ISSN-1560-604X
Thermology international

Volume 29 (2019)
Number 3 (August)

Thermology International

Are the IR cameras FLIRONE suitable for clinical applications?

Exploring the association between pressure pain threshold and skin temperature in the upper trapezius of healthy subjects

Obituary: Prof EdwardFrancis John Ring 1935-2019

This journal is indexed in
EMBASE/Scopus

Published by the
European Association of Thermology

THERMOLOGY INTERNATIONAL

Volume 29 (2019) **Number 3 (August)**

Published by the
European Association of Thermology

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Are the IR cameras FLIR ONE suitable for clinical applications?

R. Vardasca[1,3], C. Magalhaes[2], P. Silva[2], B. Kluwe[3], J. Mendes[1]

[1]LABIOMEP, INEGI-LAETA, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal
[2]Faculdade de Engenharia, Universidade do Porto, Porto, Portugal
[3]Medical Imaging Research Unit, Faculty of Computing, Engineering and Science, University of South Wales, Pontypridd, United KingdomIntroduction

SUMMARY

BACKGROUND: Infrared Thermography (IRT) has been used in clinical environments for at least six decades. In 2014 affordable and attractive low-cost infrared cameras were introduced into the market that facilitated the ability of being attached to mobile devices such as tablets and smartphones. Despite these cameras do not satisfy the minimum specifications recommended for clinical use they have already been used in clinical applications. It is therefore important to verify the performance of these devices. In this paper the start-up stability and the absolute temperature offset, in particular within the temperature range of the human body, are evaluated using the android and iOS OEM connection versions of the FLIR ONE IR 2nd generation and compared from the end user point of view.

MATERIALS AND METHODS: Four FLIR ONE IR 2nd generation cameras were used, two developed to be attached to android systems and the other two to apple iOS systems. A start-up drift test at 30 ºC and a temperature sweep from 20 ºC to 40 ºC in steps of 1 ºC, representing the human body temperature range, were carried out. For the temperature performance assessments, a blackbody Isotech Hyperion R Model 982 was used as temperature reference (uncertainty of ±0.1°C). It was first set at 30ºC temperature reference for the start-up drift test, the cameras along with the attached devices were switched on and measurements were taken at five-minute intervals for one hour at a distance of 30 cm from the blackbody target. For the temperature sweep, the blackbody reference was set to 20ºC. Images were then taken with the IRT imaging devices and readings were taken while the blackbody setpoint was increased in steps of 1ºC up to 40ºC, waiting 15 minutes in between each step for blackbody temperature stability.

RESULTS: The FLIR One 2nd generation thermal cameras overestimate the temperