# Refereed Abstracts from 12th European Congress of Thermology

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This issue is totally dedicated to the abstracts of the 12th European Congress of Thermology which will take place in Porto, Portugal, on 5th to 8th September 2012. Most of these submissions originating from European countries, North- and South America, Asia and Africa are structured [1] and extended abstracts. Different to other abstracts published in this journal [2], all papers with exception of the keynote lectures underwent a peer-review. Two referees blinded to the authorship independently assessed the submission using a 5 point scale (5 = outstanding , 4 = strong , 3 = somewhat or mixed, 2=limited , 1=unclear or not at all) in the following categories: re- levance, novelty, objective, methodology, results, conclu- sion, future implications. The mean value of the score in these categories was the result of assessment of 1 referee; the final score was built from the average score of both reviewers.

45 submission for oral presentations and 17 poster contributions were evaluated. Mean of the final scores of all papers was 3.32 (range: 4.5 to 2.15) with slightly higher scores for oral presentations (mean: 3.39 range. 4.5 to 2.36) than for posters (mean: 3.15 range: 4.43 to 2.15) Agreement between the two reviewers was fair to moderate. (Mean difference of scoring: 0.06 ± 0.78 standard deviation, range: 0 to 1.58). The difference of scoring between the 2 reviewers was for 21 papers between 0.71 and 2.0, for 36 papers between 0.14 and 0.57 and identically for 4 submissions.

The referees made proposals for revision which will be considered in the final full-length version of the submitted work, which will appear in a supplementary issue of this journal available at the congress site.

Abstracts published in this journal have been cited in other journals. The web of science reports 18 abstracts [3-20] with a cumulated sum of 24 citations. Google Scholar lists 4 additional abstracts [21-24]. The 9 abstracts [3, 5,6,17, 20, 21-24] found in Google Scholar received in total 21 citations.

I am highly confident that the refereed abstracts in this issue will attract many citations.

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# 12th European Congress of Thermology in Porto: Abstracts

## Keynote Presentations

### THE HISTORY OF THERMOLOGY AND THERMOGRAPHY – THE PIONEERS AND MILESTONES

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Knowledge of human body temperature and changes in fever within medicine ins centuries old. However, thermal detectors and radiation physics is far more modern. In the 16th century Galileo began work on thermometry, and in the 17th century, Della Porto described the sensation of reflected heat from a burning candle. However, it was William Herschel in England in 1800 who carried out his famous experiment that identified dark heat or "infrared radiation" as we now know it. The in 1840, his son John Hershel made an image from a carbon suspension and focussed sunlight, which he termed a thermogram. A German clinician Carl Wunderlich from Leipzig published his thesis in 1860 that drew attention to the value of continual monitoring of human body temperature. At that time this could only be achieved by thermometry. Wunderlich introduced the "clinical thermometer" a maximum glass thermometer with a narrow range of temperatures around 37°C

The first thermal imaging system was devised by M. Czerny in 1929 using evaporography, and it was in 1942, during World War 2, that the Smith's Pyroscan in England was created. In the 1950's several companies in England, Sweden and the Barnes Thermograph in USA developed slow working thermal imagers using electronic detectors.

In the late 1950's and early 1960's there was a rising medical interest in the use of thermal imaging for breast cancer detection. Ray Lawson in Canada in 1956 noted that the surface temperature over a cancer was raised, which was confirmed by Kenneth Lloyd Williams in London who studied 300 women with cancer of the breast using thermopiles, and a reference temperature source. In his follow up of 100 women all with a temperature increase of more than 3°C had died within 5 years.

These early thermographs we based on a single detector element, indium antimonide, cooled by liquid Nitrogen. The optical scanning system mostly with reflecting optics produced considerable noise, and could take several minutes for one image to be created. By introducing more detectors scanning time was reduced, but complications arose from the misalignment of the separate sensors.

The first focal plane array camera was introduced in 1987, but was not immediately available on a commercial basis. The advantages of improved image quality in terms of spatial and temporal resolution were obvious. By 1997 Agema in Sweden had introduced an uncooled microbolometer capable of radiometric temperature measurement. It was by now also feasible to have a combined visual camera with the thermograph, with some advantages for the user.

Over this period, the rising availability of digital computer technology had a considerable impact on thermal imaging. Digital outputs from the camera made analogue to digital conversion redundant, allowing users to improve standardisation of technique, and improved image processing. Quantitative thermography had become more reliable and with lowered costs, more available. The large slow and noisy systems of the past are now replaced by small almost silent and portable cameras that are more convenient for medical and biological applications.

### EVOLUTION OF INFRA RED CAMERAS, IMAGES AND DETECTORS

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Introduction: Infrared Thermography (IRT) technology has matured over recent years with a plethora of new radiometric imaging devices currently available. Infrared Thermography is essentially a temperature monitoring technique sensitive to radiant energy patterns emitted from a surface. These infrared radiometers have differing leveles of capability and sophistication based on application for example:

- Condition monitoring and predictive failure.
- Medical diagnostics.
- Energy and buildings.
- Research and process monitoring.

The transfer of radiant energy by electromagnetic waves in the thermal range occurs between 0.1 and 100 μm, as shown in Figure 1:

The infrared segment of the electromagnetic spectrum is at wavelengths just beyond the visible spectrum and can be divided

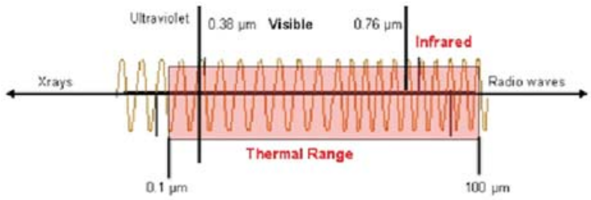


Figure 1
Thermal range of electromagnetic radiation

into three segments by wavelength [1]. The bandwidth of these wavelengths (measured in micrometers) differ from manufacturer to manufacturer for example:

- 0.8 to 2.0 micrometers = Near Infrared (NIR);
- 2.0 to 5.6 micrometers = Mid-wave Infrared (MIR); and
- 7.5 to 15 micrometers = Far or Long wave Infrared (FIR).

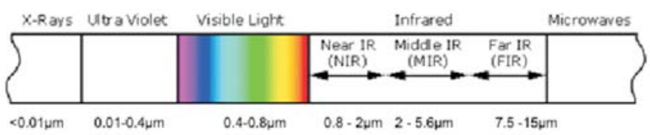


Figure 2
Infrared segments of the electromagnetic spectrum (average values of wavelength

The optimum wavelength of an infrared radiometer is determined by the wavelength distribution of the emitted radiation and type of detector [2]. Another aspect of choosing the appropriate wavelength is to consider the optimum thermal contrast desired within an image. An example of this is in identifying anomalies, patterns and shapes especially prevalent in medical applications. This may be explained by examining Planckian radiation curves of a perfect emitter, which illustrate the sharpening gradient of the curve in the mid-wavelengths, Figure 3.

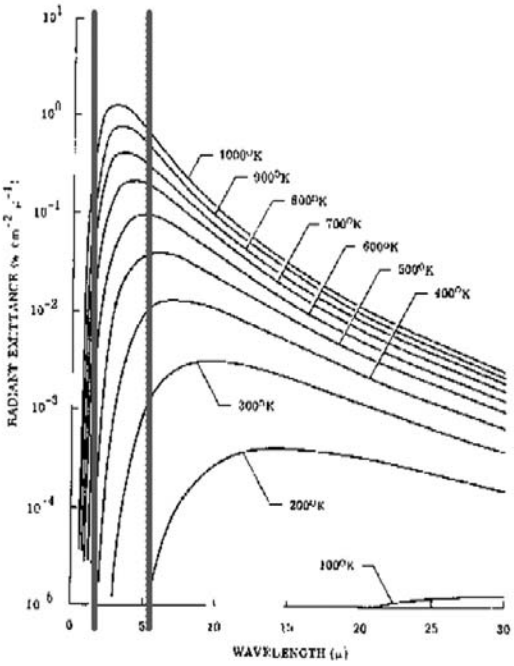


Figure 3 -
Planckian radiation curves of a perfect emitter (blackbody)

Methods: The latest technology has high levels of technical specification and thermal/spatial resolution (In the order of 18mK sensitivity with cooled 640 x 512 focal plane array). Table 1, illustrates the technical merits of infrared cameras used in medical and industrial applications:

| | Medical App. Example | Industrial App. Example |
|---|---|---|
| **Detector** | InSb | Microbolometer |
| **Cooling type** | Integral sterling cooler | Un-cooled |
| **Spectral response** | 3.6 to 5.1µm | 7.5-14µm |
| **Number of pixels** | 640 x 512 | 320 x 240 |
| **Pitch** | 15 x 15µm | 45µm x 45µm |
| **Frame rate** | Up to 100 Hz full frame, 4980Hz at 16x4 pixels | 9Hz to 60Hz |
| **Integration time** | 10µs to 20000µs programmable, 1µs step | Unavailable |
| **Remote control** | USB/CAM Link | Not available |
| **Operational temperature range** | -20 to +55°C | -10C to +50C |
| **Accuracy** | 2C or 2% (at 25C nominal, whichever is greater | 2C or 2% (at 25C nominal, whichever is greater |
| **NETD** | <18mK @25°C & without filter | 45mK |

Table 1
Typical medical and industrial infrared camera technical specification.

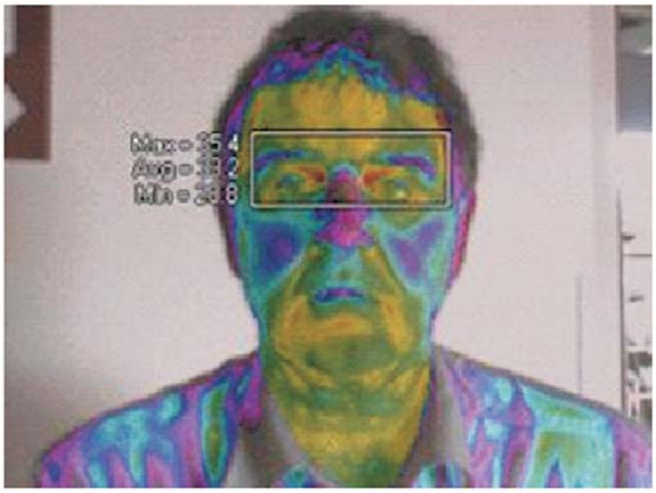

Figure 4
Infrared thermal fusion

In recent years the ability to fuse a digital photographic image of an infrared thermal image is almost standard on many cameras, the ability to adjust the amount of digital or infrared dominance in the image is proving a useful diagnostic aid, Figure 4.

Other developments include enhanced connectivity via Gigabit Ethernet, Camera Link and USB interfaces to extend flexibility and URL (Uniform Resource Locator) for easy networking. Many are IEE1394 Firewire enabled providing 50Hz frame rates. Reporting Diagnostic software enables they have a variety of analogue and digital I/O to enable trigger synchronisation, external optics correction and statistical analysis.

Results: There are a variety of advantages when using infrared radiometers as opposed to more traditional devices:

- Wide measurement range (dependent on camera and filter).
- Safe and non-hazardous to personnel and the workplace.
- Does not interfere or make contact with surface being measured.
- Can be used in explosive environments (via coating on camera body or using an intrinsically safe camera).
- Usually immune to electromagnetic noise.
- Can store and recall images as part of a route based activity.
- Can retrieve and analyse on site.
- Invariably conducted in real-time.
- Reliable, because the components have a semi-infinite lifetime expectancy.

DISCUSSION: Currently there are a number of challenges ahead if this technology is to become universally accepted particularly within medicine but also within other disciplines, these include:

- Standardisation of technical specification within application
- Standardisation of image capture
- Universal image interpretation and analysis
- Accredited training approved by relevant professional organisations.

Whilst there are International Organisations such as IEC and ISO addressing some of these issues it is imperative that these are accepted within the various industrial sectors.

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## THERMOGRAPHY IN PLASTIC SURGERY

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INTRODUCTION: One of the main goals in plastic surgery is the correction and restoration of form and function. The realm of plastic surgery is large ranging from well-known cosmetic surgery to less well known sub-specialties such as reconstructive surgery, burn, craniofacial, hand and micro-surgery. Reconstructive surgery deals with the closure of defects and restoration of form after trauma, pressure sore treatment, infection and cancer treatment. The use of tissue transfer or flaps, in the same patient is an important instrument in reconstructive surgery. Such a flap may consist of skin and subcutaneous tissue, muscle and bone or a combination. This transfer can be performed with so-called pedicled flaps and free flaps. In pedicled flaps the blood supply to the tissue is left attached to the donor site and tissue is simply transposed to a new location. Blood to the tissue of the flap is maintained via the pedicle. In free flaps, the blood supply is detached from the original location ("donor site") and the tissue is transferred to another location ("recipient site") to cover a defect. This procedure involves disconnecting its blood supply and then reconnecting in again at the site of the defect. Since the diameter of the arteries and veins that have to be sutured (anastomosed) together can be as small as 1 to 2 millimeters in diameter, skillful microsurgical techniques are employed. Both pedicled and free flaps need adequate perfusion in order for the tissue to survive. A thorough knowledge of vascular anatomy and how the tissue is perfused are essential for successful flap surgery.

In earlier days the use of myocutaneous flaps was the gold standard in reconstructive surgery. This flap consists of skin, subcutaneous tissue (fat) and the underlying muscle with its fascia. The muscle was included as a carrier of the blood supply to the overlying skin and subcutaneous tissue. The blood supply to the skin originates from a deeper lying main vessel under the muscle. Branches from this main vessel pass through the muscle, perforate the overlying fascia and continue their way through the subcutaneous tissue up to the skin. Since they perforate the fascia these branches are called perforators. During the earlier days surgeons realized that including enough perforators would guarantee adequate perfusion to the overlying skin of the flap. Theuvenet et al [1] were one of the first to introduce the use of thermography in the pre-operative planning of flap surgery. They called the technique thermographic assessment of perforating arteries. They realized that the perforators produced a hot spot on the skin surface. By cooling down the skin surface they obtained additional information on the quality and location of the perforators. It was not until the mid 1990's with publications from Salmi et al [2] and Zettermann et al. [3] from Finland and Chijiwa et al [4] from Japan that the usefulness of using thermography in flap surgery was again described.

A breakthrough in flap surgery came in 1989 when Koshima & Soeda [5] discovered that the overlying skin and subcutaneous tissue could actually survive on a single perforator without including the underlying muscle. A perforator consists of a perforating artery and its concomitant vein. The main advantage of this finding was that no muscle is included and therefore there is no loss of muscle function at the donor site. These perforator flaps are now the gold standard in reconstructive surgery. The use of perforator flaps requires microsurgical skill as the perforator is easily damaged. Selecting a suitable perforator is crucial for survival of the flap. Itoh and Arai [6, 7] described for the first time the use of thermography in the selection of a suitable perforator in perforator flap surgery. Pre-operatively they em- ployed a skin cooling technique which allowed them to more easily identify a suitable perforator.

At our department we have since 2000 successfully used dynamic infrared thermography (DIRT) as a technique to assist the plastic surgeon in the preoperative, intra-operative and post-operative phase of perforator flap surgery. DIRT involves using thermal challenges applied to the skin, usually cold challenges, to help to more clearly identify vascular patterns on the skin surface resulting from the activity of underlying perforating blood vessels. In the rewarming phase the perforators which transport warm blood from the deep tissue to the skin surface appear as a rapidly growing hot spot on the skin. [8,9]. Among other things we have been using DIRT in perforator flap surgery for reconstruction after trauma surgery, cancer surgery and treatment of pressure sores

In order to illustrate the use of thermography in plastic surgery I will use breast reconstruction with a deep inferior epigastric perforator flap (DIEP flap) as an example. The DIEP is one of the most complex perforator flaps in use. The lower abdomen can provide a large amount of skin and subcutaneous tissue that allows for the reconstruction of a naturally looking breast with soft consistency and adequate volume. This tissue can be harvested on a single perforator from the deep inferior epigastric artery and vein. This perforator passes through the rectus abdominis muscle and overlying fascia and courses to the skin where it connects with the subdermal plexux. The DIEP flap is today the gold standard in breast reconstruction using the patient's own tissue. The use of infrared thermography in the pre-, intra- and postoperative phases of DIEP flap surgery will be discussed. In addition some other application in plastic surgery, such as trauma will be discussed. The experience we have gained in using DIRT at our department shows the importance of close collaboration between different field of medicine, including physiology, radiology and plastic surgery.

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## THERMOGRAPHY IN VITICULTURE

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Precision agriculture matches inputs to crop demands, enhancing crop yields and product quality, offering economic benefits to the producer, and reducing resource wastage and pollution. Dwindling water resources make precision irrigation an area of particular interest. Precision irrigation is especially appealing in viticulture, where precise regulation of vine water status is necessary to optimize yield and grape (and hence wine) quality simultaneously. Precision irrigation requires monitoring of both spatial and temporal variation in vine water status.

Closure of stomata, the pores on the leaf surface through which gas exchange takes place, is a rapid response to water deficit. Detection of stomatal closure could alert the viticulturist to the need to irrigate. Monitoring stomatal aperture, however, until recently was a very slow processes. When stomata are open, transpiration cools the leaves, but when the stomata close, there is no longer any stomatal cooling. As a result, leaf temperature is a good indicator of transpiration rate or stomatal conductance, or conversely of water stress, when environmental conditions are constant. Much progress has been made in determining the impact of a range of variables (meteorological, leaf surface radiative properties etc.) on leaf temperature. This means that even under varying environmental conditions, stomatal conductance can now be estimated from leaf temperature.

Thermal imaging means that the temperature of large numbers of leaves, plants, rows of crops, or even whole fields can be assessed rapidly. Therefore in theory it should be possible to use thermal imaging to detect individual vines that require irrigation, and to determine changing irrigation requirements over time. In practice, there is still some way to go before thermal imaging is used routinely for irrigation scheduling. Whole crops do not behave identically to individual leaves, variation in temperature caused by variability in crop structure can be difficult to separate from variation caused by differences in transpiration, and the best means of removing the effect of variation in meteorological conditions is still unclear. There are additional challenges relating to grapevine. Firstly, it is not a continuous crop, meaning that in overhead images leaf temperatures need to be separated from the temperatures of the soil or ground herbage in corridors between vine rows. Secondly, for many cultivars understanding of grapevine physiology has been derived from measurement on the vertical leaves facing into the corridors, whereas aerial or satellite imaging captures horizontal leaves at the top of vine canopies. Nonetheless, grapevine is one of the best studied crops with respect to thermal imaging under field conditions, and the potential of thermal imaging for detection of spatial variation in vine water status has been amply proven. With sufficient focusing of effort and collaboration between disciplines, the remaining technical problems should not be insurmountable.

There has recently also been some interest in utilizing thermal imaging to better understand different physiological responses in different cultivars, and there is no reason why thermal imaging could not be used for large-scale screening of different genotypes under particular environmental conditions, as is being undertaken as part of genetic improvement programs in other crops. Thermal imaging has also been shown to be useful for pre-visualization detection of pathogen infection and for monitoring the temperature of developing grapes (an important determinant of final grape, and wine, quality). Diverse uses of thermal imaging in other disciplines, such as ecology, may also be found to be relevant to enhancing modern viticulture. Additionally, it is likely that thermography will increasingly be combined with other imaging techniques (near infra-red, chlorophyll fluorescence, multi/hyperspectral, laser-induced) for a more complete understanding of vine, or vineyard, behaviour.

## THERMOGRAPHY IN EQUINE MEDICINE AND THE INFLUENCE OF DIFFERENT ENVIROMENTAL FACTORS ON THE THERMOGRAPHICALLY DETERMINED TEMPERATURE

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INTRODUCTION: Since the mid-sixties of the last century thermo- graphy is used in equine medicine as a diagnostic tool. The application of thermography in equine medicine, especially in orthopaedics is widespread. Thermography, however, is influenced by many environmental factors. In a serial of trials we evaluated the influence of "environmental" factors as changes in distance and angle of the camera to the horse, airflow or sedation as well as the reproducibility of measurements.

MATERIALS AND METHODS: Clinically healthy horses, free of lame- ness were included in these studies. Horses were brought into an examination room and fixed in a stock and equilibration time was given to the horses. Thermographic imaging was performed with a portable infrared camera (Variocam, Infratec, Germany) equip- ped with an uncooled microbolometer focal plane array detector and a spectral range between 7.5 to 14µm. The emissivity was adjusted at 1.00.

To evaluate the influence of changes in angle and distance of the camera (trial 1), a replicate of thermographic images were taken from ten horses three times a day. Images were recorded from the lateral aspect of the third metacarpal bone of both forelimbs. Standard images were defined with the camera positioned at an angle of 90° and a distance of 1.0 m to the forelimb. Further images were recorded with an angle of 70° and 110° or a distance of 1.5 m. In addition, at the end of each replicate, five standard images were recorded within eight minutes to evaluate the short-time reproducibility.

To determine the effects of airflow (trial 2), thermographic images from six horses were recorded during three replicates (R) of 30 minutes. Each replicate consisted of a baseline image (BL), a 15 minute phase of wind on (WON) with defined wind velocities (R1: 0.5-1.0m/s, R2: 1.3-2.6m/s, R3: 3.0-4.0m/s) and a 15 minute phase without wind (WOFF). The distal frontlimb was exposed to draft, produced by a commercially available wind machine.

All images were analysed with analytical software (IRBIS, Infratec). Maximum and mean surface temperature was calculated from a region of interest (ROI) which was built out of a polygon of the lateral third metacarpal bone and fetlock joint.

Results: In trial 1 the mean differences of temperatures between left and right forelimb of standard images were 0.32°C. Temperature of the standard images was highly correlated with temperatures of images taken with changed angle and distance ($p< 0.01$). The mean difference between the temperatures of the standard images and temperatures of images with changed angle and distance was on the left side and right side approximately 0.2°C. Short-time reproducibility showed mean difference in temperature less than 0.2°C for both forelimbs.

Trial 2: After onset of wind the temperature of the forelimb decreased within one to three minutes up to 2.1°C depending on velocity and reached baseline values within three minutes after wind was stopped. With increasing wind velocity the temperature differences between BL and WON, and WON and WOFF of the forelimb increased significantly.

Discussion: In general, all results should be interpreted with care as we used only sound horses. Demonstrated changes in thermographically taken temperatures may differ in horses with local or general inflammations. Moreover we have analysed reactions at regions of the body with prominent vascularity and can only assume that thermographical temperature shows the same development at other parts of the body. The ambient temperature in trial 1 was up to 30°C; it can be speculated whether this had an effect on the results of this trial.

Further research may assess the influence of different hair length and density as well as effects of low ambient temperatures.

Conclusion: Thermography is common in equine medicine. The effects of environmental factors, however, are barely investigated yet. The present studies showed that thermographically determined temperatures of the forelimbs were not significantly affected by changes in the position of the camera, i.e. deviations in angle (20°) and distance (0.5 m). Differences between left and right forelimb must be considered during bilateral comparison in diagnostic investigations.

Even barely noticeable wind velocities affect thermographically determined temperatures of the forelimbs. Thus, it is essential for practitioners to perform thermography on horses in a draft free environment to avoid false positive or negative diagnoses. Further research is required to assess the influence of airflow on other parts of the body and the effects on horses with inflammatory lesions especially at the distal limbs.

## Oral Presentations

### ACCURACY WHEN ASSESSING AND EVALUATING BODY TEMPERATURE IN CLINICAL PRACTICE: TIME FOR A CHANGE?

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Evaluation of body temperature is one of the oldest known diagnostic methods and still is an important sign of health and disease, both in everyday life and in medical care [1]. In clinical practice, assessment and evaluation of body temperature has great impact on decisions in nursing care as well as the laboratory test ordered, medical diagnosis and treatment. The definition of normal body temperature as 37° C and fever as > 38° C still is considered the norm world wide, but in practice there is a widespread confusion of the evaluation of body temperature [2]. When assessing body temperature, we have to consider several "errors", such as the influence of normal thermoregulation, gender, ageing and site of measurement [3]. Actually, there is a lack of evidence for normal body temperature as 37°C, due to inter- and intra-individual variability [4]. In addition, as normal body temperature shows individual variations, it is reasonable that the same should hold true for the febrile range. By tradition, the oral and axillary readings are adjusted to the rectal tem- perature by adding 0.3° C and 0.5°C, respectively [5]. However, there is no evidence for adjusting one site to another, i.e. no factor does exist which allows accurate conversion of tem- peratures recorded at one site to estimate the temperature at another site [4]. This raises the question about accuracy in measurement of body temperature. What precision can we expect in clinical practice? Which differences between sites can we tolerate?

Taken together, it is time for a change when assessing and evaluating body temperature in clinical practice.

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### CORE TEMPERATURE EVALUATION: SUITABILITY OF MEASUREMENT PROCEDURES

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INTRODUCTION: Core temperature is regulated to achieve the homeo- static balance between production and dissipation of heat. The core body temperature is one of the most important factors to monitor. It helps to study the cognitive response to high temperatures' exposure and it's one of the best physiological indicators used to prevent heat injuries in different activities and in individuals with different characteristics. Has been used in several studies, either in the laboratory or in the real world, including athletes, students, and military. The gold standard methods for measuring the core temperature (rectal and esophageal temperature) have some advantages but also limitations, especially due to discomfort caused by the implantation of the sensors (Ribeiro 2010). Alternatively, it is possible to use thermal ingestible sensors (TIS) with the capability of measure the core body temperature without the technical limitations of other methods. This technique was applied, tested and validated by several researchers as Catherine O´Brien et al. (1997), Byrne & Lim (2007) or Hermann-J. Engels et al. (2009) and approved by the ethics committees of the respective organizations. Although the measurement of body core temperature (Tc) with the use of a TIS has been described for the first time, on 1962, i.e 51 years ago, only recently the method gained widespread use for research applications (Byrne & Lim 2007). This is because there are still questions about the scope of its applicability. Thus, the main goal of this paper is to compare the different available methods to measure core temperature and to select the best kind of device to use in a specific study.

METHODS: This study was based on a systematic literature search in major databases which allowed to identify, select and analyse relevant papers in the field. Only the papers with ethics com- mittee approval or, at least, informed consent, have been considered. The selection criteria include: real time data acquisition, real time monitoring, reliable and precise sensors, comfort in use, less invasive method, easy to manage and adaptable to rest and exercise situations.

RESULTS / DISCUSSION: Monitoring body core temperature is one of the best methods to reduce the risk of heat injury in different activities (Mckenzie et al. 2004, Byrn & Lim 2007). There are a lot of methods to measure core body temperature. However the ingestible telemetric temperature sensor is the one that recently won greater diffusion. A "pill" or "capsule" is ingested and transmits by radio waves a signal with the value of gastro- intestinal temperature to an external device [1]. The ingestible pill can help to prevent heat exhaustion and heat stroke, which could lead to heat-related illnesses. Were also demonstrated the advantages of continuous measurement of Tc, over different physical and cognitive activities [6,7].

CONCLUSION: The conclusion drawn was based on the synthesis of the analysed papers. All referred methods are sensitive to core temperature control. However, according to the research, the method with less technical limitations, and less invasive, is the TIS. The results suggest the telemetry pill system provides a valid measurement under conditions of decrease, increase and steady state of body core temperature. The placement of sensors into pills, using telemetry allows studying real thermal complications in the field, such as in sports science, safety, hygiene and occupational health, military and even in laboratory. It allows a continuous data acquisition, and a real time monitoring of the core body temperature. Comparatively to rectal temperature, considered the gold standard method of core temperature measurements, gastrointestinal pills presents one of the best possible approximations [5].

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## POTENTIAL ERRORS IN MEAN SKIN TEMPERATURE CALCULATION DUE TO THERMISTER PLACEMENT AS DETERMINED BY INFRARED THERMOGRAPHY


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INTRODUCTION: Blood flow to the skin is the conduit for heat transfers between internal core temperatures of the body and external conditions of the environment. The use of infrared imagining provides a thermal map of the skin that can quantify skin thermal measurements that can be correlated to qualitative measures of skin blood flow [5]. The regulation and control of heat transfer (heat gain, heat loss) is imperative for maintenance of body temperatures within the thermal survival zone. The advent of infrared (IR) imaging has allowed researchers to accurately (0.05°C sensitivity) determine skin temperature via ge--neration of a skin thermal map made up of approximately 11,000 data points. This allows researchers to determine sites of the body with the greatest variation in temperature and to examine the accuracy and validity of estimating whole-body average skin temperature using thermocouples attached to the skin at various locations. However, to date, researchers using IR imaging have only used mean skin temperature for a region, equivalent to optimal skin probe placement, to validate these formulas[2] . In reality, due to the poikilothermic nature of the skin, when placing thermocouples at a given location on the human body (e.g. "chest") one could actually be measuring the hottest or coldest spot at a certain site. This "hot" or "cold" spot would then be used as an average temperature for the region in a skin temperature calculation, introducing error into the estimation. This study used IR imaging to determine which of 13 sites used in mean skin temperature calculations has the greatest variation in a thermoneutral environment, and to quantify the error in calculating average skin temperature due exclusively to the range of possible skin temperature measurements at recommended thermocouple locations.

METHODS: Thirty college-aged subjects (15 male, 15 female) were recruited for this study. Prior to participation all subjects completed a medical screening questionnaire assessing current medication use, pre-existing orthopedic or any metabolic condition that would be contraindications for participation. Subjects were instructed to abstain from food and caffeine consumption as well as smoking and exercise three hours prior to participation and to arrive in exercise attire. Men wore gym shorts that did not cover the thigh region. Women wore gym shorts that did not cover the thigh region and a sports bra with the straps tucked into the top. Subjects stood for 15 minutes in a controlled, neutral environment with temperature held constant at 30°C and 40% relative humidity. Anterior and posterior infrared images were taken at 13 standard locations as described in figure 1. Polygons were drawn around the areas of interest where probe placement was recommended by prediction for- mulas. A range (high, average, low) of skin temperatures was determined for each site. The range of temperatures at each site represents the scope of all possible measurements that could be acquired by placing a skin probe at that site. The ranges at each location were compared to determine which sites had the most variability. Then, the minimum, maximum, and mean tempera- tures at each site were used in calculations of average skin temperature using the Burton[1] , KSU [4] Ramanathan[6] and Gagge/Nishi [3] formulas (described in table 1) to determine the range of error in the calculations due exclusively to probe placement. All calculations were compared to true mean skin temperature, as determined by using the mean value from all 13 sites measured via IR imaging in an unweighted formula that has been shown to be over 95% accurate when used in this manner[2].

RESULTS: The average temperature range at each site was 3.19 ± 0.93°C, with the smallest ranges found at the forehead (1.81 ± 0.46°C) and occipital (1.98 ± 0.47°C) and the greatest ranges occurring in the posterior lower leg (5.17 ± 1.21°C) and anterior lower leg (4.77 ± 0.92°C). The true mean skin temperature from the 13-site unweighted formula was found to be 31.70 ± 1.06°C. When the hottest and coldest temperatures were used in the

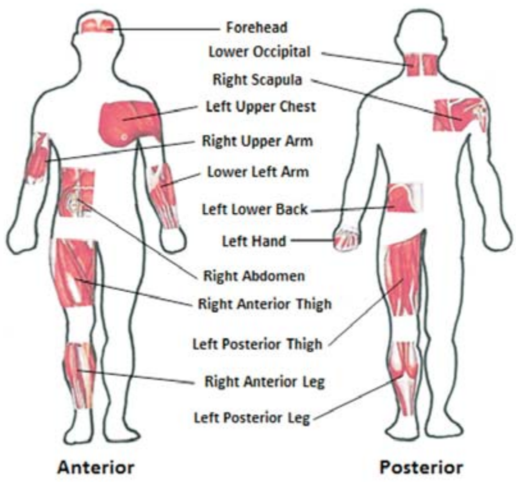


Figure 1:
Location of regional sites for means skin formulas

Table 1
Mean skin formula

| Author | Formula |
|---|---|
| Burton | (0.5 x Upper chest) + ( 0.14 x lower arm) + (0.36 x anterior lower leg) |
| KSU | (0.5 x Upper chest) + ( 0.14 x lower arm) + (0.36 x Posterior lower leg) |
| Ramanathan | 0.3 x ( Upper chest + lower arm) + 0.2 x ( Anterior thigh + Anterior lower leg) |
| Gagge/Nishi | (0.07 x Forehead) + (0.175 x Upper chest) + (0.175 x Scapula) + (0.07 x Upper arm) + (0.07 x Lower arm) + (0.05 x Hand) + (0.19 x Anterior thigh) + (0.2 x Posterior lower leg) |
| 13 Site equation | ( Forehead + Lower Occipital + Scapula + Upper Chest + Upper Arm + Lower Arm + Hand + Abdomen + Lower Back + Anterior Thigh + Posterior Thigh + Anterior leg + Posterior Leg) / 13 |

formulas, the average range of possible temperatures calculated for the Burton, KSU, Ramanathan, and Gagge/Nishi formulas were 3.71 ± 0.55°C, 3.85 ± 0.64°C, 3.33 ± 0.48°C, and 3.44 ± 0.51°C respectively. Even when using the optimal, 13-site formula, the range from using all high or all low temperatures was 3.19 ± 0.35°C.

CONCLUSIONS: Under thermoneutral conditions (30°C, 40% relative humidity) the greatest local temperature variation occurs in the lower leg, and the least variation is found in the head and neck. These results also indicate that skin temperature calculations have a wide range of error due to local temperature variation, especially when considering that a temperature difference of 0.5°C is physiologically significant (Uematsu, 1985). These results call into question the legitimacy of using skin temperature calculations from thermocouples. Since there is no way to tell whether the value measured via thermocouple is close to the mean temperature of the site outside of using IR imaging, formulas using data from thermocouples may be que- stionable for accurate or valid mean skin temperature estimation.

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## MEASURING HUMAN PSYCHOPHYSIOLOGICAL RESPONSE TO COMBINED TEMPERATURES AND HUMIDITIES: A CLIMATIC CHAMBER VALIDATION


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INTRODUCTION: Climatic chambers have been built and used for many purposes. In investigation associated to humans and to thermal environment, are used to test clinical treatments of respiratory diseases since 1955 [8], thermal comfort assessment for energy saver in buildings[1] and used with the specific application to occupational health and safety, from at least 1968 [9]. Its results have also been used to validate mathematical models of human thermoregulation responses applied in several knowledge areas [4]. The aim of this study is to validate the use of the climatic chamber FITOCLIMA 25000 in the evaluation of human physiological responses and cognitive performance, to different combinations of heat and humidity. This validation passes through the justification of the suitability of the chamber to the experimental goals and for the analysis of regulation capacity of the chamber itself.

CHAMBER DESCRIPTION: The entire chamber design was thought to be used by humans, so the appearance of the chamber transmits comfort and confidence in use. Climatic chamber FITOCLIMA 25000 was built to regulate temperature and humidity between a specific range (-20ºC to 50ºC and 30% to 98% RH), being able to control the humidity between 10ºC and 40ºC.

MATERIAL AND METHODS: To assure that the Climate Chamber is suitable to psychophysiological studies, it's important to define criteria for measuring human performance according the experimental goals. So the first step was to review scientific literature on psychological and/or physiological responses in humans with thermal sensation assessment as well the use of climatic chambers. Were also checked the international standards with sensitive limit values of temperature for human activity. These kind of studies are done: a) in an environment in steady state to evaluate the thermal response in a specific combination of temperature and humidity and b) at transient state conditions to evaluate the response to temperature variations.

RESULTS: According international standards, drifts shouldn't vary above 2 K/h and the cycle temperature fluctuation should be less than 1K peak-to-peak [4]. A difference of temperature in space of 2K, can ensure no variation in thermal sensation [2] inside acceptable limits. Literature values are more demanding than international standards. With 0,5clo, are suggested 0.5-0.6 K/h for drifts, in order to assure non-sensible variation within a period of, at least, 3-4h [1,6]. The regulation accuracy presented in some studies which use thermal sensation is ±0,12K [6] around a set point temperatures, ±0.5K, ±5% humidity and special discrepancy inferior to 0,2K [3]; ±0.2K, ±1 to 5% humidity (0.25g/kg) and to ensure that mean radiant temperature and air temperature have the same value during steady and transient states [6].

CONCLUSION: Test results showed that FITOCLIMA 25000 is able to control temperature and humidity in steady and transient states. The accuracy in steady states is higher than in transient states. Set-point values for high temperature and humidity, and for low temperature and humidity, are less accurate than set-point values with other combinations. Also the control of temperature and humidity, in the simulations of thermal transients is faster in moderate conditions than with combinations near the chamber regulation limits.

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## SKIN TEMPERATURE AND MICROVASCULAR BLOOD FLOW CHANGES IN THE FINGERS FOLLOWING A DEEP INSPIRATORY GASP MANOEUVRE

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The aims of this pilot study were to quantify the changes in finger pulp skin temperature, laser Doppler skin blood flow (LDF, microvascular flux) and finger photoplethysmography pulse (PPG, microvascular blood volume pulsatility), induced by a deep inspiration in healthy control subjects. A system comprising an electronic thermometer, a laser Doppler flowmeter and a PPG device measured simultaneous vasoconstrictor responses to a controlled deep inspiratory gasp from three adjacent fingers of one hand. Clearly defined responses were obtained in 15 of the 17 subjects studied. Skin temperature fell in all of these subjects shortly after each gasp, with a median fall of 0.089 oC ($P<0.001$). The median value of LDF flux reduction was 93% ($P < 0.001$) and PPG also showed a similar large and significant response for pulse amplitude relative to baseline. The median times for waveforms to reach their minimum were 4.6 s (PPG), 6.3 s (LDF) and 29.1 s (skin pulp temperature), with median delays between minima of LDF and PPG of 1.6 s ($P < 0.001$) and skin temperature and PPG of 23.5 s ($P < 0.001$). The vascular responses of skin temperature, LDF and PPG to an inspiratory gasp were repeatable. Additional experimental analyses were also performed to explore the utility of beat-to-beat PPG pulse wave analysis and also novel wavelet analysis to further characterize the physiological changes observed following controlled gasp, the observations from which will also be summarized in the paper.

## APPLICATION OF COLD PROVOCATION FOR BREAST CANCER SCREENING USING IR THERMOGRAPHY

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A new approach of breast cancer screening using thermovision camera is presented in this paper. The idea is to cool down the healthy and unhealthy breasts or if it's impossible the part of the breasts, and then register a sequence of thermograms in order to get a curve of temperature versus time. We assume that the thermal reaction of the external part of the skin due to the thermo- regulation for healthy and unhealthy cases.

BACKGROUND: A new approach of breast cancer screening using an infrared camera is presented in this paper. Previous studies have shown good results. In this study we are using cold provocation and movement correction in order to enhance the result. We assume that the reaction for cold provocation differs in healthy and cancerous tissue.

MATERIALS AND METHODS: The cancer patients for the study are from a preliminary investigation made in Tampere University hospital. Three out of nine patients examined were suitable for this study. We used a microbolometric uncooled camera IRvox384 thermal camera developed at Technical University of Lodz for medical applications. We cooled the breasts for 15 seconds and then a sequence of 300 images was recorded with the frame rate of 2 frames per second. The total recording time was 150 s.

RESULTS: We found out that the value of time constant is higher in cancerous areas. It means that the reaction of unhealthy tissue for thermal excitation is slower. The temperature is coming back to normal in a longer period of time.

CONCLUSIONS: In order to confirm that results are correct and the time constant of breasts with the cancer has a higher value it is necessary to collect more data from patients with diagnosed cancers. We also need to create standard procedures for the imaging sessions so that the results could be repeated as precisely as possible.

## THE EFFECT OF A VIBRATING PLATE IN THE SKIN TEMPERATURE OF LOWER EXTREMITIES IN HEATHY SUBJECTS

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INTRODUCTION: Vibration exercise has been increasing in popularity both in leisure, sport and clinical settings but the impact of this exercise modality in subjects health is still under construction by the scientific community. Vibration exercise is practiced mostly while standing in vibration platforms, as whole body vibration. Several research papers have described the effects of exposure to whole body vibration in strength, flexibility, equilibrium and blood flow but the use of thermography in these investigations is limited. The aim of this research is to study the impact of acute exposure to whole body vibration in the skin temperature of the lower extremities.

METHODS: The skin temperature of twelve healthy and untrained subjects was accessed using thermography, before and after exposure to vibration exercise. Before capturing the images with a thermographic camera (FLIR A325) all subjects were instructed to undress, remain still in the examination room for thermal equilibrium for a period of 15 minutes, with temperature stabilized at 22 ºC, humidity less than 50% and absence of air flow. Thermograms were obtained from the following views: Thighs (anterior view); Thighs (dorsal view); Leg, right (lateral view); Leg left (lateral view); Leg, right (medial view); Leg left (medial view); Lower legs (anterior view); Lower legs (dorsal view); Both knees (anterior view) and Both ankles (anterior view) before and after exposure to vibration. The mechanical stimulation was provided by the Power Plate® with parameters set at a frequency of 35 Hz, high amplitude (5-6 mm), and therefore a peak acceleration of approximately 7 g, for 5 minutes.

RESULTS: The analyzed regions of interest mean temperature increased in the lower legs (except for the anterior aspect of the right side) and ankles (except for the lateral aspect of the left ankle), however no statistically significant difference was found. In all other regions of interest there was a decrease in the mean temperature and significant differences (p ? 0.05) were found in the dorsal aspect of the thighs, in the anterior aspect of the left thigh, in the anterior aspect of the left knee and in the lateral aspect of both knees.

DISCUSSION: The results show that the exposure to 5 minutes of vibration (35 Hz) in a single session has an effect in the skin temperatures of the lower extremities. We found a mean temperature increase of 0.3 ºC and a mean temperature decrease of 0.33 ºC but in the regions of interest where we found significant differences the mean decrease in temperature was 0.47 ºC. Caution should be taken before vibration exercise prescription since decreased microcirculation of the lower extremity has been reported as a complication of ageing and disease processes such as diabetes. Ageing of the population is a problem of modern societies, as is the increasing number of diabetics and thus vibration exercise should be carefully prescribed.

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## USING CLINICAL THERMOGRAPHY AS DIAGNOSTIC COMPLEMENTARY PROCEDURE FOR HAND ARM VIBRATION SYNDROME

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INTRODUCTION: Hand-Arm Vibration Syndrome is an occupational condition that affects people exposed to vibrating tools in the workplace and needs an accurate quantitative and objective diagnostic test to aid clinicians in the judgment of the degree of injury and correspondent treatment. An objective assessing method is needed to provide a permanent evidence record of the degree of injury.

METHODS: Medical thermography was used with a developed objective mechanic provocation test involving vertical vibration exposure of hands, for 2 minutes at 31.5Hz of vibration frequency and 36 mm/s2 of vibration magnitude, which was followed by a vascular provocation challenge of the hand for a period of 1 minute at 20°C. Images were taken during the whole procedure. In order to assess the peripheral temperature changes of the hand a computational model was developed and the images standardised and analised.

RESULTS: It was possible to discriminate between degrees of injury groups ($p<0.05$) but not individuals. It was possible to identify through medical thermography the affected fingers and its temperature changes quantified assessing objectively the stage of the injury.

CONCLUSION: The proposed method is objective and repeatable, can provide information of the evolutionary stage of the condition. Medical thermal imaging can be used as diagnostic tool to provide evidence of occupational condition affecting upper limbs in support to medical history in medico-legal liabilities.

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## ASSESSMENT OF CALIBRATION AND EVALUATION PROCEDURES FOR THERMAL IMAGING METROLOGY AT THE NATIONAL PHYSICAL LABORATORY

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INTRODUCTION: Thermal imaging is the fastest growing and most dynamic segment of the temperature sensing market [1]. Instrument performance, versatility and practicality have improved dramatically with systems now offering; un-cooled detector, large focal plane arrays, portable hand held systems, touch-screen technology, visual-thermal image overlay, Bluetooth and Wi-Fi connectivity, memory card storage, voice recording annotation, increased spatial and thermal resolution, comprehensive analysis software, one click reporting etc. And, introductory instruments are now available for approximately €1000. The result is a wide ranging and increasing usage of thermal imaging systems. A recent market report stated: "In the next 5 years, the annual number of un-cooled, small array imagers sold is predicted to more than treble" [2].

This continued rapid growth in thermal imaging has been highlighted as placing infrared temperature measurement at a "potential 'cross-roads' for the future of infrared technology" [3]. Thermal imagers are either opening new measurement fields (for example lock-in thermography) or displacing current measurement instruments such as single spot infrared radiation thermometry. The latter is of particular concern to national metrology institutes (NMI's), such as NPL. Single spot infrared radiation thermometers are an historic technology designed for non-contact temperature measurement with an established metrological framework and knowledgebase. Thermal imaging, having its development routes in military applications, does not have the same history, framework or knowledgebase. For quantitative thermal imaging measurement applications (e.g. clinical thermography, industrial process control, non-destructive inspection etc.) such a history, framework and knowledgebase needs further research and development.

A survey was instigated (2011) under the auspices of the Consultative Committee of Thermometry (CCT) to identify the current temperature calibration and evaluation facilities, practices and procedures for thermal imagers and to ascertain what metrology work was required in the National Measurement Institutes (NMIs) to support this growth in quantitative thermal imager usage. The findings of this survey within the EURAMET (European Association of National Metrology Institutes) region are to be reported at the Quantitative Infrared Thermography conference, QIRT 2012.

The National Physical Laboratory (NPL), co-ordinator for the EURAMET region survey, has used the key findings of this survey [4] to critically review current evaluation and calibration procedures for thermal imagers and to develop and define a new set of parameters/procedures to investigate fully for the calibration of thermal imagers. This paper provides a brief summary of the survey's findings, the assessment of NPLs current temperature calibration and evaluation facilities and procedures for thermal imagers and the defined range of parameters/procedures/test recommended for research.

METHODS: "The outputs from the EURAMET survey were used to critically assess NPL's facilities, procedures and calibration and validation technologies

"A range of thermal imager temperature measurement specific parameters, procedures and tests were developed and defined for metrological assessment, with a view to future trials with a sub-set of modern thermal imaging cameras

RESULTS: For the following parameters, procedures were developed and defined for the assessment of temperature measurement for thermal imagers (titles are given here, full details will be in the final paper).

- Calibration against standard variable temperature blackbody sources
- Repeatability assessment
- Environmental effects, variation due to changes in environmental conditions
- Distance effects, variation due to distance from blackbody target
- Focus, variation due to changes in instrument focus
- NETD, noise equivalent temperature difference
- Image uniformity, temperature uniformity across image
- SSE, size-of-source effect, target definition performance
- Ensquared power test (point source)
- Emissivity correction algorithm
- Warm up effects (from switch on)

DISCUSSION: The survey of calibration/evaluation facilities and procedures within the EURAMET region found that standard practices for thermal imager assessment are not currently in place, most laboratories carry out thermal imager calibrations using single spot infrared radiation thermometer facilities and procedures. It is far from certain that such an approach is suitable, or indeed correct. Research into facilities, methodology and uncertainty for the temperature calibration of thermal imagers is underway at a number of measurement institutes. NPL in assessing the outcomes of the survey with respect to their facilities and procedures have developed and defined a range of parameters/procedures and tests, tailored to thermal imaging temperature assessment and calibration.

In future work, these parameters/procedures will be investigated fully by implementing to a range of 'typical' modern thermal imagers [some initial results of which may be given] to fully understand and quantify the correct facilities and procedures with which to regularly calibrate imagers with and all sources of uncertainty (image field uniformity, target definition etc.).

It is clear, with the rapidly increasing uptake and application of thermal imaging, it is essential that the metrological infrastructure is developed and established to support this.

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The CCT is a consultative committee of the CIPM, the International Committee of Weights and Measures European Association of National Metrology Institutes: http://www.euramet.org/



## RELIABILITY AND REPRODUCIBILITY OF SKIN TEMPERATURE OF OVERWEIGHT SUBJECTS BY AN INFRARED THERMOGRAPHY SOFTWARE DESIGNED FOR HUMAN BEINGS

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INTRODUCTION: The technical improvement of Infrared Thermography (IRT) is making way to new applications. [3]. Among those applications, several of them use IRT on human beings. Nevertheless, data of skin temperature patterns of healthy and/or overweight subjects are few. From the research group of Thermography of the Faculty of Physical Activity and Sport Sciences-INEF (Universidad Politécnica de Madrid, Spain), we think that one of the reasons of this lack of knowledge is due to the poor offer of IRT software to analyse human beings.

Therefore, the aim of this work was firstly: to investigate the reproducibility of skin temperature on overweight and obese subjects through IRT in different body regions, moments and thermal asymmetries ($\delta T$); and secondly to check the reliability of the new software called Termotracker®, created by the research group with the collaboration of several institutions.

METHODS: A total of twenty-two overweight and obese males (11) and females (11) (age: 39.59±8.14 years; height: 1.69±0.08 m; weight: 86.68±11.26 Kg; BMI: 30.34±2.55), exercising at least 2 times per week, took part of the study.

We recorded the whole body skin temperatures of each subject in four thermograms (Anterior and Posterior of Upper and Lower body) in two consecutive moments (5 seconds between) by the same observer. All thermal images was taken by an infrared camera (FLIR T335, Sweden) in a standardized room, with controlled temperature (23.54±1.34ºC and 44±3% humidity), following the patterns set by Gómez Carmona et al. [2] patented pending protocol. Skin temperatures from over 72 Regions of Interest (ROI) were obtained using Termotracker®. For this study only 20 ROI of all were assessed in two different computers with the same software.

Intra.class correlations analyses (ICC with two-way mixed model) were used to determine the reliability of the software same data in two different computers-, the inter-examiner reliability, two images of all participants by the same observer and the reproducibility of thermal asymmetries ($\delta T$) in two computers and different moments.

RESULTS: The reliability of the software was very high (ICC mean 0.984), and the inter-examiner reliability using the software was also very high (ICC mean 0.988). The reproducibility of the side-to-side differences ($\delta T$) were evaluated between two computers (ICC mean 0.765) and between two consecutive moments separated by five seconds (ICC mean 0.764).

DISCUSSION: The results shown a very strong reliability of the software, not only between two computers but also between two different images. Termotracker® has a feature called "artificial vision" charged of detecting automatically the ROI from the thermal images. By comparing the results with those obtained by Zaproudina et al. [5], the higher reliability even in ICC inter-examiner results could be due to this automatic process to identify ROI, task done in other studies by the observer. This automation of determining ROI improves the IRT reliability, making possible a faster and more efficient IRT analysis on human beings.

According to the reproducibility results, both are good but not such excellent as the reliability ICC before. Zaproudina et al [5]

| ROI | Software reliability (two computers) | Inter-examiner reliability (two moments) |
|---|---|---|
| Abdominal | 0.998 | 0.994 |
| Right Thigh | 1 | 0.999 |
| Left Thigh | 1 | 0.999 |
| Right Knee | 0.999 | 0.999 |
| Left Knee | 1 | 0.999 |
| Right Chest | 1 | 0.999 |
| Left Chest | 1 | 0.999 |
| Right Cal | 1 | 0.999 |
| Left Cal | 1 | 0.999 |
| Back | 1 | 0.999 |
| Lumbar | 0.999 | 0.999 |
| TOTAL | 0.984 | 0.988 |
| Max | 0.99 | 0.994 |

Table 1
Mean of ICC for the reliability of the Regions of Interest (ROI) and total values for the software and inter-examiner test.

| δT of ROI | Reproducibility of δT (two computers) | Reproducibility of δT (two moments) |
|---|---|---|
| Thigh | 0.999 | 0.99 |
| Knee | 0.999 | 0.997 |
| Chest | 0.998 | 0.993 |
| Posterior Thigh | 0.996 | 0.991 |
| Calf | 0.999 | 0.998 |
| Dorsal | 0.99 | 0.974 |
| TOTAL | 0.765 | 0.764 |
| Max | 0.856 | 0.587 |
| min | 0.647 | 0.887 |

Table 1
Mean of ICC for the reliability of the Regions of Interest (ROI) and total values for the software and inter-examiner test.

describe lower ICC's, it could be mainly due to the time interval between the two images. In our study the time difference between both images were just 5" and not a complete day, which could entail the influence of many other factors.

In general terms, the results of this study are coincident with those of Owens [4] and Burnham [1], ICC over 0.9, which indicate that IRT is a reliable and objective technique to assess skin temperature.

CONCLUSIONS: Skin temperature on overweight subjects has a good reproducibility with small time interval. The good reliability results of the software suggest the importance of using specific software to analyses IRT images on humans, eliminating the likely human error of determining ROI and improving the efficiency and objectivity of a technique with a still high potential of application in humans. The reproducibility of thermal asymmetries is a good but has the influence of several factors that should be investigated. Termotracker® is reliable and objective software to analyse IRT images of human beings.

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## 3D INFRARED THERMOGRAPHY


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INTRODUCTION: Current infrared thermograms are purely two-dimensional images. The authors demonstrate a system consisting of a normal thermographic camera and a stereogrammetric 3D camera working in the visible domain. The combined output of both cameras is a 3D data mesh textured (overlaid) by a thermal image. In addition to generating a 3D image and data set of the observed object the system allows to compensate for temperature measurement errors caused by non-perpendicularity of object areas with respect to the infrared camera.

METHOD: In this paper a FLIR A40 thermal camera and a Photometrix Mavis-III 3D camera [1] are mounted as co-axially as possible on a professional photo stand. Both cameras are triggered at the same time to capture images.

The output stereo images of the 3D camera are used to compute a 3D data mesh of the observed object. The data mesh is calculated within 20 seconds and typically has a resolution of +/- 0.5 mm in x- and y- direction and +/- 1 mm in z-direction. In a normal stereo imaging application one of the stereo images is then used to render the surface of the the 3D data mesh as shown in figure 1.

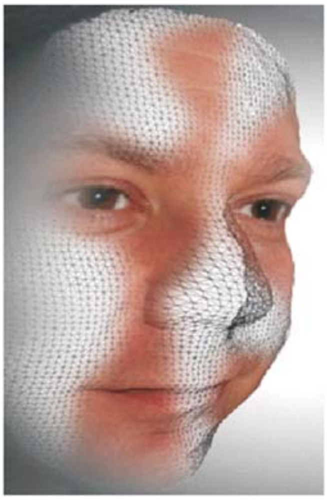

Figure 1
Overlay of 3D data mesh

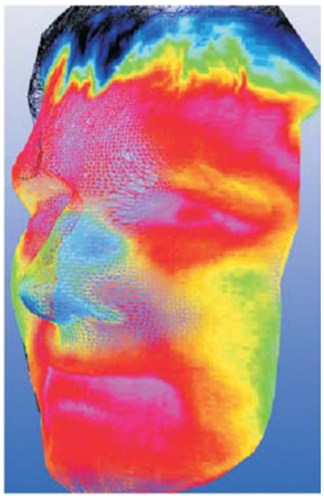

Figure 2
Overlay of 3D data mesh with infrared image texture

In our application the visual image is replaced by the infrared image. The challenge here is to determine a transformation matrix that aligns the thermal image in size, rotation angle and position with the visual image normally used. The result is shown in figure 2.

In a final step the 3D data mesh is used to determine the orientation of individual pixels with respect to the camera. Thermal cameras determine the temperature of surface points under the assumption that all points of the observed scene have a constant emissivity. In real situations this assumption is rarely correct [2] since the emissivity of a given point is a function of its orientation with respect to the camera. By calculating this orientation a correction for this error can be made and thus compensate for errors that influence applications of medical infrared thermography such as the assessment of thermal body symmetry [3].

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## INTEGRATING MEDICAL THERMOGRAPHY ON A RIS USING DICOM STANDARD

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INTRODUCTION: Radiology Information System (RIS) is an integrated system, component of the Hospital Information System (HIS), which provides patient information of all the medical imaging images and reports. This system manages all the workflows on a medical imaging department, facilitating the capture, storing, archiving and delivery of the images. The storage of medical images is done in a Picture Archive and Communication System (PACS), and the format used is the Digital Image and Communications in Medicine (DICOM) standard. There are several proposes of medical thermography in the DICOM format.

METHODS: There is a need of an information system to convert the image from the RAW camera format to the DICOM standard. But the infrared camera manufacturer does not provide that application. An implementation of capturing software that uses a DICOM work list that integrates the patient demographic information and when the capture is complete, archive the image to the PACS with all the associated information, and updates the status of the capture in the RIS. All the reporting necessary should be done in the RIS and all the tools to visualize and transform the image should be integrated to the PACS software. In the end the report created in the RIS and the image in the PACS need to be integrated to the Electronic Health Record (EHR).

DISCUSSION: The inclusion of medical thermography on a RIS and subsequently on a PACS system is essential for the widespread use on a hospital setting. The usage of the DICOM standard on the medical thermography will facilitate the introduction of this modality on all the HIS. The integration of all the systems is fundamental to the facilitation of adoption of the medical thermography within the clinical staff.

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## HISTOGRAPHIC METHOD AS A TOOL OF THERMAL IMAGE PROCESSING

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Among essential values characteristic of the histograms, the following are selected: the highest (maximum), the lowest (minimum) and the average temperature in the defined area; the median, standard deviation and skewness; the number of pixels in the examined area and the maximum value on the ordinate of the histogram.

The distribution curve D of the histogram is the integral of the histogram (Fig.1) and the derivative dD/dt of the distribution curve gives the shape of the histogram (Fig. 2). The series of distributions of histograms (Fig. 2) is more visual and efficient for comparisons than a series of histograms (Fig.1). For illustration, figures are taken from the effects of β irradiation.

Accepting that the increased temperature is a normal tissue reaction to radiation-induced skin reaction (see Fig. 1), it can be seen that at the end of the first session the skin temperature increased in contrast with the second and third sessions (weekends) when it was decreased (Fig. 2). This may indicate that the regulatory functions of the skin have been relaxed. On further irradiation, the radiation reaction was not additive; just a decrease of the average temperature was observed especially when there was a break of two days in the treatment protocol. Accordingly, the increases in radiation doses do not increase the tissue reactions but, in contrast, induce a modulation.

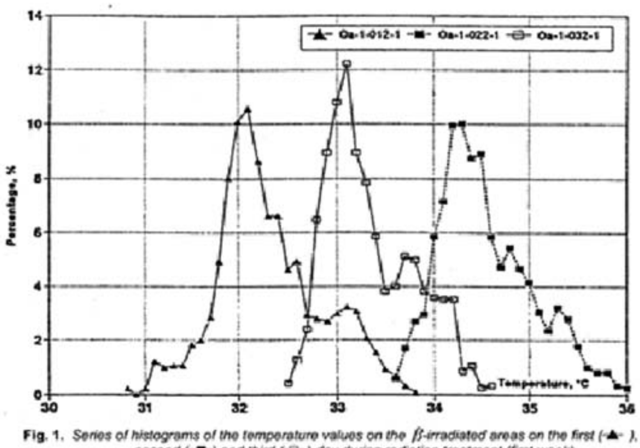


Fig. 1. *Series of histograms of the temperature values on the β-irradiated areas on the first (-▲-), second (-■-) and third (-⊖-) day during radiation treatment (first week)*

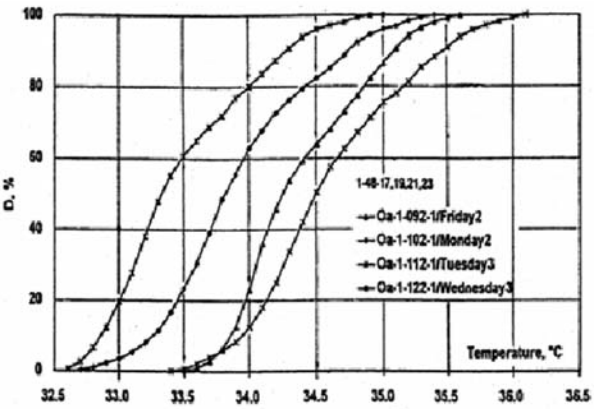


Fig. 5. *Series of distributions of the temperature histograms of β-irradiated areas in the third week*

In addition, numerous techniques can be utilized to evaluate circulation in an affected area, to determine the volume, depth and area of tissue affected. Other medical imaging techniques include angiography, radionuclide imaging and non-invasive technique such as impedance plethysmography, magnetic resonance imaging and ultrasound. Techniques capable of evaluating superficial blood flow and tissue perfusion have clinical value for the physician, who must counsel the patient and make critical decisions regarding medical or surgical treatment.

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## USEFULLNESS OF THERMOGRAPHIC EXAMINATION FOR DETECTING HYPOTHERMIA

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INTRODUCTION: There were some studies that described about the hypothermia in some situations. Hypothermia is not only unpleasant condition for the people, but also dangerous state for the life. In this presentation the usefulness of thermographic examination is demonstrated for detecting hypothermia and studying about the countermeasures for hypothermia.

HYPOTHERMIA IN SURGICAL CENTER: In my previous study it was showed that thermography seemed to be useful for diagnosing hypothermia of the patients in some situations during surgical therapy. Pneumoperitoneum using in the laparoscopic surgery was one of the cause of intra-operative hypothermia. The cold carbon dioxide is used for pneumoperitoneum. Posture in surgery also related to hypothermia. The patients with lithotomy position for some lower abdominal surgery showed hypothermia. The reason of this phenomenon is that there are small areas we can warm up the patients. Prone position in the vertebral surgery causes hypothermia. There are also small areas we can warm up the patients. But, the patients avoided hypothermia by warming the air under the patients' abdomen. Thermography was very useful for making sure the effectiveness of these countermeasures.

HYPOTHERMIA IN HIGH ALTITUDE: The hypothermia in the high mountain is one of the most serious situations. There were many climbers who died by hypothermia. In our previous study, the portable type thermo camera was used for detecting hypothermia in high altitude and for studying the mechanism concerning hypothermia in the mountain. The results of the study showed that the reaction of the men's bodies was different from that of women's bodies.

## TEMPERATURE OF THE HUMAN KNEE - A REVIEW

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BACKGROUND: Temperature measurement of the knee joint has a long tradition in medical thermometry. However, neither a standard for recording knee temperature nor agreed values of knees in healthy subjects or in joint disease are available.

AIM OF THE STUDY: To compute available data on knee temperature from the literature including the method and condition of temperature recording, measurement sites and temperature values.

METHOD: A literature search was performed in the databases Medline and Embase using the search terms "skin temperature" or "intra-articular temperature" and "knee". Only papers written in English or German related to humans were considered for inclusion. The following data were extracted from included papers: Surface (skin) temperature, intra-articular temperature, site of measurement for skin or intra-articular temperature, measurement device, number of investigated knees, diagnosis and biographic data of investigated subjects, room temperature, time of acclimatisation. If possible, temperature values were pooled if they had been recorded under similar conditions.

RESULTS: In total, the database included temperature measurements from 3463 knee joints, comprising data from 876 healthy subjects, 629 patients with osteoarthritis (OA), 512 patients with rheumatoid arthritis (RA), 67 patients with non rheumatoid and other non specified inflammatory arthritis. 86 patients suffered from joint inflammation caused by trauma, and 96 patients had various injuries of ligaments and other fibro-cartilagenous tissues of the knee. 131 temperature measurements were performed during surgery and 285 after surgery. 33 patients suffered from algo- dystrophy, 200 patients were investigated during or after various methods of cryotherapy and 50 subjects during heat treatment. Pattern description was reported in 5700 other subjects with various knee disorders.

Based on contact temperature measurements, the mean temperature of the anterior knee in healthy subjects was 30.5 ± 1.1°C. Determined with radiometers, the corresponding mean temperature was 28.7 ± 0.6°C (95% confidence interval: 27.9 to 29.5). In thermal images from healthy subjects, the mean temperature of the anterior knee was 29.5 ± 1.6°C (95% confidence interval: 28.5 to 30.5°C) and 33,1 ± 0.0 °C of the posterior knee. The side difference of temperature was 0.2 ±1°C for both the anterior and the posterior knee.

Mean intra-articular temperature varied between measurements recorded during knee surgery (29.9 ± 4.4 °C; 95% confidence interval: 23.0 to 36.8), in patients with rheumatoid arthritis (35,1 ± 0.7 °C; 95% confidence interval: 34.2 to 36.0°C) or osteoarthritis (33,5 2,7°C; 95% confidence interval: 30.1 to 36.9) and healthy subjects (32.6 ± 0.9°C; 95% confidence interval: 31.5 to 33.7).

Measurements with contact thermometers revealed in patients with rheumatoid arthritis a mean temperature of 32.5 ± 0.9°C (95% confidence interval: 31.4 to 33.9°C) for the anterior knee, while the corresponding temperature recorded with infrared thermal images was 30.5 ± 0.8°C (95% confidence interval: 27.8 to 33.1°C). In osteoarthritis patients, contact thermometers obtained a mean anterior knee temperature of 31.3 ± 1,3°C and temperature measurements from infrared thermograms revealed a mean temperature of 30.7 ± 1.3°C (95% confidence interval: 29.4 to 32.0 °C).

CONCLUSION: Knee temperatures vary with respect to the method of temperature determination and between different health conditions of the knee joint. Moreover, mean knee temperature describes the condition of the knee incompletely and should be supplemented with a description of the temperature distribution.

## SCROTAL INFRARED DIGITAL THERMOGRAPHY FOR DETECTION OF SUBCLINICAL VARICOCELE

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INTRODUCTION: Varicocele is the condition of abnormal venous dilatation of the pampiniform plexus and scrotal veins with blood reflux. In most cases it affects the left side and, rarely, the right one or both. In the literature the association of varicocele with male infertility risk has been described: venous reflux and the following scrotal thermal impairment have a deteriorating effect on spermatogenesis, even when assessed in asymptomatic subjects. Therefore a correct and early diagnosis of varicocele is mandatory.

THE AIM OF THIS STUDY is to emphasize the diagnostic value of scrotal thermography in the investigation of varicocele combined with Color Doppler Ultrasound (CDU), considered the "gold standard" diagnostic tool thanks to its feasibility for measuring venous vessel size and blood flow parameters.

MATERIAL AND METHODS: Between April 2011 to date, 51 young asymptomatic volunteers (age range 18-36 years) underwent clinical examination, scrotal thermography and CDU, after providing informed written consent. No one had recently referred testicular inflammatory or cutaneous layers diseases; four (4/51; 8%) were surgically treated for phimosis.

Sarteschi classification was used for CDU evaluation.

RESULTS: Among subjects, 21 (21/51, 40%) had left unilateral varicocele, detected using CDU; 21% (11/51) presented varico. cele grade II, 11% (6/51) grade III and 8% (4/51) grade IV. Scrotal thermography documented an increased temperature and faster recovery of the left hemiscrotum in the same ones; a basal testicular temperature greater than 32°C and basal pampiniform plexus temperature greater than 34°C were considered warning values. Moreover thermal impairment of the left pampiniform plexus was assessed in other four subjects, whose CDU exam showed an higher vessel size (? 3 mm) with normal blood flow parameters. Clinical examination, affected by a low sensibility and specificity, showed the presence of left varicocele in only 12 volunteers (12/51, 24%).

CONCLUSIONS: Our experience confirms that scrotal thermography is a feasible and low cost diagnostic tool for varicocele. Even if CDU remains the method as a reference, thanks to its high sensitivity, we suggest the use of scrotal thermography in screening programme in the assessment of subclinical varicocele.

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## SYMMETRY OF THE SKIN TEMPERATURE OF THE LOWER LIMBS IN YOUNG SOCCER PLAYERS

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INTRODUCTION: Infrared thermography (TIR) s an imaging technique that allows to record injured areas even with absence of pain. In normal thermal conditions the skin temperature (TSK) of the sides of the body must have a steady state not exceeding 0.7°C [2]. Thus, the objective is to compare the TSK differences between both sides of the lower limbs of young soccer players.

METHODS: We analyzed two thermograms of 100 football players from the lower categories teams of a first division of Brazilian football club, aged between 15 and 19 years, mean age 15.5 ± 1.37 years, body mass 67.93 ± 9.62 kg and height of 177.49 ± 8.67 cm. All studied subjects reported not present any kind of sports injury according to the criterion of Fédération Internationale de Football Association Medical Assessment and Research Centre [1]. The recommendations followed for data collection were proposed by Moreira [3]. The room temperature was maintained at 21 ± 1 ° C, the acclimation period was set at 10 minutes. Two images were taken in each evaluated, the body regions of interest (ROI) analyzed include the thighs and legs in the anterior and the posterior side, these regions were selected in the software (3.1 Smartview®). We considered the maximum and average temperatures of two body ROI. The thermographic images were collected using a thermal imager TIR-25 (Fluke®, Everett, USA) with a measurement range of -20 to +350 °C, accuracy ± 2 °C or 2%, sensitivity ? 0.1 °C, infrared spectral band from 7.5μm to 14 μm and FPA (Focal Plane Array) 160 x 120 pixels. The statistical Wilcoxon test was used to compare the sides of the body with a significance level of $P < 0.05$.

RESULTS: The results of the statistical analysis did not show significant differences in the comparison between both sides in the selected ROI both for average and maximum temperatures (table 1 and 2). Of the total of 200 images and 800 ROI analyzed by comparing the sides of the body were recorded only nine cases with differences > 0,7°C, all of them in the anterior leg.

CONCLUSION: The analysed athletes showed contralateral thermal symmetry, the difference between both sides in most players and all the ROI is not greater than 0.3°C. The symmetry obtained indicates that athletes have a normal thermographic pattern which does not suggest the presence of injury.

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## THERMOGRAPHY AS AN ALTERNATIVE TOOL TO DETERMINE PRESSURE DISTRIBUTION ON THE STUMP OF TRANSFEMORAL AMPUTEES

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INTRODUCTION: Lower limb amputation is a highly disabling condition affecting the ability to stand up, walk, run and perform activities of the daily living involving ambulation. Prosthesis is a custom made medical device intended to substitute the limb, mimicking the function of the knee and foot, connected to the limb by a socket fitted to the stump. The prosthetic socket is the component that supports the weight of the body and the reaction force from the ground. Therefore, the socket fit is a key factor which determines the comfort of the amputee when standing, walking or performing everyday activities, as well as the ability to control the device. In the absence of a snug comfortable fit, the amputee may experience discomfort, pain and friction wounds. The walking becomes then a less effective process, resulting in higher energy consumption [1].

Therefore, mapping and monitoring the pressure distribution on the socket fit is a very important step in prosthetic design and usage. However, this is usually achieved by a trial and error check procedure taking into account the patient feedback. Additionally, the tests are usually performed in a controlled environment that, in most of the cases do not represent the actual conditions the amputee faces in daily activities when walking. Therefore it is important to develop and implementing noninvasive, clinically applicable methods to help assessing socket fit design. This work intends to study the possibility of using thermography as a contact pressure indicator.

METHODS: The subject, a transfemoral amputee walked for 10 minutes in a crosswalk at a comfortable speed (4 m/s), during this time we were able to simulate a normal walk of approximately 700 m. For the experiments it was used the thermal camera FLIR® A325 with a special resolution of 320x240 pixels and a thermal sensitivity of 68 mK. The images were taken before and after the exercise, both to the subject and to the prosthetic socket.

RESULTS: The thermal images of the amputees revealed extremely low temperatures in the tip of the amputated member (figure 1), even after ten minutes walking. It is also interesting to see that the image of the prosthesis also shows the same temperature distribution, as the body (figure 2). Another important finding is the high temperature recorded in the groin zones (figures 3), once again this was also observed in the prosthesis. Figure 4 shows a picture of the setup, camera and amputee.

DISCUSSION: The low temperature in the tip of amputated member clearly demonstrates that there was no contact or friction with the prosthesis (figure 1). Also, from the thermal results, one can clear identify the areas of the socket where the contact with the body is more intense, which naturally results in a temperature increase, as it reduces the thermal resistance. Therefore thermography seems to be a very useful tool to help the fine tuning of the socket to the stump, as to give the better comfort to the amputee.

ACKNOWLEDGEMENTS: This research is sponsored by FEDER funds through the program COMPETE- Programa Operacional Factores de Competitividade and by national funds through FCT-Fundação para a Ciência e a Tecnologia, under the project: PTDC/CTM-NAN/112574/2009.

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## DIAGNOSTIC EVALUATION OF CHRONIC VENOUS INSUFFICIENCY CASES USING THERMAL IMAGING

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INTRODUCTION: One of the most common manifestations of venous insufficiency, or venous reflux, are Varicose Veins. They are the source of aching pain and discomfort and may require medically necessary treatment, being the most extreme the surgical option the removal, or closing off, the affected vein. Surgical option accounts for the severity of the symptoms, the type of vein and the source of venous reflux. Clinical examination is also supported by blood exams, Eco-Doppler soundings or other imaging studies in order to accurately assess all of the sites of venous reflux. Thermography presents itself in medical applications more as a functional than an anatomic tool when compared to other imaging techniques. This study show the early exploration phase for Varicose Veins cases recommended for safenectomy at the Surgery Department of the ULS Bragança Hospital, Portugal.

METHODS: A particular protocol for a FLIR, model T365, camera was developed for this particular pathology. This protocol differs from [1] because functional tests were also included to enhance physical limitations provoked by the disease but better captured with thermography. Two clinical cases are presented: an 18 year old male and 61-year-old female, both with

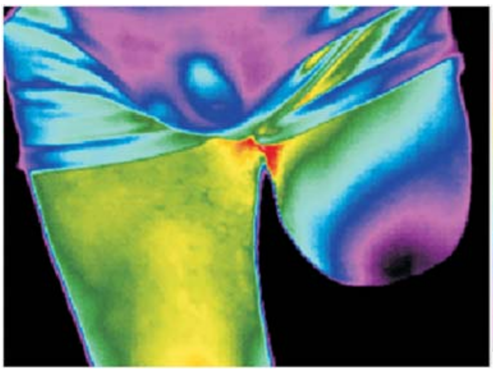

Figure 1 - Front view of the subject, after walking for 10 min

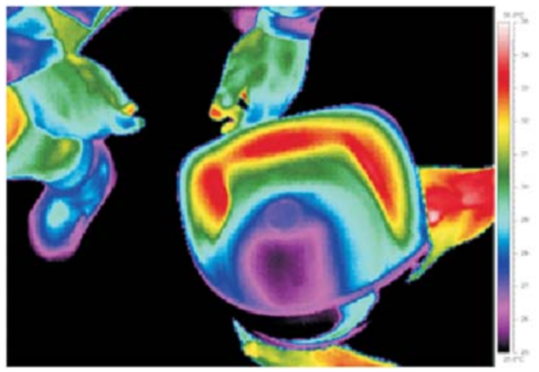

Figure 2 - Prosthesis socket thermal patterns

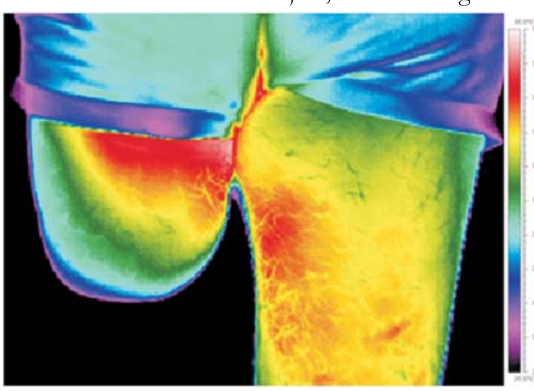

Figure 3 – Rear view of the subject

Figure 4 -Setup overview

Varicose Veins pathology identified in only one leg - with surgical recommendation. Exams in both legs with standard procedure produced the same information for the leg with the pathology. However, thermography clearly unveiled - or highlighted - additional Varicose Veins in the considered healthy legs, not identified by clinical examination or by imaging me_ thods commonly used in clinical practice. This early identi- fication of venous pathology demonstrates the advantages of the Thermal Imaging as a quickly, inexpensive and noninvasive diagnostic tool, and could lead to other course of treatments avoiding radical solutions such as Safenectomy.

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## THERMOGRAPHY OF FACIAL SKIN TEMPERATURE IN HEALTHY SUBJECTS DURING COOLING OF THE FACE WITH HILOTHERAPY

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BACKGROUND: Facial cooling has been demonstrated to reduce pain and swelling after maxillofacial surgery, leading to improved patient satisfaction and shorter hospital stays. Maximal skin vasoconstriction occurs at a skin temperature of 15ºC (Belli et. al., 2009). Rana et. al. (2011) showed that hilotherapy (in which the face is cooled by a temperature-regulated, water-cooled mask at 15ºC) was more effective than standard cryotherapy (using cold packs) in reducing facial swelling and pain after facial surgery. Moro et. al. (2011) found that hilotherapy was more effective at reducing facial swelling than ice-pack application in most areas of the face, but they found hilotherapy to be less effective in limiting swelling between the external canthus and tragus - an area not fully enclosed by the hilotherapy mask.

No data exist on the speed of cooling during the application of the hilotherapy mask, and the actual skin temperatures achieved across the face are also unknown. We investigated a facial cooling procedure using a Hilotherapy mask in a group of healthy control subjects using infrared thermography.

METHODS: The study was approved by the regional Research Ethics Committee. All subjects gave informed consent prior to participation in the study. Each subject avoided smoking, hot food, alcohol and caffeinated drinks for one hour prior to the investigation, and rested in the thermography laboratory for 15 minutes at a room temperature of 23ºC prior to imaging. Thermography was performed using an A320G Thermacam imager (FLIR Systems, West Malling, UK) with an ethernet connection to a PC running FLIR Thermacam Researcher software. The hilotherapy mask was applied to the face and set to cool in continuous mode at a temperature of 15ºC. Anterior, left lateral and right lateral thermograms of the face were recorded prior to cooling and 5, 10, 20 and 30 minutes after the commencement of the cooling procedure. The mask was briefly removed from the face to allow thermograms to be captured at each measurement time-point.

RESULTS: Data will be presented showing the evolution of facial cooling over time, using regions of interest defined by Moro et. al. for the evaluation of swelling at different anatomical sites.

CONCLUSIONS: Infrared thermography may be an effective tool in the evaluation of facial cryotherapy for the reduction of pain and swelling after maxillofacial surgery. Using the data provided from thermograms, skin temperature can be optimised across all regions of the face to improve the outcome for patients.

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## HOW DOES THERMOGRAPHY HELPS ABDOMINAL PLASTIC SURGERY

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Abdominal plastic surgery has suffered many alterations since its beginning. A revolution started in the eighties with the liposuction introduced by Illouz and his posterior abdominoplasty without undermining. Actually, authors as Avelar and Saldanha have been disseminated the modern's abdominoplasty, as the lipoabdominoplasty.

Infrared Thermography is a method that captures heat alterations of the skin with the infrared spectrum, making possible the study of the skin vascularization and function

However, there are no references in the literature about the studies of the skin micro circulation to compare surgeries.

METHOD: In this paper we studied twelve patient preliminaries, without surgery and with different techniques, with the infrared thermo- graphy, with comparison of the vascular patterns. After, we studied 25 patients before and after lipo abdominoplasty (LAP), Abdominoplasty without undermining and with preservation of the superficial fascia (APSF) and Classic Abdominoplasty (CAP) with little undermining. The results were evaluated quantitatively (number of perforator vessels) and qualitatively (capacity of maintaining skin thermoregulatory function)

RESULTS: At the preliminary study there was no possibility to establish a circulatory pattern, probably because the groups were hetero- geneous. At the prospective study the groups were homo- geneous with the control pre operatively ($F = 0.7680$ y $p = 0.5248$) and heterogeneous post operatively ($F = 11.1744$ y $p = 0.0001$).

The LAP patients had the biggest preservation in number of perforated vessels and quality of thermographic images, compared with the control, with low rates of complications.

The APSF had few complications, compared with LAP group, and a reasonable thermoregulatory function, although the number of the perforator had decreased.

The CAP group had the biggest destruction in perforator vessels and the worst thermoregulatory function, with the highest complication rate.

CONCLUSION: The infrared thermography is a simple and useful method of the evaluation of the abdominal skin vascularization and function. There were decrease in perforator vessel's number and thermoregulatory function, crescent in the groups: LAP, APSF y CAP. The CAP group had the biggest complication rate, whereas the others were comparable and low.

The APSF is an alternative to the patients who cannot have a LAP, with good preservation of the circulation and thermoregulatory function, with low complication rates.

Other studies are necessary to evaluate the aesthetic or not aesthetic possible changes after functional post-operative modifications.?

## METHOD FOR INFRARED IMAGES DESCRIPTION: 10 YEARS OF MEDICAL REPORT EXPERIENCE

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Infrared (IR) imaging has the potential of a significant role in a range of medical applications. But for this is exceptionally crucial that the report be legal and scientific valid as a traditional radiological report. The IR report is essentially the end product on which thermologists are judged by their clinical colleagues. With the development of high sensitive IR imaging sensors it was possible to enhance the description of the pathological thermal phenomena. Based on the concept of quantitative and especially qualitative (morphological) the authors developed an explanatory method to describe the IR signs. The authors have 10 years of experience with this method. The aims of this study are to compare the IR imaging skills of physicians in training with those of experienced IR thermologists by using real patients to test diagnostic skills and to evaluate the impact of a training program with this IR descriptive method.

METHOD: In an academic primary care center, 32 physicians (trainees in neurology, orthopedic and occupational medicine) evaluated with a high sensitive device (T640 FLIR Systems, USA). The thermal camera produces high resolution (640x420) and sensitive images (0.04°C, 0.68 mrad). Volunteers control group and 333 patients with chronic pain after completing a pre-clinical questionnaire were analyzed and IR patterns were detected and described to produce a topographic, systemic and etiological diagnostic. The thermal patterns were described using the adapted TPD system (Thermal Pattern Description, Brioschi, [2]). The criterions that compose this system are: similarity between the regions of interest, intensity, size, shape, limits, thermal texture and contour). They were determined beforehand by an independent skilled thermologist and were validated by ultrasonography (US) and a skilled pain physician. All the physicians agreed to participate before in a course of a week. After the course they evaluated again to the same patients (pre/post-interventional study).

RESULTS: In the volunteers controls group the examinations had been normal in all cases. The sensitivity and specificity of the US had been 79% and 100% respectively, while the IR imaging was 100% and 100%. The total accuracy was 89% for US and 100% for IR imaging. When compared US with IR imaging findings, it had a positive correlation of 89%. In 11.2% of the cases the IR imaging was abnormal while the US had been normal. The cases not detectable by US were composed by neurologic and myofascial dysfunctions that did not have anatomical substratum; they were non specific injuries. The experts were the most skillful, achieving 100% recognition of IR patterns and correct diagnoses in 100% of cases. The residents identified 80% of the thermal patterns and made a correct diagnosis in 70% of cases in the first month. After the 1 week training sessions, their mean percentage for correct diagnosis was 98% [an increase of 28% ($p<0.05$)].

CONCLUSION: The level of diagnostic skills in this relatively small group of physicians in training is indeed high and was improved by the time with this IR training course for chronic pain diagnosis. The adapted Thermal Pattern Description (TPD) system is a means of legal document communication between the thermologist and the referring physician and reflect seriously the approval of IR imaging in medical community.

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## INFRARED THERMOGRAPHY ASSESSMENT OF INFANTILE HEMANGIOMA TREATMENT BY PROPANOLOL

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INTRODUCTION: Infantile hemangioma, common in neonates, and is often naturally resolved within the first seven years of life. It can present as a skin surface disfigurement that is sometimes distressing to the child, and may impair function depending on its location on the body. Propanolol, a beta blocking agent has been reported by several investigators to be an excellent treatment, reducing blood flow to the lesion and therefore accelerating the healing process.

METHOD: In this study we have investigated the use of infrared thermography on a group of 35 children, before and after treatment (2mg / kg daily). 6 children,(2m. 4f. av. age 7 months) were examined before and after 6 weeks treatment. A larger group of 28 children (7m. 21f. av. age 15 months) were assessed after an extended period of treatment (up to 18 months) where evidence of regression of symptoms was found.

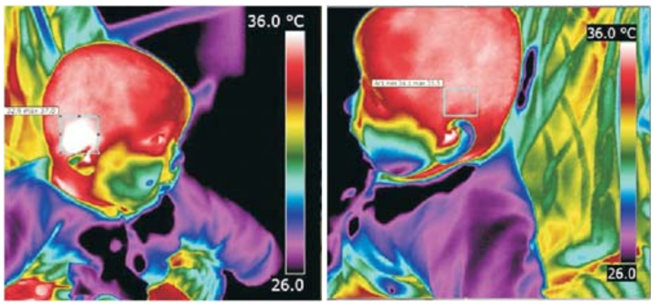


Figure 1
Hemangioma in 3 month child which is 1.0°C warmer than the contralateral

Figure 2
Photograph of Hemangioma in 9 month child which is 0.5°C warmer than

There were 7 additional children who did not undergo treatment, and who were assessed once.

The range of investigations employed were, E.C.G, Echocardiography, biochemical studies and Doppler ultrasound, and Infrared thermography of the affected area of the body using a FLIR T640 infrared camera in a stable environment (21-23°C).

All images were analyzed using FLIR Quick Report software. The hemangioma lesions were located in many different areas of the body, most on the face and neck but some on the arms and trunk of the body. Where possible the thermograms were recorded with reference areas on the contralateral side of the body, or alternatively an area adjacent but clear of the lesion for comparison. The mean temperature of the affected and of the reference (normal) area of skin were subtracted as expressed as delta temperature.

RESULTS: Group 1 with 6 patients mean temperature decrease in 6-8 weeks, 0.9°C (-0.3 - 2.5°C)

Group 2 with 28 patients longer duration therapy (min 4months, max 18 months) mean decrease in temperatures 0.47°C (0.2 - 5.1°C). A high proportion of this group had a significant reduction in size and symptoms of the hemangiomas.

This preliminary study has shown that the variety and complexity of the different hemangioma lesions (figures 1 and 2) has not presented problems for thermography being a non contact technique. The ultrasound technique, most commonly used is difficult in some locations such as the eyelid or mouth of a young child. The decrease in temperature of these lesions with the propranolol therapy has been accompanied by a reduction in size and symptoms. The speed of image capture with thermography, and the ability to simultaneously capture a visual image of the lesion is a great advantage, and one which is very convenient in very young children. A controlled trial of this treatment using the additional temperature assessment is required to substantiate these promising results.

## MOTHER AND CHILD IN SYNCHRONY: THERMAL FACIAL IMPRINTS OF AUTONOMIC CONTAGION

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INTRODUCTION: Mothers' ability to empathically share offspring's emotional feelings is considered integral to primary affective bonds and a healthy socio-emotional development. What neurobiological mechanism is responsible for this ability in humans? Autonomically-mediated visceral responses are proposed to be strictly related to the experience of emotional feelings. It is therefore plausible that the vicarious response of empathy also embodies a direct sharing of changes in body physiology between the involved individuals. The present study aimed at investigating whether a mother's empathic sharing of her offspring's distress is accompanied by physiological sharing of autonomic responses. For this purpose, we used thermal infrared (IR) imaging, a contact-free methodology, which estimates variations in autonomic activity reflected by cutaneous temperature modulations by means of recording the thermal infrared signals spontaneously released by the human body.

METHODS: Six mothers (age 31-46 years) and their typically developing biological children (3 male, age 38-42 months) participated in the experiment. After acclimatization and neutral baseline periods, children were presented with a stressful experience: children were invited to play with the experimenter's favorite toy, which was previously manipulated to break on the child's hands when playing with it, thus suggesting that the child accidentally broke the toy ("mishap" phase). Subsequently, the experimenter re-entered the room ("entrance" phase) and soothed the child ("soothing" phase). Mothers observed their children through a one-way mirror from a separated room.

Thermal images of the faces of the mother and the child were simultaneously acquired along the whole experimental paradigm by means of two digital thermal cameras (FLIR SC3000, Flir Systems, Sweden), with a Focal Plane Array of 320 x 240 QWIP detectors, capable of collecting the thermal radiation in the 8-9 ?m band, with a 0.02 second time resolution, and 0.02 K temperature sensitivity. Cutaneous temperature was extracted from speci fic facial regions of interest in mothers and their children: 1) nasal tip and 2) maxillary area. Correlation analyses of the thermal time courses of these regions of interest were performed investigating quantitatively whether the mother-child dyads showed a synchronicity in autonomic activity. In order to control for respiratory effects, mothers' temperature dynamics were correlated with respiratory cycle durations.

RESULTS: Behavioral evaluations confirmed an increase of children's distress after the mishap. Facial thermal imprints of the mothers suggested that observation of their child's experience of distress induced significant emotional arousal mediated by the autonomic nervous system (figure 1). Accordingly, analysis of variance showed a significant modulation of temperature during the emotionally charged experimental phases for the child ($p<0.05$) as well as for the mother ($p<0.05$), but not during the neural baseline period ($p>0.3$). Correlation analyses showed that facial thermal modulations of the mothers significantly covaried with the modulations of their children at the individual (table 1) as well as at the group level (figure 2; reported correlations group data: $p<0.001$) during the emotionally charged experimental phases. Multiple regression analysis showed that the relationship between nasal tip temperature variations in the mothers and those in the children (beta=0.91, t=7.963, $p<0.001$) was statistically independent from the mothers' respiratory activity (beta=0.02, t=-0.17, $p>0.8$).

DISCUSSION: Mother-child dyads showed a significant and situation-specific synchronicity between the autonomic reactions individually exhibited by each partner. The findings offer rather direct evidence for the affective aspect of empathy as a vicarious process that also embodies a direct sharing of visceral- autonomic responses. The present study provides reliable measures of autonomic responses recorded simultaneously for both distressed children and their empathizing mothers, without the disadvantages of most of the physiological methods when applied to psychological domain, including the poor practicability and psychologically demanding character of the measurement equipment. By means of thermal IR imaging, physiological correlates of emotional reactions were investigated in an interactive and ecological experimental context without interfering with spontaneous behaviour and without age restrictions. This suggests important applications of thermal IR imaging for providing data that add to developmental, comparative and evolutionary research on emotion in humans as well as non-human individuals.

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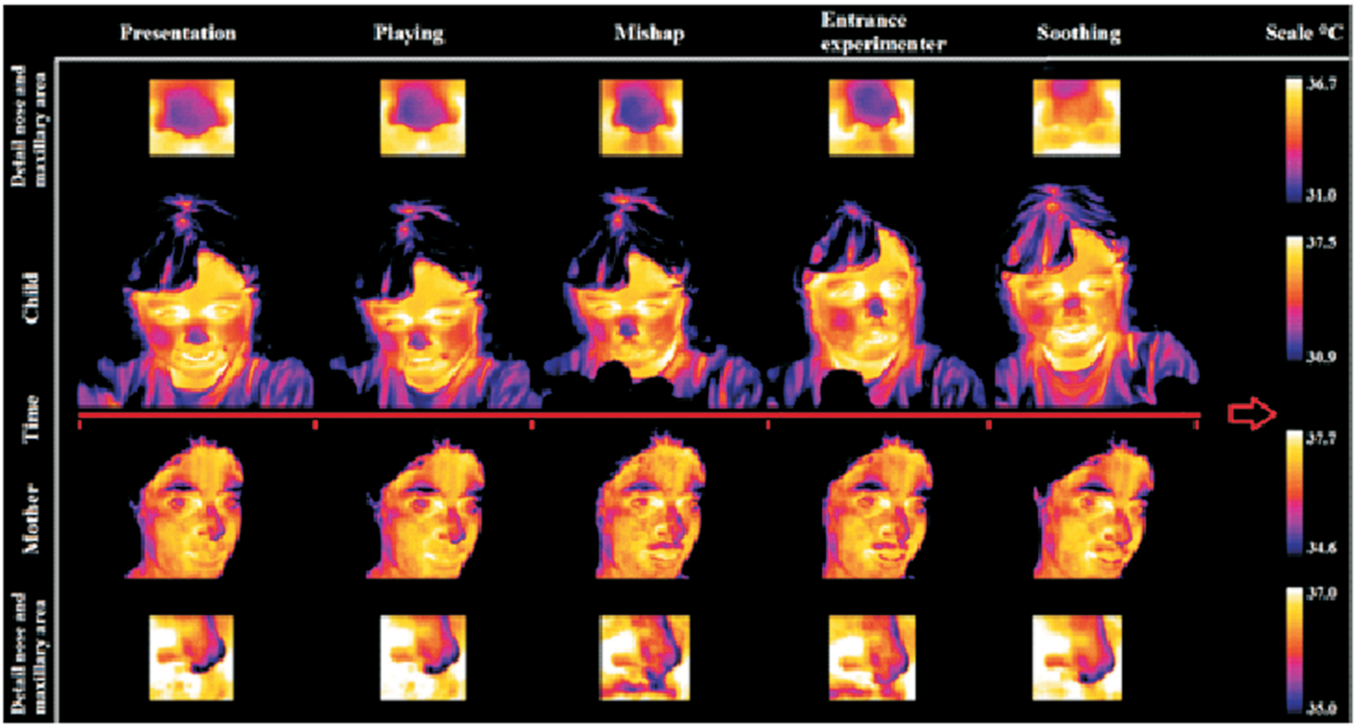


Figure 1.
Facial thermal imprints of one of the mother-child dyads.

Table 1.
Correlation coefficients reflecting the relationship between the time courses of the temperature dynamics of the nasal tip and maxillary area during the experimental phases as well as the neutral baseline period in the individual mother-child dyads

| | Distress ($r_{mother\text{-}child}$) | | Baseline ($r_{mother\text{-}child}$) | |
|---|---|---|---|---|
| Mother-child dyad | Nasal tip | Maxillary area | Nasal tip | Maxillary area |
| 1 | 0.64 * | 0.56 * | -0.15 | 0.44 |
| 2 | 0.90 * | -0.25 | 0.50 | 0.19 |
| 3 | 0.63 * | 0.43 | 0.22 | 0.2 |
| 4 | 0.52 * | 0.55 * | 0.84 * | -0.46 |

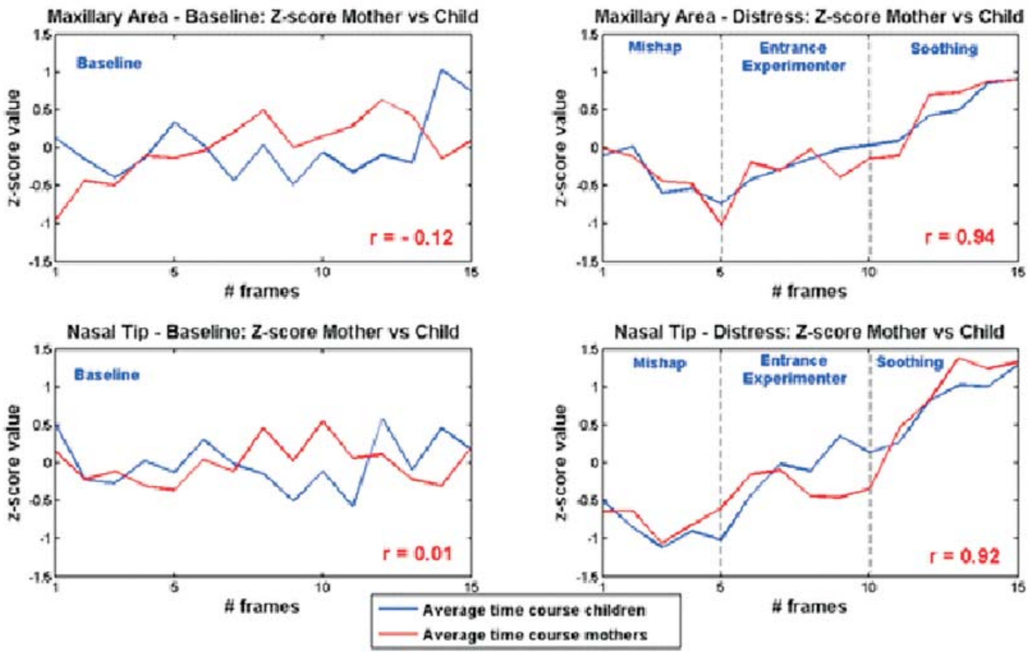


Figure 2.
Graphical representation of group temperature variations of the nasal tip and maxillary area during the experimental phases as well as during the neutral baseline period

## SCREENING FEVER, A NEW APPROACH

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The use of the inner canthus in Humans as a reference for core temperature can be compromised by a series of factor that can lead to faulty measurement.

Despite at inner canthus the ophthalmic artery flow beneath, cerebrovascular disease at internal carotid artery will diminish flow at downstream arteries, and consequently the amount of heat dissipated at inner canthus and temperature at surface drops. Accumulation of mucus discharge at inner canthus will enhance the dropping. Thermographilly speaking, the area has an emissivity very well determined, 98 %, which implies, besides this accuracy, the determination of reflected apparent temperature.

On the hand external auditory meatus are wave-guides and need to be kept at constant temperature; otherwise the velocity of sound propagation will vary along it length, creating echoes inside of it selves. In this way, external auditory meatus are isothermal cavities and due to it geometrical configuration, an illusion of black body is always present at the interface with the exterior. Unlike the tympanic thermometers which are affected by crooked meatus or wax, because they have to "see" the eardrum, thermographic cameras do not have the accuracy compromised, provided that, the problem is not visible from the outside. In all other situations, the external auditory meatus, when observed from the outside, always have an emissivity of 100 %, relieving the measurement from determination of the reflected apparent temperature.

With this technic, screening fever can be done on people walking in line, without being at a controlled environment and with all sources of error removed.

## THERMAL IMAGING IN GRAVES' ORBITOPATHY

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Graves' orbitopathy (GO) is a debilitating condition. Its management relies on identifying both the active phase of the disease when intervention with medical therapies is most effective and the burnt out phase when rehabilitative surgery can take place. Assessment of disease activity is therefore vital. It relies on clinical assessment of the presence of features of acute inflammation, and is therefore partially subjective). Objective, quantitative methods for assessing the inflammatory component of GO would be valuable and thermal imaging may have such a role.

Fifteen patients with GO were studied, (13 female), mean (SD) age = 52 (17) years. Patients were clinically assessed by ophthalmologist for disease activity utilising the Clinical Activity Score (CAS) and underwent thermography within a few days of clinical assessment. An active disease state was diagnosed when CAS ? 3 and this was found in 6 patients; when CAS < 3 the disease was defined as inactive. The thermal imaging protocol included 20 minute acclimatization in a cooled measurement room (at 18 ?C). The thermal imaging system comprised a FLIR SC300 camera. Regional temperatures, and their differences, were measured using dedicated software (FLIR ThermaCam Researcher, skin emissivity assumed to be 0.98). Binary logistic regression identified 2 key thermography parameters as the most important and statistically significant at discriminating between active and inactive disease. Using this model, thermography was associated with a specificity of 100% and a sensitivity of 83% in identifying active disease. Preliminary data suggest that thermographic measurements can detect areas of inflammation in patients with active GO with good classification accuracy when used in multi-feature discriminant analysis.

## CORRELATIONS BETWEEN QUANTITATIVE SENSORY TEST AND INFRARED THERMOGRAPHY IN LOW BACK PAIN PATIENTS - A PILOT STUDY

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BACKGROUND: Infrared Thermography (IT) has been proposed as a potential tool to assess musculoskeletal pain. However, there is a paucity of studies evaluating the correlations between low back pain, trigger points (TrP) and thermogram data.

METHODS: Thirty patients with primary low back pain (mean pain VAS> 30mm) and active TrP were included. They filled out the first part of the Brief Pain Inventory and underwent low back IT and mechanical quantitative sensory testing (mechanical detection, pain and supra-threshold-MDT, MPT, MSupra) of four points marked on the skin: the most intense pain location (MIPL) as pointed by the patient, its mirror area in the contralateral side (MIPL-mirr); the skin area over the main active trigger point (MATP) and its mirror area (MAPT-mirr). MIPL was central (MIPLA-C) when located + / - 1 cm from the midline and lateralized (MIPL-L) when > 1 cm. IT: Patients were evaluated unclothed, two meters away from the camera in a 22° C room (A320, FLIR, USA).

RESULTS: Twenty-eight patients were included (47 years, 22 female; VAS = 51 mm). MIPL-L was lower than the MIPL-C [40.0 (12-93) vs. 69.2 (34-90); p = 0.009). MSupra in MIPL-C was more intense than in MIPL-L (81.6 +/- 15 vs. 66.0 +/- 20.1; p = 0.049). The difference between MIPL and MIPL-mirr MSupra scores correlated to the IwVAS score (rho=0.51). MIPL and MATP X and Y coordinates showed high correlation (rho=0.76 and 0.50). Temperature on MIPL and MTPL correlated (rho=0.83).

CONCLUSIONS: Centrally located pain was more intense and presented higher mechanical hyperalgesia than lateralized pain. The area of maximal pain was spatially close and presented similar temperature as the area over the MATP.

## THE UTILIZATION OF FUNCTIONAL INFRARED IMAGING SIGNATURE INDEX PROTOCOLS IN STAGING PATIENTS WITH COMPLEX REGIONAL PAIN SYNDROME (CRPS)

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INTRODUCTION: Complex regional pain syndrome (CRPS) is a neuropathic pain disorder with significant autonomic features characterized by regional pain. CRPS usually develops after an initiating noxious event, is not limited to the distribution of a single peripheral nerve, and appears to be disproportionate to the inciting event. The autonomic features are commonly manifested in the distal aspect of an affected extremity or with a distal to proximal gradient in the affected extremity. This poorly understood disease is the result of a multi-factorial interplay between altered somato-sensory, motor, autonomic and inflammatory systems associated with peripheral and central sensitization.

DIAGNOSIS of CRPS is based upon patient history and evaluation of presenting clinical signs and symptoms. CPRS patients commonly experience hyperalgesia, allodynia, spontaneous pain, abnormal skin color, changes in skin temperature, abnormal sudomotor activity, edema, active and passive movement disorders and trophic changes of nails and hair. Sudomotor/ sweating limb differences and atrophic changes, including nail, hair and skin changes, occur in less than half of the clinical CRPS patients. In contrast, verified temperature asymmetry, edema, and decreased motor function are frequently cited as predictive.

Historically, CRPS possibly to occur in three (3) distinct pathophysiological stages: Stage 1 Acute-Hyperemic, Stage 2 Dystrophic-Ischemic, and Stage 3 Atrophic. Recent literature suggests that these individual stages are not absolute and in fact, may not all be observed in any single patient. Signs and symptoms fluctuate over time and are reflective of ongoing dynamic-neuroplastic changes in both the peripheral and central nervous systems. More recent descriptors of CRPS have used the terms "warm CRPS" (acute) denoting cases with initial increased temperature and edema stages and "cold CRPS" (chronic) denoting cases with the affected limb having a cooler temperature with decreased edema.

CLINICAL DIAGNOSTIC CRITERIA FOR CRPS by the International As- sociation for the Study of Pain is thought to be overly sensitive and is problematic in differentiating between those patients with other pain complaints and those with actual CRPS. Utilizing clinical criteria alone to diagnose CRPS in many cases is not dependable nor necessarily reliable. Therefore, objective testing to evaluate the integrity of the sympathetic nervous system (SNS) is required. Infrared Imaging (IR) effectively detects the thermal signature of vasomotor disturbances that are an im- portant factor in establishing the diagnosis. Bruehl et al. de- monstrated a sensitivity of 60% and specificity of 67% in evaluating thermal asymmetries in patients with CRPS. Wasner et al. showed a sensitivity of 76% and specificity of 93% by evaluating computer generated side-to-side temperature differences of homologous body regions following controlled alteration of sympathetic activity. The use of quantitative temperature differences alone lacks diagnostic specificity because numerous pathologies produce skin temperature asymmetry. For example, temperature asymmetry occurs in focal inflammation and vascular disease. Moreover, thermal asymmetry can result from somato-autonomic vasoconstriction secondary to acute trauma, limb immobilization, fracture, anti-dromic vasodilatation from small fiber distal neuropathy, and neuropathic pain with sympathetic activity. Gulevich et al. demonstrated a 93% sensitivity and 89% specificity by incorporating functional infrared imaging protocols (see below).

fIR SIGNATURE INDICES: Functional Infrared Imaging (fIR) does not merely measure limb temperature. The infrared study is significantly enhanced when the IR data is interfaced with software that enables the examiner to obtain the following fIR signature indices: (1) Qualitative IR signatures (temperature map), (2) computer generated side-to-side quantitative temperature differences, (3) statistical evaluation of the integrity (i.e., normality vs. abnormality) of distal thermal gradient IR signatures and (4) response to cold-water autonomic functional stress testing. These separate and distinct IR signature indices assist the highly trained and experienced examiner in identifying the stages of CRPS (i.e., "warm CRPS" vs. "cold CRPS" vs. transitional stages).

An understanding of the capabilities and limitations of IR technology is critical to establishing its significance in detecting physiological changes that are relevant and meaningful to the diagnosis of CRPS. Multiple pathophysiological mechanisms are involved in CRPS. As the condition evolves, there are distinct alterations in the manifestation of the pathophysiology. The impacts on the SNS by alterations in the pathophysiological mechanisms are identifiable by careful observation of the changes in the IR signatures of four (4) separate and distinct indices. The IR signature indices are helpful in identifying both the warm CRPS, transitional and cold CRPS stages. The warm CRPS (acute hyperemic) stage, with accompanied pathophysiological changes that include neurogenic inflammation, altered systemic levels of anti-inflammatory cytokines, pro-inflammatory neuropeptides, dysfunctional SNS thermal regulatory activity (decreased SNS outflow) and absent vasoconstriction to cold water autonomic functional stress testing is evidenced by the IR emission visualized in the four distinct fIR signature indices. The cold CRPS (chronic dystrophic/atrophic) stage with the accompanied pathophysiological changes that include dysfunctional SNS thermal regulatory activity (increased SNS outflow), hypersensitivity to circulating catecholamine, altered SNS activity in contralateral asymptomatic extremity and exaggerated vasoconstriction response to cold water autonomic functional stress testing is evidenced by the IR emission visualized in the four distinct fIR signature indices.

CONCLUSION: The warm stage, transitional stage and cold CRPS stage may be identified by carefully interpreting the four separate and distinct IR signature indices obtained with functional IR imaging. This author posits, IR protocols for evaluating patients with presumptive CRPS include the four fIR signature indices to obtain optimal SNS functional data. This objective SNS data will assist the clinician in identifying real time pathophysiological mechanisms (CRPS stage) that are instrumental in achieving the goal of mechanism based CRPS diagnosis and treatment.

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## CRPS: COMPLEX REGIONAL PAIN SYNDROME TYPE I AND THERMOGRAPHY: A NEW TOOL FOR DIAGNOSIS?

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The thermal patterns of neuropathic physiological disorders are usually hyperthermic in the acute stage, owing to antidromic vasodilation triggered by neurosecretion from hyperactive nociceptors, and then hypothermic in the chronic stage, as a result of sympathetic overactivation or denervation super-sensitivity of the arteriolar smooth muscle. We describe a case of a 35 Year-old male patient, suffering from chronic skin pain localized both in zigomatic and nasal right area, without any dermatological conditions, and negative to any alteration in RX, RMN and CT. After thermographic analysis, we find a particular and well-circumscibed hypothermal area due to referred pain.

# THERMOGRAPHY IN FRONT CRAWL SWIMMING AT ANAEROBIC THRESHOLD INTENSITY

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INTRODUCTION: The anaerobic threshold is considered the highest sustained exercise intensity at which the balance between production and removal of the lactate persists, expressing a traditional measure of the athlete's aerobic capacity [1]. Since 1980s the anaerobic threshold has become a fundamental part of training control and evaluation of swimmers [2]. The protocols to assess the anaerobic threshold are usually performed in front crawl swimming. To the best of our knowledge up to now, only one study was conducted using thermographic assessments comparing different swimming strokes [3]. This study aimed to evaluate the cartographies of swimmers' cutaneous temperatures on three different instants during a front crawl swimming effort at anaerobic threshold intensity.

METHODS: Nine swimmers (4 female and 5 male: age: 22±5.97 years, body mass: 62.44±9.34 kg, height: 1.69±0.05 m) were separated into two groups according to their performance level (trained or high level swimmers). After a low intensity warm-up, each swimmer performed 15 min continuous front crawl swimming protocol at the individual anaerobic threshold swim speed. The swimming speed was controlled with a stopwatch and an acoustic feedback. All tests were conducted in a 25m indoor swimming-pool and the same environmental conditions (air temperature: 26-28°C; water temperature: 27-28°C, humidity: 53-55%). The thermographic readings were conducted using a FLIR A325 camera with 320x240 pixels, thermal sensitivity of 68mK at a speed of 30Hz. The swimmer distance was set so the swimmer would fit in the entire image. The thermal images were taken in three different instants: before and immediately at the end of testing, and during the 5th min of recovery period.

RESULTS: All swimmers presented a maximum temperature in the head, trunk, upper and lower limbs zones before the testing and following the 5 min recovery period. An example for one swimmer is shown in Figure 1A and C, and the lowest temperatures were noted immediately after swimming testing (Figure 1B). The shoulders, upper arms and thighs displayed the highest temperatures. The overall left/right differences were not meaningful except in the neck. The muscles that presented a highest activity presented highest temperature and thermal spots with highest peaks (Figure 1A and B). Between the two groups the main difference observed was the face average temperature, the trained swimmers displayed higher temperatures than the national level swimmers.

DISCUSSION: To our knowledge, this is the first attempt to describe the effects of an individual anaerobic threshold swimming protocol on thermographic profile of two level groups. The vasoconstriction of the peripheral blood vessels after the swimming testing can explain the decreasing in the skin temperature. Moreover, the immersion of the body in a fluid might implies that the skin acquires the fluid temperature, although some body zones contradict this tendency. As expected, the shoulders, upper arms and thigh muscles showed highest temperatures, which is in agreement with previous studies [4]. In fact, it has been reported that especially the muscles involved in arm and shoulder rotation contribute most significantly to the propulsion in front crawl swimming [3], while the thigh muscles are the agonist to propel swimmers in a hydrodynamic position. The thermal differences recorded on the neck could be related to the breathing side, although this was not a controlled parameter and no inferences could be taken from these differences.

CONCLUSION: The direct relationship between skin temperature and muscles activation intensity during the thermoregulation process indicates that thermography could provide important information regarding swimming performance. In future studies greater groups should be used and bioenergetical variables should be measured in order to provide a better understanding of the thermal response to exercises. The face presented the highest temperatures in all the swimmers, this could result from the usage of the swimming cap, since the study did not focus on the study of the face more variables are required to explain this reaction.

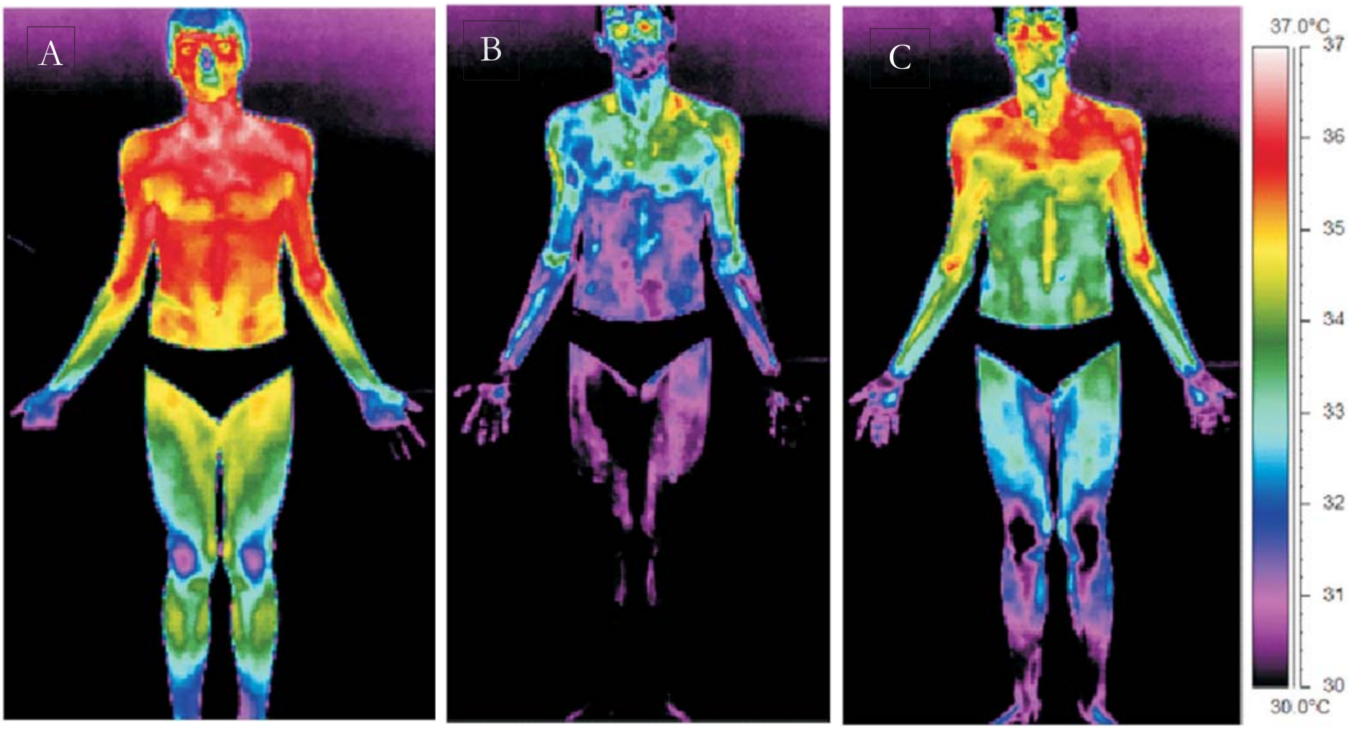


Figure 1
Thermal acquisitions at three different instants: A) before swimming B) after swimming, C) 5th min of recovery period

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## EFFECT OF YOGA AND SWIMMING ON BODY TEMPERATURE OF PREGNANT WOMEN

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INTRODUCTION: Physical activity for pregnant women should be controlled and adapted in order to minimize the risk of loss of balance and fetal trauma [1]. Non-invasive technologies are required for understanding better the effects of physical activity on pregnant women. Infrared thermography allows, remotely, securely and without any contact, to measure and display accurate temperatures on the human skin.

METHODS: We studied the effect of two different organized physical activities on the skin surface temperature of 28 volunteers 31-weeks-pregnant women (Yoga: n=14; Swimming: n=14). Two sets of six thermograms (Anterior and Posterior of the Upper and Lower limbs, and Left and Right Lateral Upper body) were registered by a T335 FLIR infrared camera: the first after 10 minutes of acclimatization to the room conditions and before the physical activity, and the second within the ten minutes after finishing the physical activity.

RESULTS: Because of the significant difference in general temperature of the women in the first assessment (TSWIM = 31.96 ± 0.77 ºC vs. TYOGA = 29.46 ± 0.66 ºC. $t(26) = 9.21$; $p < 0.05$) probably due to increased use of creams ($\pi 2(1) = 9.33$; $p < 0.05$), lower room temperatures ($t(26) = 4.00$; $p<0.05$) and humidity ($t(26) = 7.49$; $p<0.05$) in the yoga group, only in- crement of temperatures between pre- and post-activity measure- ments are going to be considered.

Our results indicated that general body temperature was significantly reduced ($t(26) = 10.5$; $p < 0.05$) after swimming (ΔTS = -3.30 ± 0.43 ºC) and slightly increased after the yoga practice (ΔTY = 0.21 ± 0.55 ºC). This tendency was similar in all the body areas (ΔTS-UPPER LIMB = -3.45 ºC vs. ΔTY-UPPER LIMB = 0.38 ºC; ΔTS-TRUNK = -3.21 vs. ΔTY-TRUNK = 0.45 ºC; ΔTS-BREAST = -2.70 ºC vs. ΔTY-BREAST = 0.52 ºC; ΔTS-BELLY = -3.15 ºC vs.ΔTY-BELLY = 0.77) except for the lower limb in which temperature was also reduced after the yoga practice (ΔTS-LOW LIMB = -3.32 ºC vs. ΔTY-LOW LIMB = -0.21 ºC).

DISCUSSION: The results point out a significant reduction of body temperature of expectant mothers even in the breast and belly areas, probably due to inadequate water temperature and the characteristics of the activity performed, although the values of body temperature does not appear to be hazardous to the fetus.

Practicing yoga during pregnancy slightly increases the body temperature in the whole body probably due to the characteristics of the activity (low intensity and controlled movements, many of them in sitting or lying positions).

Studies about the influence of water temperature and the amount and intensity of the aquatic activities on the recovery of the normal temperature processes after aquatic exercise should be performed not only in pregnant women but also in any swimmer.

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## THE HIGHLY FOCALIZED THERMOTHERAPY IN THE TREATMENT OF SOLID TUMOURS: TEMPERATURE MONITORING USING THERMOGRAPHY

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INTRODUCTION: Hyperthermia, in the tumour treatment, is based on the well-established concept that heat has selective lethal effects on tumour tissues [1]. Nowadays, many techniques are available to produce hyperthermia, but they are generally limited by the inability to selective target the tumour cells, with subsequent risk of affecting adjacent healthy tissues [1, 2, 3]. In an attempt to solve this limitation, a new hyperthermia technique was developed, the Highly Focalized Thermotherapy (HFT). This new methodology is based on the concept of the Magnetically Mediated Hyperthermia (MMH). The technique consists in the direct injection of an experimental material, the Ferrimagnetic Cement (FC) within the tumour and then the exposition to a high frequency magnetic field (HFMF). The aim is to increase the tumour temperature, based on the principle that a magnetic particle can generate heat, under a HFMF. Heat is than dissipated throughout the tumour tissues. With this approach we pretend to localize the heat in the tumour region, to the intended temperature (4 to 10 ºC upper them the initial temperature), without damaging normal tissue. The temperature monitoring during the treatment is crucial, because at higher temperatures, up to 56 ºC, will produce the unwanted "thermo-ablation", yielding widespread necrosis, coagulation or carbonization.

METHODS: B16F10 melanoma mouse (C56BL6) were injected with FC and exposed to a HFMF (frequency 10 kHz) created by a vertical coil (diameter 110 mm, 12 turns), using the induction system High Frequency Electronic Furnace K10/RV (CALAMARI and Milan, Italy). The animal body temperature was monitored through a thermal camera FLIR A325, after removing the fur in the area of the tumour. Through thermography, the skin temperature was assessed and logged its maximum value. The control of the HFMF strength was manually adjusted, so that the desired temperature of the tumour was kept constant.

RESULTS: The HFT application in the melanoma mouse model resulted in a temperature increase in the tumour. It was observed, through the thermographic image that the initial tumour temperature varies between 30 and 35 ºC and the animal's body temperature showed values between 27 and 31 ºC, depending on the animal (Figures 1A and 2A). However, comparing the initial tumour temperature with the tumour treatment temperature, there was an increase of 5-6 ºC in the first 5-10 minutes, whereas the body temperature showed only a limited increase (2-3 ºC). When the desired temperature was reached, it was maintained during all the treatment period, by controlling the magnetic field intensity (Figure 3). The temperature increase during the HFMF exposition is confirmed in all animals, independent of its initial temperature, as seen in figures 1B and 2B.

DISCUSSION: In this superficial melanoma model, the animal's temperature can be monitored using a thermographic camera. With this methodology, it is possible to measure the temperature variation, simultaneously, in the whole body and in the tumour, during the treatment. Since energy deposition in tissues, as well as, cooling by blood flow are difficult to model, a good thermometry control is always needed in clinical practice. With the thermographic camera used in this study, it is possible to determine the temperature distribution in the tumour, the tumours average temperature, selected points in the image field and the temperature evolution along the time, just throughout the surface observations. This is essential to control the tumour temperature during the treatment period. In some studies it was used an optical temperature probe inserted intramuscularly near to the tumour, or within the tumour, near to the injection site of the magnetic particles. The disadvantages are that the temperature measured doesn't correspond to the real tumour temperature, is necessary skin opening and the leakage caused in the gelatinous melanoma tumour parenchyma increases the variability in tumour volumes. The only limitations of the thermographic camera, is the tumour location. In the melanoma model and in a mammary tumour model, superficial tumours, this methodology has a great potential as a thermometry control method. In deeper location tumours, is necessary to use thermometry probes, which are invasive and give us just a temperature point and not the real temperature of the entire tumour.

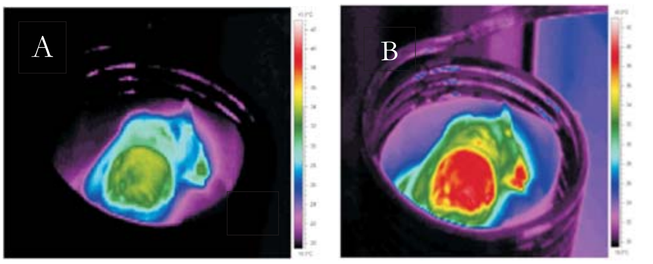


Figure 1
Animal thermographic image.
A) Initial state temperature - before the HFMF exposure.
B) During the treatment - 30 minutes of exposure to the HFMF.

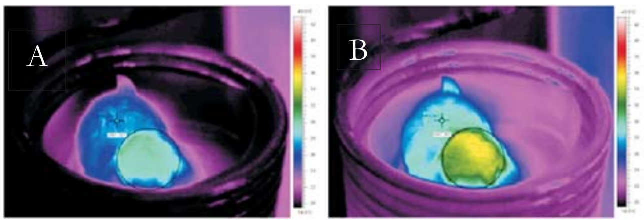


Figure 2
Animal thermographic image. The software used with the thermographic camera allows the determination of defined temperature points (spot) or areas.

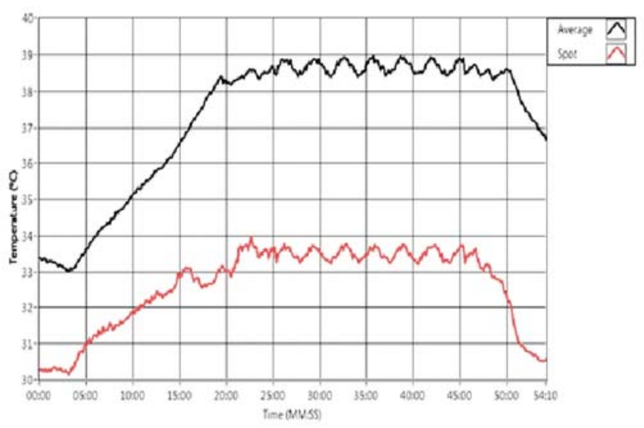


Figure 3
Time/temperature monitoring during the animal 's HFMF exposition.


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## TEMPERATURE CHANGES DURING KETAMINE ANAESTHESIA IN LABORATORY ANIMALS


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INTRODUCTION: Ketamine is an anaesthetic and analgesic agent used frequently in research and clinical practice [1]. More specifically, this drug is used in painful diagnostic procedures, traumatic and hypovolemic shock and burn situations. However, this drug is related with memory deficits, and these deficits are dependent of the temperature. Room temperature of the 21°C may exert neuroprotection but 25°C is a potential stressful event that increases brain vulnerability and may potentiate ketamine-induced deficit [2]. In other way, hypothermia may lead to death of animals during anaesthesia. Furthermore, it was reported that high doses of ketamine may cause hypothermia, indicating an involvement of the N-methyl-D-aspartate receptor in the thermoregulation pathway [3].

Body temperature is an important parameter to monitor during anesthesia. The determination of body temperature by traditional means is stressful to animals, and extremely time consuming. Conventionally the core body temperature of mice has been measured by either the insertion of a thermometer into the anus of the mouse or a thermocouple via the anus into the large intestine. Thermography is a rapid non-invasive method to determine mouse superficial body temperatures without the need to insert thermometers, thermocouples or implantable microchips. Therefore the purpose of this study was to evaluate thermography as noninvasive method for monitoring thermal superficial changes during ketamine anaesthesia in mice.

METHODS: This project was reviewed and ethically approved by the Portuguese competent authority for animal protection, Direcção Geral de Veterinária, (Lisbon, Portugal).

ANIMALS: Six 12 months of age, male C57BL/6 mice bred in the animal facility of the institute (F1-F2 offspring of animals bought from Charles River, Barcelona, Spain) were used. The mice were housed with controlled temperature (21º) and relative humidity at 55%. Lights were on a 12/12h cycle, with lights off at 17.00h. The animals were housed in groups of three to five mice per cage (Makrolon type II cage, Tecniplast, Dias de Sousa, Alcochete, Portugal) and it received a commercial pellet diet (4RF25-GLP Mucedola, SRL, Settimo Milanese, Italy) and water ad libitum.

ANAESTHESIA: Ketamine (Imalgéne® Merial, Portugal; 100mg $ml^{-1}$) was used for anaesthesia. Standard physiological saline 0.9% (Braun Vet, Portugal) was used for diluting the drug (to ease handling).

The mice were weighed using an electronic scale and the drug dosage calculated for each animal. Ketamine was administered as a single intraperitoneal (i.p.) injection. Injection and restraint were always performed by the same person. After i.p. injection, each animal was placed to a blanket with circular acrylic protection.

Body temperature was measured continuously during anaesthesia and recovery of the animals. Thermal measures were conducted using a FLIR long infrared camera with a spatial resolution of 320x240 pixels, a thermal sensitivity of 68 mK (figure 1) During induction of anaesthesia animals were placed in a transparent cilinder. Statistical analysis was performed using repeated measures ANOVA.

RESULTS: Tail temperature decreased significantly during anesthesia and it stabilized during recovery with a slight rise in temperature at the last minutes before righting reflex recovering. Nose temperature did not decrease significantly during anaesthesia (figure 2 and figure 3).

DISCUSSION: In anaesthetic situations, animals decreased their metabolism and consequently the body temperature is reduced. This work showed that body temperature changed with different rates in different areas of the body. Tail is the major thermoregulatory organ in mice and it is a good indicator of superficial body temperature. Moreover, nose temperature can be used to extrapolate internal body temperature. Nose plays an important role in raising or lowering the temperature of the air we breathe in, bringing it close to the normal body temperature. Our results showed that tail temperature decreased but nose temperature did not decreased significantly during anesthesia. A possible explanation for that is mobilization of heat from the surface and tail of the animal to vital organs and so temperature of the nose was not significantly changed.

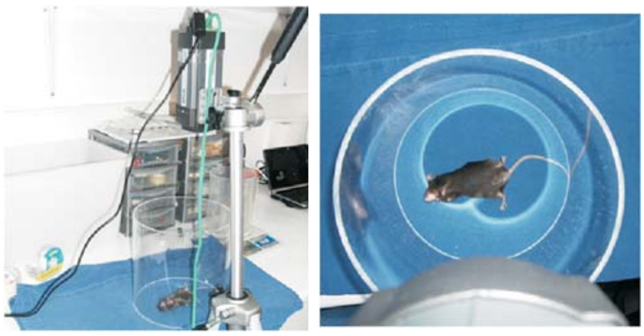

Figure 1
Thermal image acquisition setup

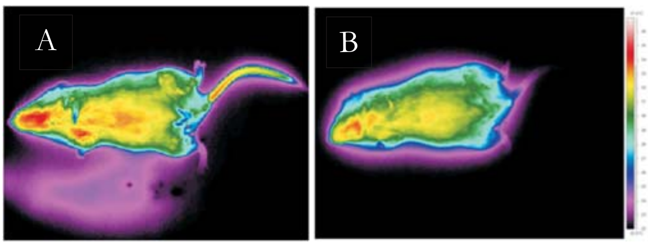


Figure 2
Thermal images A) after anesthesia induction, B) Recover starting point

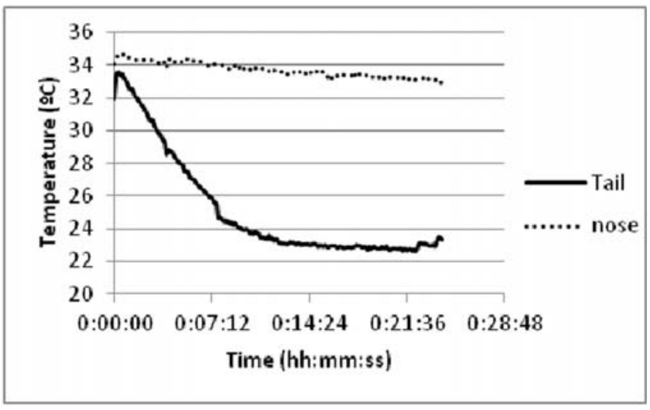


Figure 3
Temperature evolution during anaesthesia.

CONCLUSION: Anaesthetic agents, such as ketamine, produce a drop in superficial body temperature in mice. Thermography showed to be a good, fast and easy method to evaluate the thermal distribution in living beings. Moreover, this work demonstrated that thermography can be used for developing better and more effective types of anaesthesia.

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## THERMOGRAPHY AND ORAL PATHOLOGY

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INTRODUCTION: The purpose of this study is to illustrate the clinical use of thermography in identifying asymptomatic dental (oral) pathology. In this study we found a common cause of dental (oral) infection and inflammation to be a root canal, a very common dental procedure.

Many people today (including healthcare professionals) are not as attentive to their oral health as they should be. This issue has led many to (at times) experience dental sensitivity and nerve pain, to the point of requiring immediate treatment - which is usually a root canal.

For a number of years, there has been a growing debate amongst proponents of root canals and those who view this procedure as a potential health threat. Current convention is to save the tooth at any cost. However, while a root canal may offer a solution which helps the patient to maintain the appearance of oral health, this procedure also makes it extremely difficult for them to later on realize when an oral infection is present - until it becomes a much more serious issue. Unless the area becomes abscessed (a situation which occurs over an extended period of time), we are completely unaware that there is a problem.

Multiple research studies have linked root canals with oral cancer and other diseases. With thermographic imaging we can now identify early areas of inflammation and infection, because they present with heat. Once the infected area is identified we can then investigate further and offer a comprehensive solution.

METHODS & MATERIALS: The Study Population was 20 patients, and each was evaluated with Infra Red (IR) imaging, utilizing a FLIR A-320 Infra Red camera. These evaluations were followed up with numerous dental examinations which included an oral x-ray and a physical examination. Patients received additional dental examinations for up to one year. The study patients were evaluated using the examination guidelines established by the International Academy of Clinical Thermology.

RESULTS: In 73% of patients, we found that IR imaging discovered positive dental pathology shortly after the initial examination, or within one year. IR findings correlated with patients' longstanding complaints of tooth sensitivity and nerve discomfort, often ignored or dismissed by professionals due to the lack of physical or anatomical evidence, or based on other tests. In many cases, the IR findings preceded the realization of physical symptoms.

DISCUSSION: Root canals are inherently susceptible to infection and inflammation. Nerve pain is our warning sign that something is wrong. When that nerve system is removed, a patient has no way of determining if and when an area is infected until it becomes abscessed. When a patient has no symptoms of pain or discomfort, the assumption is that all is well. When an abscess develops it is usually treated as an emergency. But by then, the infection could have been present for a while, and may have already led to other health complications. Chronic inflammation can lead to chronic disease, heart disease and cancer, and has now been accepted as a "silent killer".

For many years our clinic has imaged and evaluated thousands of women using infrared thermography. In many cases we have clearly seen instances of infection and inflammation in the dental area by using this heat-sensing technology. Many of these instances have been attributed to dental or oral issues related to root canals. Invariably, some cases are very subtle, even asym-, ptomatic for many years. But these cases have slowly and incessantly affected peoples' health. Those living with chronic infection and inflammation will eventually find that their immunity has been adversely affected. In some cases, this will actually promote the growth of a malignancy. The body's natural defensive mechanism to fight malignant development has been impaired because the immune system is too busy fighting the infection and inflammation. This can be resolved by first identifying and treating the infected area, thereby allowing the body to concentrate on battling the malignancy.

CONCLUSION: The IR imaging procedure provided vital information about the physiological processes of infection and inflammation via examination of facial temperatures, then comparing those to the same internal processes. The early indications provided by IR imaging can be used as a prognostic indicator in detecting oral and dental pathology. The merits of utilizing a non-invasive IR imaging modality are great. IR imaging can help to identify earlier stages of infection and inflammation not visible with other current imaging modalities, thereby providing the patient with a much earlier and more appropriate response to their condition.

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## THE USEFULNESS OF THERMOGRAPHY IN THE ASSESSMENT OF TEMPOROMANDIBULAR DISORDERS IN ORCHESTRA MUSICIANS

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Temporomandibular disorders (TMD) consist of a group of pathologies that affect the masticatory muscles, the temporomandibular joints (TMJ) and/or related structures. The signs and symptoms referred by the patient are usually, pain, joint sounds, muscle tenderness, joint tenderness and limitation of jaw movement. Associated to these clinical situations other symptoms can appear affecting the head and neck region such as head-ache and ear-ache.

Orchestra musicians can spend many hours with changes on head posture which can have an influence on the biomechanical behavior of the TMJ, and the muscles of the cranio-cervico-mandibular complex (CCMC). The association between head and cervical posture of musicians can increase muscular activity, with muscular hyperactivity. When playing a string or a wing instrument the musician regarding his musculoskeletal system and head posture has a close relation with the orofacial anatomic zones. Some studies, report the position of the head affects the resting position of the mandible and masticatory muscles, showing evidence of a close association in the possibility of appearance of TMD.

Given the duration and intensity of the daily practice of orchestra musicians, they may well develop a parafunctional activity, especially in the masticatory and postural muscles. Thus, it is extremely important to monitor such activity, so that muscular hyperactivity does not interfere in maintaining a functional equilibrium of the CCMC. Therefore, understanding what kind of muscles are being used in the CCMC during their performance with the the thermographic camera FLIR® A325, can be extremely useful in order to detect and diagnose a concrete muscular disorder originated by repetitive movements. With the thermography we can obtain information of anatomic- physiological structures while the orchestra musician is playing his/her piece.

## BONE TEMPERATURE CHANGES AND DISTRIBUTION DURING DENTAL IMPLANT BED PREPARATION

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INTRODUCTION: Osseointegrated dental implants present very high long term success rates due to, among other factors, an adequate and atraumatic implant bed preparation or osteotomy [1]. Osteotomy is a surgical procedure of bone removal where strong inflammatory reaction and trauma are present [2]. Drilling causes not only a mechanical trauma, but also a considerable thermal damage to the surrounding bone, being this the most harmful factor regarding this tissue [3]. After the implant bed preparation and placement of the implant in its final position, several cellular and molecular events occur as a response of the wound healing process [4]. During bone drilling, if the temperature reaches 47ºC or more for 1 minute, irreversible osteonecrosis [5] will occur depending its extension on temperature magnitude and time of exposure to the thermal agent [6]. Consequently, denaturation of alkaline phosphatase occurs [4, 5] preventing the implant from osseointegration [5]. Several factors have been described as being responsible for the temperature rising during osteotomy for implant bed preparation such as: drill speed [3, 7], pressure applied to the drill [8], drilling depth [9], irrigation [10, 11] and continuous vs intermittent perforation (11]. The aim of this study is to assess the bone and bur temperature during the drilling process, when different protocols are used.

METHODS: To simulate the human jaw, porcine femura of uniform density were used. The porcine and canine bones best resemble human samples. To measure the temperature during implant bed preparation, a FLIR A325 thermal camera was used with a close-up lenses (25µm/pixel), recording one image per second. All the drillings were performed with the W&H Osseoset 100 dental implant motor. Different parameters regarding drilling speed, drilling depth, pressure applied to the drill, irrigation and continuous vs intermittent drilling were used.

RESULTS: When different parameters (drilling speed, drilling depth, pressure applied to the drill, irrigation and continuous vs intermittent drilling) were used during dental implant bed preparation, significant differences were found regarding bone temperature. In bone like structures a simple thermal camera is not adequate to measure temperature changes since these are extremely high and localized in very small portions of material.

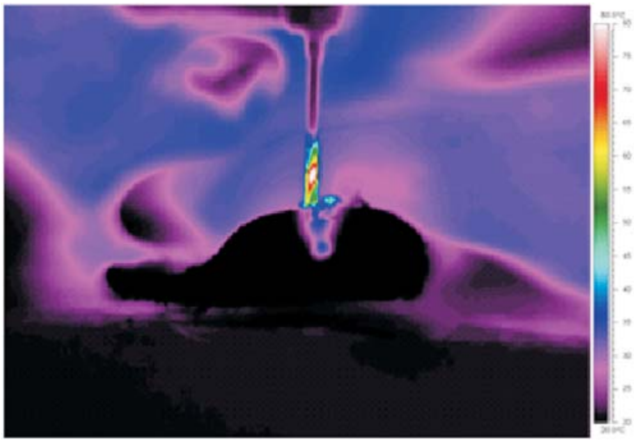

Figure 1
Start drilling, (without close-up lenses).

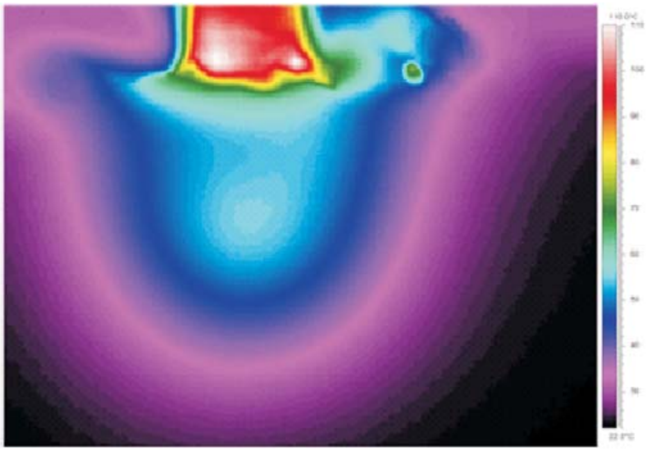

Figure 2
Start drilling, view with close-up lenses.

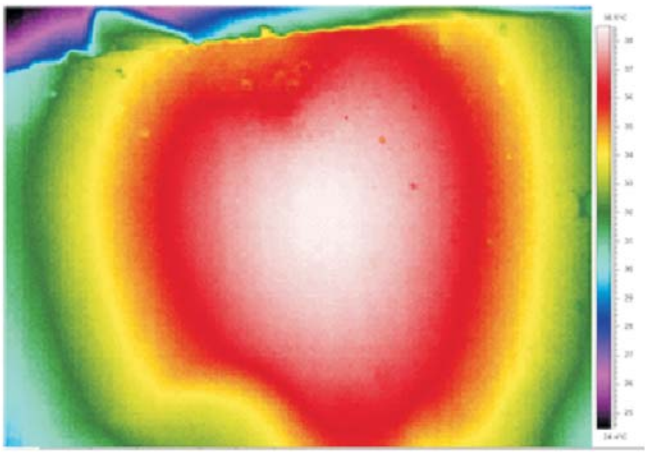

Figure 3
Temperature distribution one minute after the end of the drilling process

Therefore the use of a close-up lenses is crucial, fact that is obvious by comparing figure 1 with figure 2, were the maximum temperatures differed in more than 30 ºC. (80 ºC to 110 ºC). Figure 3 shows the temperature distribution one minute after the end of the drilling process.

CONCLUSION: Maximum caution must be taken during dental implant bed preparation in order to avoid bone damage that could lead to osteonecrosis and, therefore, to implant failure.

Temperature should be kept as close to the body temperature as possible, by providing air or water flow to the drill, and by using new, or almost new drills.

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## THERMOGRAPHIC EVALUATION OF THE EFFECTS OF ELECTROTHERAPY ON PERIPHERAL CIRCULATION IN PATIENTS WITH STROKE


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BACKGROUND AND AIMS: In recent years it is noticed a significant increase in number of patients suffering a stroke. A significant percentage of these patients experience an important pathological background of cardiovascular risk factors (diabetes, smoking, hypertension, peripheral circulatory disorders).

The purpose of this paper is to find a way to improve peripheral circulation, especially in the territory affected by neurological deficit in these patients.

Thermography is a noninvasive method for assessment of peripheral circulation, which can give information about changes at this level.

MATERIAL AND METHOD: We selected a group of 15 patients hospitalized in our clinic. The patients should meet the following inclusion criteria: presence of one or more risk factors (hypertension, diabetes, smoking, obesity) the stroke to be less than or equal to 6 months old.

The patients were evaluated from clinical and functional point of view at the beginning and at the end of the period of hospitalization. We also used a control group with the same risk factors but without stroke. All patients received the same electrotherapy program applied for 10 days.

Patients were assessed thermographic daily, before and after electrotherapy program (foot and hand).

Evaluation was performed according to the Glamorgan protocol.

RESULTS: Study results were statistically analyzed using specific methods of this process.

CONCLUSIONS: This study is seen to improve peripheral circulation in the affected segments, expressed by increasing local temperature by applying electrotherapy program.

It is required repeated assessment of these patients to observe the effect of the treatment on long term.

## SURFACE TEMPERATURE EVOLUTION ON DANCING ACTIVITIES

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INTRODUCTION: In many situations a group prescription is used in dance training. Before a performance, professionals warm-up collectively, performing the same type of exercises. Individualization is a fundamental principle in any training process, because the same working load has different effects on different people depending on personal characteristics (age, gender, technical expertise, etc.). In this study, the infrared imaging was used to assess individual differences in two dance routines (general exercise versus local exercise).

METHODS: Ten subjects (8 females, 2 male) with an average of 25 years old were measured with a FLIR A325 infrared camera. The study was conducted in a gymnasium with ambient temperature in the range of 16-18ºC. Thermal images were collected before, during and after exercise (immediately and passed 20, 40 and 60 min).

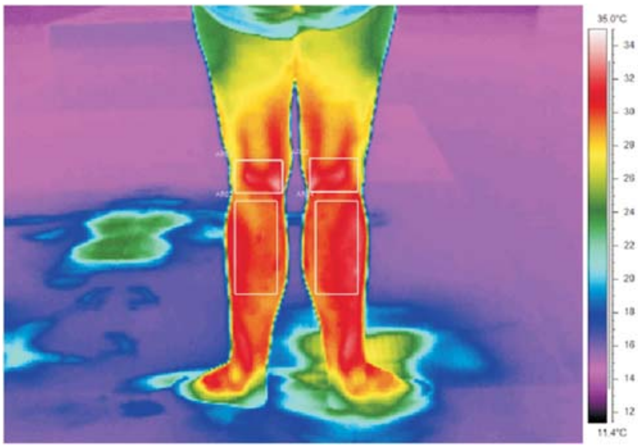


Figure 1
Lower limbs temperatures

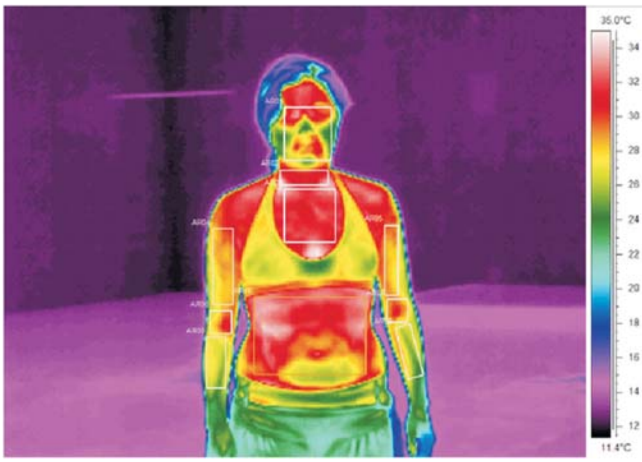


Figure 2
Upper limbs and torso temperatures

RESULTS: The evolution of the surface temperature varies between subjects and between different segments of the body. The warm-up situation that explores continuous dance displacements during 15 min, generated an increase of temperature in the lower limbs (figure 1) and a general decrease in the muscles on the face and upper trunk (figure 2), with some inter-individual variation: e.g., in the inferior limb the difference found before and after warm-up for one subject was an increase of 2°C and for another was a decrease of 2°C.

Additionally, in the tasks with a more localized incidence (spinal motion series of gyrokinesis) it is clearer the decrease of skin temperature and this difference is significantly higher in the subjects with more experience compared with subjects who have never experience the gyrokinesis technique. The experts have a different pattern, showing a reduction of the skin temperature when the work intensity increases, and more time to recover the initial surface temperature (60 min).

DISCUSSION: Vasoconstriction and perfusion patterns probably caused by non-thermal factors, can explain the fall in the surface temperature during exercise. The pattern normally accepted is: the skin temperature began to fall immediately at the onset of exercise, and remained low during exercise and rise rapidly after cessation of exercise. These results show a no linear model, dependent of the type of exercise (global vs local) and the experience (experts vs novices).

The surface temperature response to exercise is characterized by specific patterns with influence of many variables. Thermography is an useful objective tool that can sense individual differences for the same load in dance training performance evaluation and risk assessment, with a procedure somewhere between direct (heat flux) and indirect calorimetry (O2 consumption).

ACKNOWLEDGEMENTS: This research is partially sponsored by FEDER funds through the program COMPETE-Programa Operacional Factores de Competitividade and by national funds through FCT - Fundação para a Ciência e a Tecnologia, under the project PTDC/CTM-NAN/112574/2009.

## LEGALITY ASSOCIATED WITH THE USE OF INFRARED THERMAL IMAGING IN VETERINARY MEDICINE

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INTRODUCTION: In 1970 the Horse Protection Act was passed by the United States Congress to ban use of chemical and mechanical means of "soring" of horses. It was common practice in the 1960's and 1970's, with Tennessee Walking horses, to use mechanical devices (boots, rollers, chains) on the horse's front legs to enhance their performances. The chains of various weights were put on the mid pastern region of the thoracic limbs during the horse show. There was also some evidence that mustard oil was applied to the skin region of the mid pastern to further enhance the horse's performance. Use of these devices induced irritation of the skin and caused lesions and also produced scars in pastern areas.

To prevent this abuse the horse protection act was passed. To use physical examination, including digital palpation was not a re. liable enough source to prosecute the horse owner or the trainer in the court of law. This promoted the USDA-APHIS (United State Department of Agriculture and Animal Public Health Inspection Services) to fund studies for the diagnosis of "Soring".

Thermal imaging was then used by Nelson and Osheim in Iowa [1] and Purohit et. al [2, 3, 4] at Auburn to perform studies for the diagnosis of inflammatory processes in horses and in response to various chemical and physical factors.

Auburn University studies resulted in revising the Horse Protection Act in 1983. This was also followed by implementing new guide lines by the USDA-APHIS.

As time went by use of thermography was discontinued and horse inspection for horse shows was completed by physical examination that also included digital palpation.

Since 1970's to present day there were and are several court cases. APHIS had taken a position in early 1990's that palpation by itself is sufficiently reliable to accurately determine whether a horse has been sored or not. Horses which were written up and not allowed to appear in shows, some of which ended up as litigation in federal courts. In recent ruling by federal Law Judge Peter M. Davenport, he questioned whether palpation alone was sufficient "scientific" means to allow expressing an expert opinion [5]. He cited a Supreme Court Case which set forth four factors to determine that reliability. He used thermography references of published papers in veterinary medicine. His recent ruling caused APHIS to lose the court case. Now USDA-APHIS went back and reinstituted the use of thermography as an additional means to document if the horse was sored or not.

DISCUSSION: The efficacy of non-contact, electronic infrared thermography has been demonstrated in numerous clinical settings and research studies as a diagnostic tool for veterinary medicine. Sometimes it is very difficult to use x- ray, ultra sound, and MRI for large animals like horses and bovines (bulls). These procedures require coming in direct contact with the animal. In some cases the animal had to be under general anesthesia to perform these tests. Thermography has been very helpful as a preliminary diagnostic tool in many of the clinical cases. Painful conditions associated with peripheral neurovascular and neuromuscular injuries can be easily diagnosed by thermography.

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## THE USE OF THERMOGRAPHY TO EVALUATE BACK MUSCULOSKELETAL RESPONSES OF YOUNG RACE HORSES TO TRAINING

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INTRODUCTION: Constant overloads of equine musculoskeletal system can cause abnormalities associated with painful conditions or diseases, leading to loss of performance. Back overloads are associated with physical responses to training. Thermography has been used for the diagnosis of skin tem perature variations due to change in the local circulation, caused by stress of the musculoskeletal system. The present study was aimed to evaluate the efficiency of thermography in monitoring racehorses' musculoskeletal system response of back overloads due to increasing intensity of training cycle.

METHODS: The thermographic examinations were performed at Partynice Racing Track (Poland) every 3 weeks during a period of 10 months and complied with international veterinary standards [1]. Thermograms were obtained from the dorsal view including thoracic, lumbar and sacroiliac joint area. During the research horses underwent a gradual increase in training intensity. A thermograpic camera 'VarioCAM' 640 x 480 was used. The thermograms were analysed with the use of IRBIS version 3 Professional computer program. The back was divided into 5 areas: thoracic vertebrae (T), lumbar vertebrae (L), sacroiliac join area (SIJ), and symmetric sides of the thoracic vertebrae area: left side of the muscles: (ML); right side of the muscles: (MR) From each area the average temperature was measured. For statistic analyses the nonparametric Kruskal- Wallis test was used.

RESULTS: An increase in the training intensity resulted in significant decreases in average temperature differences between T and L area ($H = 22.143$ $p < 0.000$); T and SIJ area ($H = 21.453$ $p < 0.000$); T and ML area ($H = 47.466$ $p < 0.000$); and T and MR area ($H = 40.218$ $p < 0.000$).

DISCUSSION: Thermography was used to characterise the horses back surface temperature distribution changes in response to increasing training intensity. High average temperature differences between T-L; T-SIJ; T-ML and T-MR at the beginning of the training cycle could be associated with low levels of athletic activity and riding techniques in trot. It has been found that the weight of the rider in trot increases strain in the T area [2]. In present study a gradual increase in training intensity caused a decrease in average temperature differences between the measured areas. This confirms results from previous studies which indicated that strains and overloads of the musculoskeletal system under demanding exercise resulted in increased blood circulation that can predispose later injuries [3].

CONCLUSION: The analysis of the surface temperature distribution over the horse's back will allow us to develop a model of normal blood circulation within this area. It will also help specialists, breeders and veterinarians to understand the fundamentals of the physiological response of the musculoskeletal system to intensive training. Regular thermographic analyses will enable back overloads to be monitored and facilitate identification of pathological conditions during the training cycle. This will allow trainers to select appropriate training programmes to achieve and maintain optimal horse performance.

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## EFFECT OF HIGH REGIONAL NERVE BLOCKS ON THE THERMOGRAPHIC PATTERNS IN THE LIMBS OF HORSES

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INTRODUCTION: It is often difficult to judge the effectiveness of a high regional nerve block (i.e., anesthesia of the median, ulnar, peroneal, or tibial nerve) in the horse. After a high regional nerve block, skin can be tested for loss of sensation at a specific site on the limb for each nerve, but this method of testing may yield erroneous information for several reasons: (1) the horse may be stoic and show little reaction to noxious stimulation of skin, (2) the region of skin desensitized may vary somewhat among horses, and (3) some horses react violently to the slightest provocation, making a positive reaction to skin testing difficult to interpret. A positive response to a nerve block (i.e., resolution of lameness) is good evidence that the nerve was actually anaesthetized, but a negative response may mean that the source of pain causing lameness was not in the region supplied by that nerve or that anesthesia of the nerve was not achieved; the accuracy of a lameness examination depends upon the ability to make this distinction.

Thermography studies done on the thoracic (front) and pelvic (back) limbs of horses before and after neuroectomies showed that posterior digital nerve neuroectomy had a significant increase in heat patterns in the areas supplied by the nerves [ 1, 2, 3]. Sensory - sympathetic dermatome patterns of the cervical regions in horses were determined by using 0.5% mepivacaine hydrochloride as a local anesthesia in horses [4, 5].

The nerves of the skin are mainly divided into two categories: sensory and autonomic. The sensory nerves are for transmission of the sensation of temperature, pain, itch, light, touch, pressure, and proprioception; whereas the autonomic nervous system controls the tone of cutaneous blood vessels and skin glands.

We reasoned that neurological control of blood vessels in skin is interrupted when the nerve supplying blood vessels is anaesthetized and that those blood vessels would dilate in response to nerve block. Dilation of blood vessels increased flow to skin, in turn causing an increase in skin temperature, which can be detected on thermography [6]. The primary objective of this study was to demonstrate that thermography can be used to accurately predict whether or not a high regional nerve block was successfully performed.

METHODS: Six horses ranging in age from 15 to 21 years were selected for this study. A digital infrared camera (Flir B360) was used to record thermal images. Images of the front leg were taken from the forearm and hoof and posterior leg images from the stifle to hoof. The anterior, posterior, and lateral images were taken to provide thermal mapping of the dermatome regions related the specific nerve block.

Average temperature of the dermatome regions were determined by using Flir software (Flir Reporter 8.5). A baseline thermographic image was recorded prior to each perineural injection of mepivacaine HCL of the ulnar, median, peroneal, or tibial nerves. A total of 20mL of mepivacaine HCL was administered perineurally using a 20-gauge, 1.5 inch hypodermic needle. Thermography patterns of the all limbs of each horse were obtained immediate post injection and at 15 minute intervals for one hour post injection. A sham treatment, injection of saline for each site was also performed on separate occasions to determine the effect of potential injection site irritation, if any.

RESULTS/DISCUSSION: In response to regional nerve block, two responses were produced. First, blocking the sympathetic portion caused increased thermal (heat) patterns due to vasodilation, and second, the area of insensitivity was produced by the sensory portion of the nerve block. Increased thermal gradients were consistent in all nerve blocked areas. Thermography can be used to determine the accuracy of a high regional nerve block, and the area can be easily demarked. Results of a thermographic evaluation of the limbs is at least as accurate as testing for skin sensation to determine the accuracy of a high regional nerve block and may be a safer method of making this determination.

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## FORCE DISTRIBUTION IN WHEELCHAIRS USING FORCE SENSORS AND THERMOGRAPHY


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INTRODUCTION: Wheelchair's users spend most of their time seated in the same position. Over the time due to unrelieved pressure, shearing forces, friction, humidity, temperature, continence, and medication, these persons tend to develop several injuries. During the movement of the wheelchair through the use of the arms, torso and legs are not only subjected to the pressure resulting from body weight but also a friction force, some temperature increment and humidity from sweat. This leads to a series of problems being one of the most serious, pressure ulcers [1]. Despite all the health problems, this is also very uncomfortable for any person especially for a handicap person, since he/she is already in a conditioned status. The main corrective action regarding pressure ulcers is, to remove the pressure, changing the position ever two or four hours, depending on the patient [2]. Over the years, if there is no movement or exercise of the lower limbs, the risk of developing pressure ulcers increases. Mainly due to the diminution of muscle volume in the legs, it increases the zones of skin overlying bone prominences. In 1993 Pell Ferguson presents a system based on a matrix of pressure sensors in order to map and measure the pressure distribution in

Figure 1
Overall setup. On top right, the wheelchair covered by the matrix force

a wheelchair [3]. The pressure measurement by itself does not provide exact readings of the possibility of ulcers prediction [4], but depending on the global and local physiology of the person and his physical condition [5] can provide good guidance. The main goal of this work is to study the possibility of using infrared thermography to get more information regarding the pressure distribution in wheelchairs.

METHODS: A matrix force sensor (Tekscan) was placed over the wheelchair seat before a subject with a normal statue, male, 1.82 m height, 73 kg and 45 years old seat on it. The test lasted for 3 minutes, during which the person was seated in the wheelchair without moving. The force readings were stable over the time.

The thermal camera used in this work (Flir®, A325) was adjusted to the lower range (20 to 120 ?C) and fixed in a tripod (Figure 1). The thermal images were captured at a distance of approximately 1.2 m before and after the subject have the seat. The thermal camera used in this work has a thermal sensibility of 0.068 ?C and a resolution of 320x240; the emissivity was set to 0.93 and humidity to 52% as read by an external sensor.

RESULTS: After several attempts to perform a good and smooth interpolation for the force measurements, the original data was not sufficient to produce a result that possess has good spatial resolution has the thermography image. Nevertheless, the force distribution pattern as a very good correspondence to the thermal pattern observed with the camera.

CONCLUSION: This work indicates that thermography can be used to get a contact distribution pattern, as the temperature increases where the contact forces are higher. Thermal images are easier to collect and have a very good special resolution, but naturally it requires that the subject is not seated during the measurements.

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## THERMAL ANALYSIS OF THE HEATING AND SEALING PROCESS OF A DYE-SENSITIZED SOLAR CELL

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INTRODUCTION: The world total primary energy supply is currently about 12×103 MToe and it is expected to increase to 18×103 by 2035 [1]. The need for sustainable and "clean" energy sources, together with the requirements of diversification of supplies, creates a framework for developing competitive technologies to produce energy from renewable sources. Dye- sensitized solar cells (DSCs), a third generation of photovoltaic cells, may greatly contribute positively to the solution of this energy challenge. DSCs result from a successful combination of various materials: a 3D photoelectrode made of TiO2 nanoparticles coated with an adsorbed monolayer of an organic-metallic dye, an electrolyte containing usually iodide/triiodide redox couples and a platinum counter-electrode. As DSC's can be built in a large range of forms, colors and having good behavior with diffuse radiation, they are suitable for building-integrated photovoltaics (BIPV) applications taking advantage from facades and roofs without compromising the building aesthetics. Basic requirements for all solar cell technologies, and in particular for DSCs, are long-term stability and performance/efficiency. Despite all efforts to enhance DSCs' performance, long-term stability is still a major issue that limits market implementation of this technology. The long-term stability problem of the DSC design is directly related to the traditional sealing methods, which normally use thermoplastic sealants. The present work refers to a thermal evaluation of a new sealing method developed for DSCs devices by the research group. This study will be helpful in further improvements of the custom made laser-sealing device and process.

METHODS: A new effective sealing method was developed for application in dye-sensitized solar cells. The sealing method employs a cord of low temperature melting glass frit paste that bounds the entire perimeter of the glass substrate. The glass precursor is heated to its melting point assisted by a YAG laser beam, allowing the two glass substrates of the cell to be completely sealed. The sealing method is carried out by heating the substrates for minimizing the thermal stress of the substrates during the laser sealing procedure. Four cartridge resistances with 300 W each embedded in the heating plate (200 200 mm2) used to heat the two 100 100 mm2 TCO coated glass substrates. A Eurotherm on/off solid-state relay controller controls the power delivered to the resistances. The sealing method is so fast and so concentrated that it was impossible to follow the dynamics of temperature change with a thermographic camera (FLIR A325, max. temperature 350 °C). However, it helps to obtain the heat distribution of the heating plate and glass substrates. Complementary, temperature measurements were obtained during the sealing process at several positions of the glass frit cord using precision K-type 0.050 mm diameter thermocouples.

RESULTS: Figure 1a. shows that the temperature in the plate surface is not uniform during the heating up step and hotspots glow nearby the cartridge resistances.

Therefore, the temperature on the top of the upper glass substrate is highly influenced by the relative position in relation to the heating plate (Figure 1b).

Under steady state conditions, the controller can easily maintain the temperature of the plate surface uniform. It was expected that with 2 mm-thick glass substrates, the temperature would not be much different from the bottom to the upper substrates. However, the thermal image shows that there is a significant temperature difference between the two adjacent surfaces. (Figure 2). This effect influences the sealing process since it may cause temperature induced stress cracks in the glasses. Figure 3 shows the temperature evolution obtained at the center of the glass frit cord by the thermocouples. The laser hits this point ca. 14 times during the sealing process. As expected, the temperature at 0.5 mm from the glass cord is approximately the same as over much of the substrate(Figure 3).

CONCLUSION: The laser heating is so localized and fast that it did not affects the other cell components, being therefore a good solution. As shown in the thermal images, the heating plate temperature is compatible with the commonly used materials of the photoelectrode and counter-electrode layers, i.e. titanium dioxide photoelectrode (~500 °C) and platinum counter-electrode (~400 °C), respectively. The sealing process is achieved at a relatively low temperature, 250-360 °C, and the laser induced tempe-

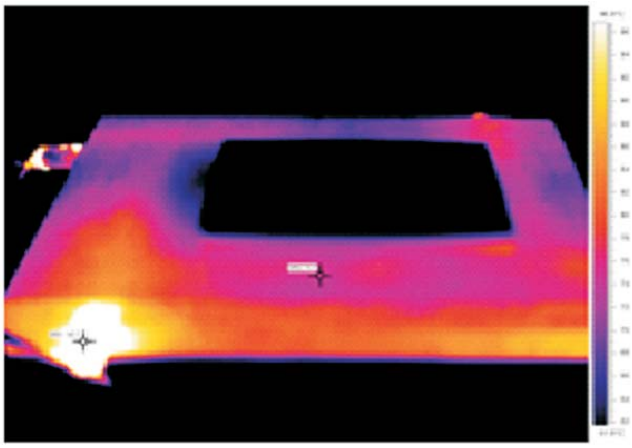

Figure 1 a
Heating plate showing the temperature distribution, 143.7 °C on top of the resistance and 74.5°C on plate surface

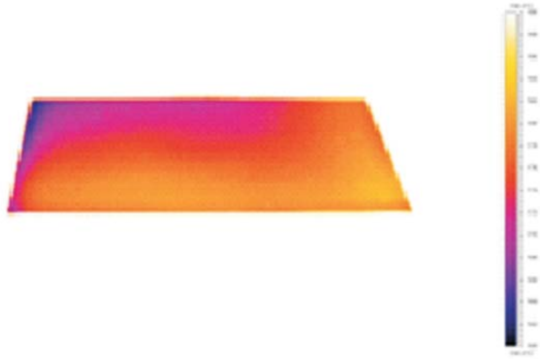

Figure 1 b
Temperature distribution on the upper glass substrate, the temperature

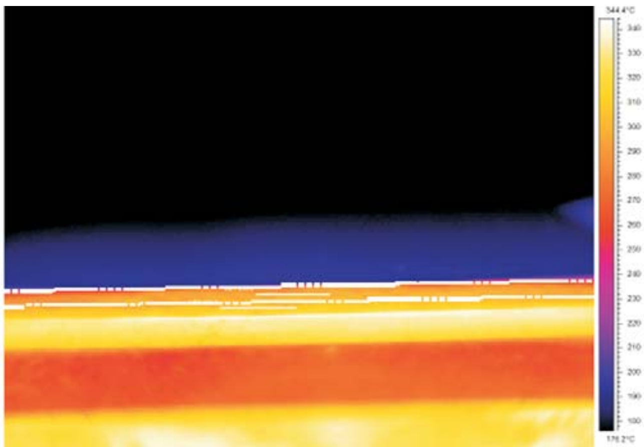

Figure 2
Temperature in the two glass substrates at a steady state heating plate temperature - side view, 299.2 °C on the top substrate and 310.5°C on the bottom.

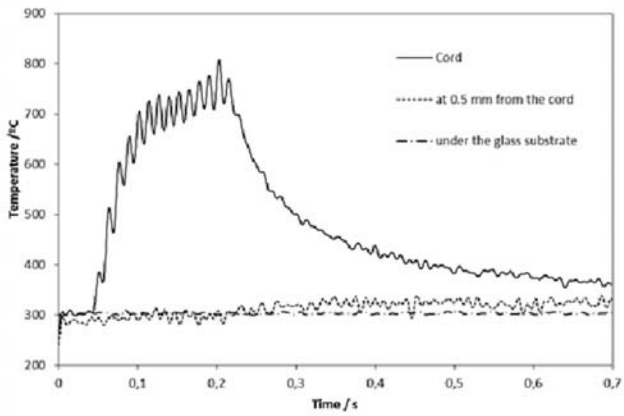


Figure 3
Temperature evolution during the laser assisted sealing at different positions.

rature increase is very localized. These facts confirm that this new sealing process is suitable for bonding DSC devices. The thermal analysis showed the special temperature distribution, helping to improve the design.

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# Posters

## OBSERVATION OF PERIPHERAL CAPILLARY BLOOD FLOW IN PROXIMAL NAIL FOLDS AND THERMOGRAPHY

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INTRODUCTION: We could non-invasively analyze capillary blood flow velocity of the proximal nail folds (cuticles), by using JMC's peripheral capillary observation unit M320 (JMC Inc., Kyoto). We could easily observe many capillaries and erythrocyte movement in the capillary vessels on a PC monitor with patients. M320 software required only a 10-second captured digital video file for analysis. We evaluated the effectiveness of capillary observation as a clinical marker and nutritional education of diabetic triopathy.

METHODS: The study was conducted with 15 diabetic patients (DM) and 30 non-diabetics (non-DM). In a climate-controlled room (25 degrees Centigrade, 50%, no wind), we took a thermographic picture of a finger. We observed the capillaries of the proximal nail folds and analyzed the capillary blood flow velocity, blood flow volume and capillary diameter. We also examined the relationship between the finger temperature, blood pressure and blood biochemical variables with them. We utilized Peason's correlation coefficient-test and non-paired t-test for statistical analysis ($P < 0.05$).

RESULTS: The capillary blood flow velocity had a positive correlation with the systolic blood pressure ($p<0.05$, $R=0.40$, $N=28$), and a negative correlation with HbA1c ($p<0.05$, $R=0.72$, $N=18$).

The mean capillary blood flow velocity of DM group (76.9 ± 12.2 μm/s) was slower than that of the non-DM group (93.0 ± 14.5 μm/s). The mean capillary blood flow volume of DM group (10910 ± 3892 μm3/s) was significantly less than that of the non-DM group (14821 ± 5065 μm3/s). Though we didn't find the correlation between the mean capillary blood flow velocity and finger temperature, it was found that the cases who had extremely slow capillary blood flow velocity showed low finger temperature. Further study is needed for more details.

DISCUSSION: It was shown that the observation and analysis of capillary blood flow attracted patients' interests, and it may help patients continue their dietary and exercise therapy.

## SYMPATHETIC NERVE BLOCK EFFECTS OF PHOTOTHERAPY NEAR STELLATE GANGLION

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INTRODUCTION: Stellate ganglion block therapy had been often used to reduce pain and increase blood flow for the patients suffering Raynaud's phenomenon and shoul- der hand syndrome (RSD in stroke). But recently we could rarely apply the treatments by the risk of puncture. Infra- red or Xenon phototherapy to the stellate ganglion had been demonstrated to reduce pain and increase blood flow not invasively, and the effects were similar to the stellate ganglion block therapy. We studied physiological effect by the phototherapy near the neck stellate ganglion.

METHODS: The healthy volunteers were irradiated at the left neck stellate ganglion by polarized infrared light for 10 minutes after cold water immersion test (15 Degrees Centigrade, 3 minutes).Polarized infrared light irradiation system is Super Lizer HA-550 and 70%power,1 second irradiation 2 seconds resting cycles. And the irradiation group of eleven were irradiated at the right neck stellate ganglion by polarized infrared light irradiation for 20 minutes, And the control group of eleven were treated for 20 minutes use the same irradiation instrument that the light were completely obstructed. We analyzed the blood laboratory test and the temperatures of limbs and perspiration quantity of palm and blood pressure before and after of irradiation.

RESULTS: The irradiated side temperature increased. The perspiration quantity of irradiated side was decreased ($p<0.05$) and the peripheral temperature of bilateral upper and lower limbs increased. The leukocyte counts decreased ($p<0.01$).We have not find statistical significance blood pressure change.

CONCLUSION: It was considered that the effect by the polarized infrared light irradiation for near the neck stellate ganglion was similar to the sympathetic nervous ganglion block.

## TIME TO STABILIZATION OF THERMOGRAPHIC IMAGES AT REST

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INTRODUCTION: The application of thermography in professional practice and researches requires a series of procedures to obtain images that should be standardized. One point to highlight from these methods is the time required for acclimatization evaluated in a controlled environment.

OBJECTIVE: Thus, the purpose of this study is to identify the time needed at rest to equilibrate the skin temperature (ST) in men and women of college age.

METHOD: Forty-four subjects participated in the study, 18 men (22.3 ± 3.1 years) and 26 women (21.7 ± 2.5 years). Thermographic images were collected using a thermal imager, a total of 44 photos in a period of 20 minutes in each was assessed. ST was evaluated at each the points of analysis, which included the minutes 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20. The body regions of interest (ROI) analyzed include the hand, forearm, arm, thigh, leg, chest and abdomen. We applied the Friedman test with Dunn's post hoc, in order to determine the time required to equilibrate the ST. The Mann-Whitney test was used to compare age, BMI, fat percentage and temperature variations between men and women. A significance level of $p<0.05$ was used in all calculations.

RESULTS: The results showed that women had greater temperature variations than men over time ($p <0.01$). In men, only the body region of the abdomen showed significant difference ($p<0.05$) during the period examined, both in the anterior and posterior portion of the body. In women, the anterior abdomen and thighs (right and left) showed significant differences ($p<0.05$), while the right hand, left hand, right forearm, left forearm and abdomen had significant differences in posterior of the body.

CONCLUSION: Based on these results, we can conclude that the time required to equilibrate the ST in men and women of college age is variable. For analysis of the whole body, it is recommended at least 10 minutes for both genders.

ACKNOWLEDGEMENTS:
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## THERMAL RESPONSE OF THE SKIN TEMPERATURE ON MUSCLE AND JOINT BODY AREAS AFTER STRENGTH TRAINING BY INFRARED THERMOGRAPHY

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INTRODUCTION: There is no doubt that core or central temperature has a direct relationship with the exercise intensity. Some studies focused on measuring the central thermal response. However it is also interesting to investigate the thermal response of skin temperature after exercising. Between many reasons, it could provide important information about the recovery status -making possible to assess when the athletes are completely recovered as well as determining the influence of exercise on skin temperature.

OBJECTIVE: The purpose of our study is to determine by Infrared Thermography (IRT) the evolution of skin temperature for muscles and joints areas after strength training, besides to evaluate the thermal asymmetries.

METHODS: A total of fourteen physical active males (age: 21.44±2.64 years; height: 1.78±0.05 m; weight: 73.23±7.63 Kg), exercising at least 3 times per week, took part of the study. They did not report any diseases, consumption of medicaments, drugs, alcohol or tobacco the hours prior to the test. Subjects were asked to avoid a list of skin influence factors concerning daily activity and habits.

The study was conducted in three stages: the first one corresponded to a familiarisation period where the objectives, requirements and right technique of the exercises were described to the subjects, as well as the collection of anthropometrical data from the sample. The second one consisted of the performance of a 1RM (1-repetition maximum) of each exercise. Finally, the third stage consisted of hypertrophy training.

The training program started with a 5-minutes warm-up in cycle. The same order for exercises were followed for all participants, starting with bench press, leg press (main exercises), and followed by flat bench cable fly and leg extension (more analytic). Before each exercise, subjects did from 6 to 10 repetitions with light load to check the right technique and rhythm of execution. All the participants performed 4 x 10 rep (70% of 1RM) of the four exercises with 90" between sets and 3' of resting among exercises. Participants were instructed to perform the movement at a rate of 2:2 (2 seconds eccentric - 2 second concentric phase). All subjects were followed during the whole training season, providing them with real-time feedback about velocity and movement angle on each exercise. Immediately after the last repetition of leg extension, all subjects were to the acclimated room to do the thermography images.

Ten series of four thermograms (Anterior and Posterior of the Upper and Lower body) were registered before the exercise (B), immediately after (A) and once each hour during the eight following hours after the workout ("A+1" to "A+8"). Maximal, minimal, average and standard deviations of the temperatures from 24 anatomical Regions of Interest (ROI) were obtained from the thermograms using Termotracker software (Pemagroup, Spain). The thermographic analysis of the data followed the patterns set by Gomez Carmona et al. (2010) patented pending protocol. After the training trial, subjects remained in the room during the 8 following hours with a constant temperature between 18.5ºC and 21.0ºC. The statistics treatment consisted on a descriptive analysis, as well as an ANOVA and Tukey test to check the "time" factor with a significance value of $p < 0.05$.

RESULTS: In table 1 averaged temperatures and standard deviation are presented, taken from the analysis of joint areas from the baseline moment before the training, immediately and 8 hours after the trial, likewise the ANOVA result considering the ten time thermal data recorded. In table 2 the same results are presented for the muscles regions.

Table 1
Averaged temperature and standard deviation in joints ROI before, immediately and 8 hours after strength training.

| RCI | RIGHT | | | | LEFT | | | |
|---|---|---|---|---|---|---|---|---|
| | **Rest** | **After Exercise** | **8 h Recovery** | *P* | **Rest** | **After Exercise** | **8 h Recovery** | *P* |
| SH-F | 31,98 ± 0,65 | 31,57 ± 0,83 | 32,38 ± 0,46 | 0,000 | 32,03 ± 0,66 | 31,66 ± 0,86 | 32,36 ± 0,59 | 0,010 |
| SH-B | 30,94 ±0,83 | 29,96 ± 1,23 | 31,32 ± 0,64 | 0,000 | 30,91 ± 0,86 | 29,91 ± 1,28 | 31,29 ± 0,75 | 0,000 |
| Knee-F | 28,31 ± 1,13 | 27,61 ± 1,23 | 28,32 ± 1,01 | 0,303 | 28,31 ± 1,24 | 27,43 ± 1,01 | 28,34 ± 1,20 | 0,132 |
| Knee-B | 31,00 ± 0,68 | 29,01 ± 0,91 | 30,99 ± 0,67 | 0,000 | 3,15 ± 0,79 | 29,33 ± 0,81 | 31,10 ± 0,71 | 0,000 |
| Elbow-F | 31,82 ± 0,71 | 31,86 ± 0,52 | 32,10 ± 0,63 | 0,850 | 31,77 ± 0,67 | 31,75 ± 0,56 | 32,00 ± 0,64 | 0,691 |
| Elbow-B | 28,95 ± 0,80 | 29,61 ± 0,69 | 29,42 ± 0,77 | 0,300 | 28,92 ± 1,00 | 29,67 ± 0,66 | 29,20 ± 0,97 | 0,341 |

SH = Shoulders; F = Front body ; B = Backs body

Table 2
Averaged temperature and standard deviation in muscles ROI before, immediately and 8 hours after strength training.

| RCI | RIGHT | | | | LEFT | | | |
|---|---|---|---|---|---|---|---|---|
| | **Rest** | **After Exercise** | **8 h Recovery** | *P* | **Rest** | **After Exercise** | **8 h Recovery** | *P* |
| Pectoralis | 31,78 ± 0,54 | 31,04 ± 1,12 | 32,39 ± 0,58 | 0,000 | 31,75 ± 0,58 | 31,08 ± 1,09 | 32,36 ± 0,58 | 0,000 |
| Lat-Dorsi | 31,12 ± 0,66 | 29,35 ± 1,15 | 31,74 ± 0,71 | 0,000 | 31,19 ± 0,66 | 29,44 ± 1,20 | 31,79 ± 0,69 | 0,000 |
| Arm F | 31,52 ± 0,66 | 31,47 ±0,70 | 31,84 ± 0,64 | 0,707 | 31,46 ± 0,70 | 31,48 ± 0,65 | 31,73 ± 0,71 | 0,847 |
| Arm B | 29,32 ± 0,97 | 29,09 ± 0,76 | 29,99 ± 0,77 | 0,026 | 29,27 ± 0,99 | 29,16 ± 0,76 | 29,92 ± 0,86 | 0,126 |
| Leg F | 29,68 ± 0,77 | 29,67 ± 1,01 | 30,06 ± 0,67 | 0,068 | 29,56 ± 0,76 | 29,63 ± 0,96 | 29,96 ± 0,66 | 0,120 |
| Leg P | 30,23 ± 0,93 | 28,65 ± 1,06 | 30,90 ± 0,71 | 0,000 | 30,25 ± 1,04 | 28,68 ± 1,09 | 30,90 ±0,71 | 0,000 |

Lat-Dorsi= Latissimus Dorsi; F = Front body ; B = Backs body

DISCUSSION: Of the 24 Regions of Interest (ROI) evaluated, in 13 (54%) of them a significant difference was found through the time. It could indicate specific thermal responses depending of the analyzed body area. Concerning joints areas, there is a tendency of skin temperature decrease after the training (presented in 9 of the 12 ROI). After eight hours of recovery, the temperatures were slightly higher in 10 of the 13 ROI compared to the rest condition. Asymmetries between body areas were very small. The thermal response of muscles regions also decreased immediately after the training in contrast to the rest condition, with an upward curve along the eight-hour recovery, being still warmer at the end of this period in comparation with the rest condition. There was a bilateral thermal symmetry condition in all muscle regions evaluated excepting for the posterior muscles of the right arm, which have a significantly difference.

CONCLUSION: Skin temperature presents specific responses depending on the ROI studied. There is a clear tendency to maintain a thermal symmetry response. Both the joints and in muscles regions, the temperature tends to decrease after the strenght training, but never with a greater difference than 2°C. In addition, after eight hours of recovery the general thermal response tend to be warmer as the rest condition, but not more than 1ºC.

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## PHYSIOLOGICAL AND PHYSICAL ASPECTS OF CUTANEOUS COOLING IN HEAT STRESSED HUMAN

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One expected effect of global warming is a higher frequency of more intensive heat waves, in southern regions as well as in northern. This will lead to a higher incident of heat related illness and death. Immediate and fast cooling is essential for reducing morbidity and mortality. In the Swedish health care system there are no guidelines for the initial care of people with heat related illness. The objective with this study was to gain deeper insight into human thermoregulation, focusing on the cutaneous circulatory response during cooling, identifying factors important for effective cooling and eventual risks for overheating. The methods used were literature review and heat balance equations. The results show that the human thermoregulation is of complex nature and is primary controlled via the cutaneous blood flow. This regulation is not yet fully understood Effective methods for cooling are; whole body immersion in circulating cold water, wetting of the skin with cold water and fanning. Water temperature for optimal cooling is yet not established. Heat balance equations established that best cooling effects were obtained via evaporation and convection. The wetted (water or ethanol) body area should be as large as possible and a high fan speed should be used directed across the body's longitudinal direction. Preferably, the skin should have a profuse blood circulation. Risk groups for exertional heat stroke are for example athletes, military and rescue personnel. The classical form of heat stroke usually occurs among the elderly, small children, chronically ill, and the physically or mentally disabled. Risk factors besides hot weather and high humidity are for example physical exertion, infection, certain drugs, social isolation, residing at an institution and lack of air conditioning. Subsequently, the results of this study lead us to recommend the following treatments, based on the individual's health condition: Total body immersion in cold circulating water or placing the individual in an airy hammock and spraying water continuously over the whole body whilst fanning. In summary, a larger assort of research is needed concerning heat related illness and the effects of different methods of cooling.

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## ASSESSMENT OF FEVER FOR INFECTIONS CONTROL BY USING THERMOGRAPHY IN JAPAN

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INTRODUCTION: In order to control for infections of a new type influenza and severe acute respiratory syndrome, the thermography is applied to monitor the patients with fever caused by the infection. However, the evidenced-based cut-off level of the thermographic index to discriminate the patients with fever from healthy people is yet to be established. Therefore, we compared the facial temperatures of the patients with fever and those of healthy volunteers, which are measured by the diagnosis standard advocated by the Japanese Society of Thermology, and the assessment for infectious control by using thermography has been reconsidered.

METHODS: Thermographic examinations were performed on 50 cases of healthy volunteers, 16 cases of patients with influenza type A and 2 cases with influenza type B. We performed acclimatization of subjects for 20 minutes in the environment of room temperature at 25.0-26.0°C and 50% of humidity. The axillary temperature was measured by a clinical thermometer. This study was performed under the approval of the ethical committee of Hyogo University of Health Sciences, and all human samples were obtained from whom written informed consents were obtained.

RESULTS: 1. The comparison between the facial thermographies of healthy volunteers and those of the patients with influenza: The facial temperatures of the healthy volunteers were observed as follows, i.e. forehead at 34.7 ± 0.4°C, right cheek at 34.1 ± 0.6°C, left cheek at 34.1 ± 0.6°C, nose at 34.5 ± 1.0°C and chin at 34.2 ± 0.6°C. On the contrary, the facial temperature of the patients with influenza were observed as follows, i.e. Forehead at 36.3 ± 1.9°C, right cheek at 36.2 ± 1.8°C, left cheek at 36.4 ± 2.1°C, nose at 36.4 ± 1.7°C and chin at 36.5 ± 1.8°C. The facial temperatures of the patients with influenza demonstrated significantly higher than those of the healthy volunteers ($P<0.05$, Welch's t-tests).

2. The correlation between the facial thermography and the axillary temperature measured by a clinical thermometer in the patients with influenza: The significant correlations were found in forehead ($R=0.57$, $P=0.04$), right cheek ($R=0.54$, $P=0.04$) and chin ($R=0.67$, $P=0.01$), while the correlations in left cheek and nose were not significant (Spearman's correlation coefficient by rank test).

DISCUSSION: When the facial temperature of the traveler was higher than cut-off level in quarantine office, the officer had been judging them to be positive with fever. This cut-off level, however, is has not been scientifically set by the data of patients with fever. In this study, the facial temperatures of the patients with influenza showed higher than that of the healthy volunteers, whilst the axillary temperature does not necessarily correlate with facial temperature. It might be difficult to detect patients with fever by using cut-off level only. The current study suggests that the new accurate evidence-based standard for the detection of patients with fever needs to be constructed for avoiding future pandemic.

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## THERMOGRAPHIC PROTOCOL OF HC-FMUSP: PUBALGY


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INTRODUCTION: The mechanical pain in the groin area presents an important and often confusing clinical dilemma. This is especially true in osteitis pubis, an inflammatory condition affecting the pubic symphysis.

The osteitis pubis (pubalgia) is a syndrome characterized by inflammation of the pubic symphysis pain in this region that produces and / or in the tendons of the adductors.

The first citation in the literature was made by Beer (1924) as a result of a complication of urological surgery. Currently, despite being relatively benign, has been recognized as a potential source of pain in athletes and have high morbidity, destroying careers at the peak of their performance or on the rise.

The infrared image (IRTG) is used since 1990 in various diseases, being non-invasive diagnostic method, non-radiative and non -ionizing, easy to perform and rapid response, able to quantify objectively, image, local inflammatory reactions of the musculoskeletal system plays an important role in monitoring the inflammatory activity and therapeutic evaluation.

Patients with pubalgia complain of dull pain, nonspecific bilateral pelvic throughout the region of the symphysis pubis, in the lower abdomen, groin and buttocks at the root of the thigh and inserts on muscle-tendon stiffness and occasionally neighbors. This pain is aggravated with the same efforts and relief with rest.

There are many causes of pubalgia, for example:
- Inserting the proximal enthesopathy average adduct
- Loss of strength of the abdominal wall or inguinal canal
- Changes in the morphology of the hip joint
- Fracture of the ischio-pubic branch of the femoral neck or
- Conflict of a space industry nervous
- Tumor formation in the groin
- Crural or inguinal hernia
- Endometriosis

METHOD: Thermographic examinations performed in patients with symptoms of pubalgia in order to record standard protocol.

The IR thermography (IRT) should be performed without prior manipulation of the patient (physiotherapy, acupuncture, massage, etc..) 12 hours prior. In the case of female patients to prevent menstrual period no interference pattern termovascular.

Report to the patient throughout the procedure and provides informed consent to be signed by the same. You must also get a brief history of the disease and record of examinations as well as examination of the skin (varicose veins, skin folds, wounds, bruises, tumors, etc ...)

The examination must be performed at room temperature between 20 and 21° C and the patient should be acclimatized and it should remain naked for 10 to 15 minutes without touching, rubbing or pressure.

Since there is a local inflammatory reaction, preferably carries it from 09:00 to 12:00 am. Do not smoke until 90 minutes before the exam. Perform sensitivity test standard 24-34 ° C Preferably keep two identical images reproducible.

As for positioning, leaving the patient walk and record whole-body imaging (front and back) then the pelvis (anteroposterior, posteroanterior, D and E and oblique, MMII face internal and external). Complete the examination record of the pubic region.


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## TEMPLATED MODEL FOR HAND MEDICAL THERMAL IMAGE STANDARD ANALYSIS


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INTRODUCTION: Medical thermal images of hands provide clinical information about their physiological state. Despite all healthy humans have two hands with five fingers each, these limbs are characterized of having complex shape, which differ slightly within subjects such as their size. It makes is difficult to execute an accurate analysis. A standardization method is needed to perform an accurate comparison or average of several images.

METHODS: The method used in this experiment defines a geometrical approximate shape template model based on an average shape of hand. Using anthropometric reference measurements with 38 control points delineating each hand areas of interest composed of triangles (figure 1).

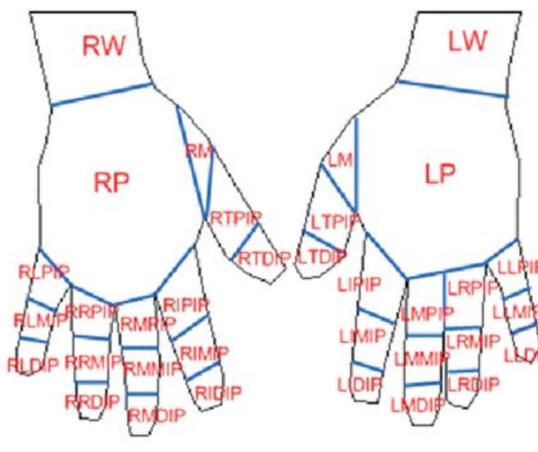


Figure. 1
Hands model with areas of interest

For the translation of pixels information within the areas of interest from original thermal images to the resultant standardized images, a translation algorithm based on warping triangulation through barycentric coordinates was used (figure.2).

RESULTS: The templated model allowed scaling and alignment of thermal images without scrambling the original data between

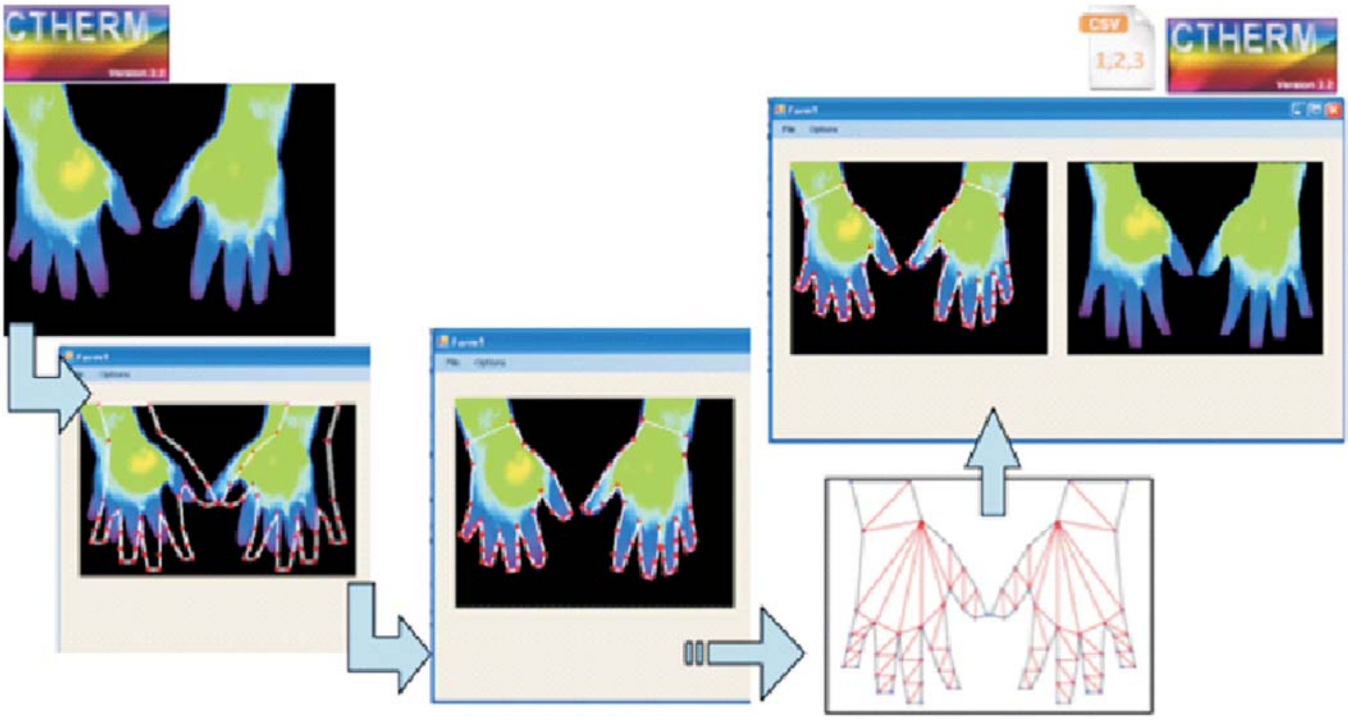


Figure 2
Method used in the experiment

different anatomical areas in an average time per image of 1.72 seconds. This simple process of warping thermal images presented an accuracy of 98% within the studied 1200 images. The calculated error between users of the developed application was inferior to 1% within the tested 12 users.

Discussion: Standardising several hand images is possible using this technique along with extended statistical evaluation, discrimination and balancing of groups of images with minimal processing time. However, work future work is needed in the automatic discovery of the areas of interest delineation control points.

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## THE EFFECT OF DIFFERENT VIBRATION EXERCISE FREQUENCIES IN THE SKIN TEMPERATURE OF LOWER EXTREMITIES IN HEATHY SUBJECTS

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INTRODUCTION: Vibration exercise has been increasing used for leisure, sport and clinical settings, however their effects in blood flow and consequently in skin temperature remains unknown. The aim of this research is to study the impact of acute exposure to different vibration frequencies of whole body vibration in the skin temperature of the lower extremities in healthy subjects.

METHODS: The skin temperature of twelve healthy and untrained subjects was accessed using thermography, before and after exposure to vibration exercise with different vibration frequencies. A standard capture protocol was followed for image recording, subject, examination room and equipment preparation. The mechanical stimulation was provided by the Power Plate® with parameters set at frequencies of 35Hz and 40Hz, high amplitude (5-6mm), and therefore a peak acceleration of approximately 7g, for 5 minutes.

RESULTS: The analyzed regions of interest mean temperature increased in the lower legs. In all other regions of interest there was a decrease in the mean temperature in both vibration exercise frequencies.

DISCUSSION: The obtained results demonstrated that the exposure to 5 minutes of vibration (35Hz and 40Hz) in a single session has an effect in the skin temperatures of the lower extremities. This should take in consideration before vibration exercise prescription since decreased microcirculation of the lower extremity has been reported as a complication of ageing and disease processes such as diabetes. The results of this investigation can be used as a reference for assessing future research in specific pathologies affecting the lower limbs.

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## CORRELATIONS BETWEEN QUANTITATIVE SENSORY TEST AND INFRARED THERMOGRAPHY IN LOW BACK PAIN PATIENTS - A PILOT STUDY

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BACKGROUND: Infrared Thermography (IT) has been proposed as a potential tool to assess musculoskeletal pain. However, there is a paucity of studies evaluating the correlations between low back pain, trigger points (TrP) and thermogram data.

METHODS: Thirty patients with primary low back pain (mean pain VAS> 30mm) and active TrP were included. They filled out the first part of the Brief Pain Inventory and underwent low back IT and mechanical quantitative sensory testing (mechanical detection, pain and supra-threshold-MDT, MPT, MSupra) of four points marked on the skin: the most intense pain location (MIPL) as pointed by the patient, its mirror area in the contralateral side (MIPL-mirr); the skin area over the main active trigger point (MATP) and its mirror area (MAPT-mirr). MIPL was central (MIPLA-C) when located + / - 1 cm from the midline and lateralized (MIPL-L) when > 1 cm. IT: Patients were evaluated unclothed, two meters away from the camera in a 22° C room (A320, FLIR, USA).

RESULTS: Twenty-eight patients were included (47 years, 22 female; VAS = 51 mm). MIPL-L was lower than the MIPL-C [40.0 (12-93) vs. 69.2 (34-90); p = 0.009). MSupra in MIPL-C was more intense than in MIPL-L (81.6 +/- 15 vs. 66.0 +/- 20.1; p = 0.049). The difference between MIPL and MIPL-mirr MSupra scores correlated to the IwVAS score (rho=0.51). MIPL and MATP X and Y coordinates showed high correlation (rho=0.76 and 0.50). Temperature on MIPL and MTPL correlated (rho=0.83).

CONCLUSIONS: Centrally located pain was more intense and presented higher mechanical hyperalgesia than lateralized pain. The area of maximal pain was spatially close and presented similar temperature as the area over the MATP.

## THE EXTENT OF CONVECTIVE COOLING

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INTRODUCTION: Just as wind cools down one's skin when exposed, it also cools down a hotspot on electrical systems, especially those brought about by $I^2R$ losses. A good rule of thumb that's been used in industry for many years is that a 16km/h (10mph) wind can reduce a hotspot's temperature by up to 50% and a 24km/h (15mph) wind can reduce a hotspot's temperature by up to 60%. Do these "rules" still apply to the thermography industry? The problem with these "rules" is that it does not mention anything about the hotspot temperature. Does this means that the same results would be obtained irrespective of the hotspot temperature?

The cooling effect of convection can be seen as the "wind chill" of non-living objects. The rate at which convective cooling occurs depends on Newton's law of cooling:

$$Q = h \times A\Delta T$$

Where:

Q= Heat energy in Watts or Btu/hr

h= Convective heat transfer coefficient

A = Area

ΔT = Temperature difference

METHODS: To test Newton's law of cooling and the rule of thumb a relatively simple experiment were conducted. For the experiment two heat sources of similar type, at different temperatures, were exposed to the same wind conditions for the same duration of time. The temperatures of the heat sources were randomly selected and the wind speed varied from 5km/h (8mph) to 30km/h (48mph). During the experiment, thermal images were taken every minute over a 10 minute period of which the wind was forced towards the heat sources

RESULTS: The normal reaction would be that a hotter heat source will loose more temperature compared to a colder heat source when exposed to convection for the same period. This is true if we consider only °C lost. This can be seen in table 1.

Table 1
Temperature loss of heat source X and Y.

| | av. wind speed in km/h | T at 0 minutes in °C | T at 10 minutes in °C | T loss in °C | % T loss |
|---|---|---|---|---|---|
| Heat source X | 7.63 | 496.00 | 447.90 | 48.10 | 9.69% |
| Heat source Y | | 248.00 | 210.47 | 37.53 | 15.22% |
| Heat source X | 10.25 | 494.53 | 431.20 | 63.33 | 12.75% |
| Heat source Y | | 253.13 | 199.40 | 53.73 | 15.38% |
| Heat source X | 15.19 | 497.30 | 418.90 | 78.40 | 17.85% |
| Heat source Y | | 251.27 | 186.17 | 65.10 | 26.18% |
| Heat source X | 18.50 | 495.40 | 396.10 | 99.30 | 21.65% |
| Heat source Y | | 243.93 | 178.80 | 65.13 | 26.39% |
| Heat source X | 22.67 | 496.17 | 384.63 | 111.54 | 24.61% |
| Heat source Y | | 243.27 | 172.50 | 70.77 | 30.20% |
| Heat source X | 28.18 | 498.17 | 365.93 | 132.24 | 28.54% |
| Heat source Y | | 252.10 | 167.77 | 84.33 | 35.27% |

CONCLUSION: For this experiment the hotter heat source temperature were reduced by 17.9% when it were exposed to an average wind speed of 15.2km/h for 10 minutes and 28.5% when it were exposed to a 28.2km/h wind for 10 minutes. The colder heat source temperature were reduced by 26.2% when it were exposed to an average wind speed of 15.2km/h for 10 minutes and 35.3% when it were exposed to a 28.2km/h wind for 10 minutes. These values differ from the rule of thumb. From the experiment results it seems that wind of nearly 16km/h (10mph) do not reduce the hotspot temperature by 50% but by nearly 20% and a 28km/h (17.5mph) wind will reduce the hotspot temperature by nearly 30% and not 60% as thought

Table 2
Rule of thumb vs experiment results

| | % Temperature loss | | |
|---|---|---|---|
| **Wind speed in km/h** | **Rule of thumb** | **Hotter heat source** | **Colder heat source** |
| 15.2 | 50 | 17.9 | 26.2 |
| 28.2 | 60 | 28.5 | 35.3 |

earlier depending on the hotspot temperature. The results are summarized in Table 2.

Due to a combination of various factors that influence the temperature readings as well as airflow around the heated object that were not considered during this study, the results of this study cannot be used to formulate a correction factor for wind but can only serves as an indication to the behavior of hotspots in windy conditions. By taking the above mentioned results into account next time you do a thermal survey in windy conditions, will add more credibility to your reported results.

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## DEVELOPMENT OF A CLINICAL VASCULAR OPTICS MEASUREMENT FACILITY - THE NEWCASTLE UPON TYNE EXPERIENCE

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The microvascular diagnostics service based in Newcastle upon Tyne provides a comprehensive array of mainly optical and thermal technologies which are utilised to access micro- circulatory blood flow and function. These vascular optical techniques include thermal imaging, capillaroscopy, laser Doppler imaging and flowmetry, tissue spectroscopy and multi-site photoplethysmography. The test portfolio covers four main areas: Connective Tissue Disease and Raynaud's phenomenon assessments, Specialist Limb studies (i.e. amputation level, muscle compartment perfusion and venous physiology), Neurovascular Assessment and Burn Depth Assessment. The measurement service at Freeman is greatly benefiting from a new state- of-the-art purpose-built temperature and humidity-controlled room, enabling investigations to be performed efficiently and with confidence. The room's special air conditioning system can also be programmed to rapidly shift operating conditions between cold (e.g. 15 oC) and hot (30 oC) ambient temperatures for whole body thermal physiology assessments. Development project work is undertaken which includes microvascular endothelial function assessment, novel assessments in Chronic Fatigue Syndrome / ME, multi-site photoplethysmography, fluorescence spectroscopy in scleroderma, and thermoregulation in restless leg syndrome and Frey syndrome. The measurement facility forms a unique clinical measurement and research resource in the UK. The history and development of the facility, routine clinical services offered, and research work currently undertaken will each be summarized.

## EVALUATION OF MICRO-CRACKS IN FACADES USING THERMOGRAPHY

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Infrared thermography is a non-destructive testing technology that can be applied in several areas of knowledge. Cameras collect infrared radiation emitted by the surface, covertly into electrical signals and create a thermal image showing the superficial temperature distribution.

Thermography has been applied to buildings for some decades and allows the detection of insulation defects, air leakage, heat loss through windows, dampness, "hidden details" (subsurface pipes, flues, ducts, and wall ties), examination of heating systems and preventive maintenance. The potential for this technology is high although its application to civil engineering has not been greatly studied.

The Building Physics Laboratory (LFC) of Engineering Faculty - Porto University (FEUP) has been carrying out research in this field over the last ten years. Several studies were carried out, namely:

"Sensibility analysis of parameters that affect measurements (emissivity, environmental conditions - temperature and relative humidity, colour and reflectivity);

"Studies concerning the wetting/drying process and capillary absorption of specimens;

"Studies about thermal comfort of floor coatings.

One important question is to know if thermography allows a quantitative approach or only a qualitative one. To answer this question we have been developing a research proposal with a project financed by FCT (PTDC/ECM/114189/2009) where one of the goals is to show if a quantitative analysis in thermography is a real possibility.

In this paper we present the results of wetting/drying processes of wall coating samples with micro-cracks carried out in laboratory with very closely controlled climatic conditions (inside climatic chamber). The same experiments were made "in situ" on different facades of micro-cracked buildings. It was clearly demonstrated the difficulty to control measurements in field conditions due to the wide range of parameters that may affect the termograms.

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## INFRARED IMAGING OF THE CRANIO-CERVICAL-MANDIBULAR COMPLEX IN BRUXISM PATIENTS

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INTRODUCTIOn: Many authors have suggested the existence of a functional dependence between the cervical muscle and mastication muscles. In the sequence of this functional dependence postural, changes, especially in the head and neck, can influence certain neuronal-muscular patterns leading to the development temporomandibular disorders. The existing of hyperactivity of the mastication muscle in bruxism patients can originate areas of neuro muscular sensibility that can be detected by thermography with asymmetric thermogram patterns. It is therefore important to evaluate the existing differences of head and neck posture in bruxism patients and asymptomatic individuals and the respective correlation of the thermographic patterns.

METHODS: 32 individuals (16 bruxism patient and 16 asymptomatic individuals) ages between 22-26 years old, all students of the Dental Faculty of Porto University were selected for this experiment. A clinical examination was made in order to diagnose the presence of signs and symptoms of bruxism. The thermographic evaluation was made using the thermographic camera FLIR® A325.

RESULTS: The temperature differences obtained by thermography showed asymmetric patterns in the temporomandibular joint and within most of the muscles of the cranio- cervic-mandibular complex.

CONCLUSION: Infrared imaging technique can be a complement method of diagnostic in temporomandibular disorders, when evaluating the possible association of specific muscles of the cranio-cervico-mandibular complex with an increased muscular activity seen in bruxism patients.

## ASSESING THE TEMPOROMANDIBULAR JOINT TEMPERATURE OF PROFESSIONAL SINGERS USING INFRARED THERMOGRAPHY

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Professional singers need technical, physical and physiological skills that determine their career regarding the performance productivity. Performing arts medicine studies the pathological consequences of a daily activity inherent to various artists, in this particular case we intend to introduce infrared thermography in the examination of the biomechanics of the temporomadibular joint (TMJ) during singing. It is important to study and have a precise screening of any eventual problems inherent to their daily activity with specific tasks, on maintaining different vocal registrations according to their pitch. The orofacial structures in this particular case should be of vital importance for professional singers, especially the TMJ.

In this research we studied the TMJs biomechanics in a group of Professional singers in order to diagnose temporomandibular disorders (TMDs) and/or condilar hypermobility, and compared the different existing thermogram patterns using the thermographic camera FLIR® A325. Lateral thermograms of the TMJ were obtained of the professional singers.

## EVALUATION OF THE MASTICATORY MUSCLES TEMPERATURE BY THERMAL IMAGING DURING MASTICATION

L. Barbosa[1], M. Clemente[1], A. Silva[2], J. Gabriel[2], J. Pinho[1]

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Mastication is a complex process involving many different movements, as well as automation of different intra and extra oral structures. In this context, the mastication not only involves jaw movements, but also other associated structures, such as head and neck, with a mandibular kinematic and/or alteration of bioelectrical potentials of the muscles involved in chewing. This study intended to compare the bioelectrical potentials during mastication, of the masticatory muscles when chewing a carrot, with the thermal imaging obtained of lateral orofacial thermograms with the thermographic camera FLIR® A325, before and after mastication. Ten young, healthy individuals, without temporomandibular disorders (confirmed by the Research Diagnosis Criteria) and with full dentition, were included in this research.

# News in Thermology

## AAT Newsletter re-established

During die reconstruction process of the American Academy of Thermology which started last year, the AAT newsletter was revived and two issues were already published. The following information was taken from this publication

## AAT Newsletter March 2012 - Editors Column

We are pleased to accept the editorship of the AAT newsletter. It is our hope that the newsletter can be a forum for not only providing information regarding academic conferences and progress in thermography, but for the exchange of ideas and clinical insights regarding the use of medical thermography.

Our experience with complex regional pain syndrome spans over 20 years. While over the past 10 years we have used the autonomic testing battery and quantitative sudomotor reflex testing as diagnostic tools for this condition we found that the results still left us with questions concerning the clinical presentations we were challenged with. We expanded into Medical Infrared Thermal Imaging to fill that gap.

After we set up our Thermography laboratory we had the good fortune of meeting Dr. Bobby Schwartz who encouraged us to attend an AAT Certification Course. We are delighted to say that we did the same. Not only was our understanding of the unique role that Medical

Thermography can play in the diagnosis of patients with CRPS enhanced but so was our ability to change our treatment plans in a meaningful, patient specific way based upon the findings. After our laboratory was in operation for about six months we had gained an even broader perspective on the clinical utility of thermographic assess ment.

We believe that to advance further as a legitimate medical diagnostic tool, thermography requires further standardization of diagnostic protocols as well as continued clinical research emphasizing quantification of sensitivity and specificity of thermography measured in defined clinical situations. We hope that this newsletter will serve as a forum for encouraging this type of research and communicating results to a broad audience of interested clinicians, as well as a medium for communication among interested clinicians utilizing thermography in a variety of medical applications.

We plan on publishing this newsletter on a quarterly basis and each month hope to add more features to it. The AAT is its membership so we invite you to participate in any fashion that you feel comfortable. If you want to help out with the newsletter just let us know. Send any letters to the editors, comments, or interesting clinical observations that you would like to share with your colleagues to:
editor@aathermology.org.

J. Tashof Bernton MD and George Schakaraschwili, MD
Co Editors, AAT Newsletter

## AAT Newsletter March 2012 - President's Column

With the turn of the new year the American Academy of Thermology has started a new chapter in its 28 year history. We have successfully kicked off the 2012 membership drive, instituted new Bylaws, consolidated our tax, banking and reporting obligations, and refreshed the Academy Web site. We have received regular inquiry about our plans for external resources and are working to make ourselves more visible to the community. We are pleased with the progress we have made so far.

At this time I would like to introduce each of you to the current AAT Officers and Board. Jeffrey Lefko, MHA is our Executive Director. Jeff has been an executive director for the Joint Commission in the past and his wealth of experience is a big asset to the AAT.

Philip Getson, DO, a longtime member of the AAT, has also joined the Board. He lectures frequently throughout the country on both neuro musculoskeletal and breast applications for thermal imaging. One of Philip's major responsibilities is chairman of the AAT Breast Thermal Imaging Guidelines Committee. Not surprisingly Philip has had to jump right in. His contributions thus far are already greatly appreciated.

Bryan O'Young, MD has also joined the Board. Bryan hails from the Rusk Institute at NYU and has been a major advocate of Medical Infrared Imaging. He is an international speaker and is assisting the Academy in its plans to put on upcoming national and international meetings.

Timothy D. Conwell, DC has returned to the Board as well. Tim has shown consistent support of the AAT over time. His perspective and insight have already made a big impact on how we move forward.

James Melton, MHA is a new member to our Board. James is a great asset for us. He has served as the Executive Director of the Duke Clinical Research Institute at Duke University.. His contacts and breadth of experience in the research and academic arena are invaluable to us.

Last but not least, we are blessed that James Giordano, PhD has joined the AAT Board. James is the Director of the Center for Neurotechnology Studies and VP of Academic Programs for the Potomac Institute for Policy Studies. He is recognized as one of the world's leading neuroscience professors and has a strong interest in promulgating thermal imaging for neuromusculoskeletal disease.

We have created several new committees and have started to fill several positions within them. The most notable addition is the Past Presidents Emeritus Committee. The AAT has a long line of truly noteworthy and highly respected Past Presidents. This committee will allow for those Past Presidents that want to continue to make a contribution to do so from an elevated pedestal within the Academy. We have already contacted several Past Presidents who are eager to help out and plan to continue to reach to those we have not yet contacted.

Of course special thanks is given to J. Tashof Bernton, MD and George Schakaraschwili, MD for co-chairing the AAT newsletter and editing the premier edition. I also want to thank Dr. Andrzej Zielke, MD for serving as chairman of the Devices & Equipment Committee and Maria Ponton, DOM, Lac for serving as chairperson of our CAM & Allied Health Committee. Both are committed to advancing the goals and objectives of the Academy.

We have several committees that need to be filled. In addition to those mentioned earlier there are open positions in both Technical and Clinical Guidelines, and Membership. Please don't hesitate to contact the Academy from our websitehttp://www.aathermology.org or just email us at contact@aathermology.org if you have interest in participating on any level.

We need everyone's support and look forward to helping find a place for anyone that wants to help. 2012 is a watershed year for the AAT. Now is the perfect time to get involved.

Bobby Schwartz, MD
President, AAT

## AAT Newsletter June 2012
## Executive Director's Column

Over the last several months as the Executive Director of the American Academy of Thermology, I have had the opportunity to work with many dedicated and passionate people who share the same interests in preserving and advancing the Mission of AAT since 1971 as the "premiere organization in North America for the scientific development, healthcare training, and clinical application of medical infrared imaging". This Mission is the driving force behind the work and the services we are trying to bring to our Members.

I'd like to share with you some of the progress we are making in this year's plans to move AAT forward and ways for our members to assist in these efforts. We have created with our Board leadership, several opportunities for membership input and guidance through the revitalization of our Standing Committees as well as other Committees and Advisory Groups. These will create new and expanded ways for our members to contribute and to share with other members.

The core of any Academy like AAT is our membership and suffice it to say that our dedicated efforts are focused our membership.An expanding and vibrant membership organization like ours can only remain that way with involved and interested members. We encourage you to help us by encouraging other professionals interested in thermography and infrared medical imaging to join us and get involved in AAT.

We are now actively planning our CME sponsored AAT Annual Scientific Session to be held on Saturday, October 27, 2012 in Greenville, South Carolina. The Scientific Session will be preceded on October 26th with an AAT Certification course and followed on the 27th with AAT Committee and Board Meetings. Early registration is encouraged as the registration fees increase after July 4th. Members can take advantage of discounted registration fees. Please visit our web site at www.aathermology.org. for more information on this landmark scientific session and a weekend of activities on October 26-28th, 2012.

We are in the process of adding new AAT membership benefits and services as well as enhancing many of our existing services. Many of these are in various stages of development and completion. I encourage you to visit www.aathermology.org for more details regarding AAT structure, membership, benefits, and resources.

Several benefits and new services including expanded certification training and examinations, compendiums of Official Statements, and Thermology Practice Guidelines including the soon to be released internationally peer-reviewed AAT Guidelines on Breast Thermography. As we build out a complete Members Only Resource page there will be more opportunity for the AAT website to become the best resource for Meetings and Conferences, Networking Opportunities, Discussion Groups and Reference accumulation. These are all in the process of development and implementation.

I look forward to working on all of these exciting efforts the AAT Board, committees and advisory groups, and with all of our AAT members to make this year the most important year in AAT's history. In order to do that, we appreciate your active membership and your involvement. Please contact me at jlefko@aathermology.org. We want your input as well as your questions and comments.

Jeffrey Lefko. MHA
Executive Director, AAT

## General Assembly of the EAT in Porto

This year, the function period of the **EAT Board** and the **Council of National Representatives** will end. Therefore, a General Assembly is scheduled for the

**5th September 2012,** 17 hours
during the 12th European Congress of Thermology in Porto, Portugal, at the **Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal**

With the following Agenda:
Report of the president
Report of the treasurer
Statement of the auditors
Appointment to the Council of National Representatives
Election of a new board
Miscellaneous

Nominations for Board membership, the Council of National Representatives membership and other applications to the General Assembly must reach the Board in writing at least 3 days beforehand.

# Meetings

## 5th September 2012
## EAT certified Pre-CongressMedical Thermography 1-day course

Faculty of Engineering at University of Porto,

Course program:

09h00-09h10 -> Registration

09h10-09h15 -> Opening (R. Vardasca & J. Mercer)

09h15-09h45 -> Heat Exchange and IR Radiation (R. Thomas)

09h45-10h30 -> Concepts of thermal physiology (J. Mercer)

10h30-10h45 -> Coffee break

10h45-11h15 -> Infrared equipment operation (P. Plassmann)

11h15-12h00 -> Medical Reasons for temperature changes and provocation tests (K. Ammer)

12h00-12h30 -> IR Image analysis and reporting (R. Vardasca)

12h30-14h00 -> Lunch

14h00-16h00 -> Practical session (P. Plassmann, R. Thomas, J. Mercer, R. Vardasca)

16h00-16h10 -> Coffee break

16h10-16h40 -> Examples of applications in medical thermography (F. Ring)

16h40-16h55 -> Educational resources in Medical Imaging (K. Ammer)

16h55 -> closing (J. Gabriel and J. Mercer)

## 5-8 September 2012,
## XII EAT Congress on Thermology and 25th Symposium of the Austrian Society of Thermology in Porto, Portugal

Conference Secretariat
Miss Tatiana Oliveira

Faculty of Engineering, UP
Rua Dr. Roberto Frias, s/n
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Fax: +351 22 508 1445

## Preliminary Programme

| time | Wednesday | Thursday | Friday | Saturday |
|---|---|---|---|---|
| 08:30 | | Registration | Morning Session | Morning Session |
| 09:00 | Course part 1 | Morning Session | | |
| 09:30 | | | | |
| 10:00 | | | | |
| 10:30 | Coffee break | Coffee break | Coffee break | |
| 10.45 | Course part 2 | | | |
| 11:00 | | Morning Session | Morning Session | Coffee break |
| 11.30 | | | | Morning Session |
| 12:00 | | | | |
| 12:30 | | Lunch | Lunch | |
| 13:00 | Lunch | | | Lunch on-board at Douro river and visit to a Porto wine vineyard and return in a touristic train |
| 13:30 | | | | |
| 14:00 | | Afternoon Session | After-noon Session | |
| 14:30 | Course part3: Practical session | | | |
| 15:00 | | | | |
| 15:30 | | | | |
| 16:00 | | | | |
| 16:30 | Course part 4 | Coffee break | Coffee break | |
| 17:00 | | Evening Session | Evening Session | |
| 17:30 | EAT General Assembly | | | |
| 18:00 | | | | |
| 18:30 | | | | |
| 19:00 | | Visit and event at Casa de Musica | Visit and ceremony dinner at Tailors Porto wine cellar | |
| 19:30 | | | | |
| 20:00 | Reception at Solar do Vinho do Porto (Porto wine and snacks) | | | |
| 20:30 | | | | |
| 21:00 | | | | |
| 21:30 | | | | |
| 22:00 | | | | |
| 22:30 | | | | |

## DAY 1 - 06 September 2012

08:30 Registration

09:00 Congress opening

09:10 Keynote presentation: **The History of Thermology and Thermography - The Pioneers and Milestones - F. Ring (UK**)

09:35 Accuracy When Assessing and Evaluating Body Temperature - M. Sund-Lavander (SWE)

09:55 Core Temperature Evaluation: Suitability of Measurement Procedures - E. Quelhas Costa (POR)

10:15 Potential Errors in Mean Skin Temperature Calculations Due to Thermistor Placement as Determined by Infrared Thermography - D. Pascoe (USA)

10:35 Coffee-Break & Posters (I)

11:00 Measuring Human Psicophysiological Response to Combined Temperatures and Humidities: A Climatic Chamber Validation - J. Guedes (POR)

11:20 Skin Temperature and Microvascular Blood Flow Changes in the Fingers Following a Deep Inspiratory Gasp Manoeuvre J. Allen (UK)

11:40 Application of Cold Provocation for Breast Cancer Screening Using IR Thermography - B. Wiecek (POL)

12:00 The Effect of a Vibrating Plate in the Skin Temperature of Lower Extremities in Healthy Subjects - A. Seixas (POR)

12:20 Using Clinical Thermography as Diagnostic Complementary Procedure for Hand Arm Vibration Syndrome - R. Vardasca (POR)

12:40 LUNCH

14:00 Keynote presentation: **Evolution of IR Cameras, Images and Detectors - R. Thomas (UK**)

14:30 Assessment of Calibration and Evaluation Procedures for Thermal Imaging Metrology at the National Physical Laboratory R. Simpson (UK)

14:50 Reliability and Reproducibility of Skin Temperature of Overweight Subjects by An Infrared Thermography Software Designed for Human Beings - I. Fernández-Cuevas (ESP)

15:10 3D Infrared Thermography - P. Plassmann (UK)

15:30 Integrating Medical Thermography on a RIS Using DICOM Standard - T. Vardasca (POR)

15:50 Histographic Method as a Tool of Thermal Image Processing - I. Benko (HUN)

16:10 Coffee-Break & Posters (II)

16:40 Usefullness of Thermographic Examination for Detecting Hypothermia, H. Usuki (JAP)

17:00 The Temperature of the Human Knee - A Review - K. Ammer (AUT)

17:20 Scrotal Infrared Digital Thermography for Detection of Subclinical Varicocele - A. Merla (ITA)

17:40 Sy)mmetry of the Skin Temperature of the Lower Limbs in Young Soccer Players - D. Moreira (BRA)

18:00 Thermography as an Alternative Tool to Determine Pressure Distribution on the Stump of Transfemural Amputees E. Mendes (POR

18:45 DEPARTURE TO CASA DA MÚSICA

## DAY 2 - 07 September 2012

08:30 Registration

09:00 Keynote presentation: **Thermography in Plastic Surgery - J. Mercer (NO**R)

09:30 Thermography of Facial Skin Temperature in Healthy Subjects During Cooling of the Face With Hilotherapy - K. Howell (UK)

09:50 Infrared Thermography in Plastic Surgery: A Comparative Study of Pre and Post-operatory Abdominal Skin Circulation After Different Techniques - The Effect of Undermining - C. Nogueira (BRA)

10:10 Method for Infrared Images Description: 10 Years of Medical Report Experience - M. Brioschi (BRA)

10:30 Coffee-Break & Posters (III)

11:00 Infrared Thermography Assessment of Infantile Hemangioma Treatment by Propanolol - F. Ring (UK)

11:20 Mother and Child in Synchrony: Thermal Facial Imprints of Autonomic Contagion", A. Merla (ITA)

11:40 Screening Fever, A New Approach", A. Cardoso (POR)

12:00 Thermal imaging in Graves' Orbitopathy - J. Allen (UK)

12:20 Correlations Beween Quantitative Sensory Test and Infrared Thermography in Low Back Pain Patients - M. Lima (BRA)

12:40 LUNCH

14:00 The Utilization of Functional Infrared Imaging Signature Index Protocols in Staging Patients with Complex Regional Syndrome (CRPS) - T. Conwell (USA)

14:20 CRPS: Complex Regional Pain Syndrome type I and Thermography: a new tool for Diagnosis? - L. Laino (ITA)

14:40 Thermography in Front Crawl Swimming at Anaerobic Threshold Intensity - K. de Jesus (POR)

15:00 Effect of Yoga and Swimming on Body Temperature of Pregnant Women - M. Sillero (ESP)

15:20 The Highly Focalized Thermotherapy in the Treatment of Solid Tumours: Temperature Monitoring Using Thermography A. Portela (POR)

15:40 Temperature Changes During Ketamine Anaesthesia in Laboratory Animals - P. Ribeiro (POR)

16:00 Coffee-Break & Posters (IV)

16:30 Thermography and Dental Pathology - A. Mostovoy (CAN)

16:50 The Usefulness of Thermography in the Assessment of Temporomandibular Disorders in Orchestra Musicians M. Pais Clemente (POR)

17:10 Bone Temperature Changes and Distribution During Dental Implant Bed Preparation - T. Pinto Ribeiro (POR)

17:30 Thermographic Evaluation of the Effects of Electrotherapy on Peripheral Circulation in Patients with Stroke - A. Nica (ROM)

17:50 Surface Temperature Evolution on Dancing Activities - L. Xarez (POR)

18:10 Keynote presentation: **Thermography in Viticulture - O. Grant (IRL)**

19:30 Departure to ceremony dinner

20:00 CEREMONY DINNER AT TAYLORS CAVE & POSTER PRIZE

## DAY 3 - 08 September 2012

10:00 Keynote presentation: **Thermography in Equine Medicine and the Influence of Different Environmental Factors on the Thermographically Determined Temperature - S. Westermann (AUT)**

10:30 Legality Associated with the Use of Infrared Thermal Imaging in Veterinary Medicine - R. Purohit (USA)

10:50 The Use of Thermography to Evaluate Back Musculoskeletal Responses of Young Racehorses to Training - M. Soroko (POL)

11:10 Coffee-Break & Posters

11:40 Effect of High Regional Nerve Blocks on the Thermographic Patterns in the Limbs of Horses - R. Purohit (USA)

12:00 Force Distribution in Wheelchairs Using Force Sensors and Thermography - A. Silva (POR)

12:20 Thermal Analysis of the Heating Process and Sealing of a Dye-Sensitized Solar Cell - F. Ribeiro (POR)

12:40 **Closing & Presentation prizes**

12:50 DEPARTURE TO DOURO CRUISER

## Posters:

PP1 Observation of Peripheral Capillary Blood Flow in Proximal Nails Folds and Thermography - T. Wanatabe (JAP)

PP2 Sympathetic Nerve Block Effects of Phototherapy Near Stellate Ganglion - I. Wanatabe (JAP)

PP3 Time to Stabilization of Thermographic Images at Rest - J. Marins (BRA)

PP4 Diagnostic Evaluation of Chronic Venous Insufficiency Cases Using Thermal Imaging - M. Martins (POR)

PP5 Thermal Response of the Skin Temperature on Muscle and Joint Body Areas After Strength Trainning by Infrared Thermography - J. Marins (BRA)

PP6 Physiological and Physical Aspects of Cutaneous Cooling in Heat Stressed Human - R. Christiansen (SWE)

PP7 Assessment of Fever for Infections Control by Using Thermography in Japan - H. Shibata (JAP)

PP8 Thermographic Protocol of HC-FMUSP: Pubalgy - M. Lima (BRA)

PP9 Templated Model for Hand Medical Thermal Image Standard Analysis - R. Vardasca (POR)

PP10 The Effect of Different Vibration Frequencies in the Skin Temperature of Lower Extremities in Healthy Subjects - A. Seixas (POR)

PP11 Correlations Beween Quantitative Sensory Test and Infrared Thermography in Low Back Pain Patients - M. Lima (BRA)

PP12 The Extent of Convective Cooling - R. Thomas (UK)

PP13 Development of a Clinical Vascular Optics Measurement Facility - The Newcastle Upon Tyne Experience - J. Allen (UK)

PP14 Evaluation of Micro-Cracks in Facades Using Thermography - S. Freitas (POR)

PP15 Infrared Imagign of the Cranio-Cervical-Mandibular Complex in Bruxism Patients- V. Castro (POR)

PP16 Assesing the Temporomandibular Joint Temperature of Professional Singers Using Infrared Thermography - F. Almeida (POR)

PP17 Evaluation of the Masticatory Muscles Temperature by Thermal Imaging During Mastication - L. Barbosa (POR)

## October 27, 2012, American Academy of Thermology Meeting in Greenville, South Carolina

**Pre Meeting Certification Course:**
Friday, October 26th, 2012

Take the next step toward AAT Membership status elevation! Take an AAT Certification Course

1:30pm - 7:30pm
Neuromusculoskeletal Emphasis On CRPS/RSD & Fibromyalgia

**General Sessions**:
Saturday, October 27, 2012

8am: Registration

8:30: Welcoming Remarks

8:45-10:30 Session 1: Basic Science, Clinical Conditions, Skin Temperature Regulation, AAT Guidelines & Indications

10:30-10:45 Break

10:45-12:00pm Session 2: Medical Thermal Imaging: Its Role in Objective Measurement and Treatment Planning

12:00pm-1:30pm Lunch (on your own, around town)

1:30pm-3:30pm Session 3: Vasomotor Monitoring, Neurovascular Considerations, Pitfalls and Look Alikes

3:30- 3:45 Break

3:45-5:00pm Session 4: Infrared Thermal Imaging Case Presentations and Paper Presentations

5:00-5:30pm Honor Ceremony for Past Presidents

6:30-7:30pm Meet and Mingle with the Leadership

**AAT Committte Meetings**:
Sunday, Ocotber 28th, 2012

8:30-10:00am AAT Board Meeting (Board Members only)

10:00-12:00pm AAT Committee Meetings:

Breast Guidelines

Complementary Alternative Medicine (CAM) and Allied Health

Devices and Equipment

Get Involved!
Journal/Newsletter

Membership

Past Presidents (Past Presidents only)

Website

e

## 2013

### March15th-17th,2013
### 17thNationalCongress of the PolishAssociation of Thermology in Zakopane

Abstract deadline: February 15th, 2013

Deadline for hotel reservation:March1st,2013

Registrationfee:200.-Euro

Local organizing committee

Prof. Anna Jung (Chair)
Dr Janusz Zuber (DeputyChair)
Dr BoleslawKalicki
Mgr Ing.Piotr Murawski

Further information

Prof Dr. Anna Jung

ajung@wim.mil.pl or a.jung@spencer.com

### 3-5 July, 2013
### 18th International Conference on Thermal Engineering and Thermogrammetry (THERMO)
### Budapest University of Technology and Economics

Information :

Prof.Dr.Imre BENKO"

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Thermology international

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• It serves as the official publication organ of the the American Academy of Thermology, the Brazilian Society of Thermology tthe UK Thermography Association (Thermology Group) and the Austrian Society of Thermology.
• An advisory board is drawn from a panel of international experts in the field. The publications are peer-reviewed.
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Thermology international

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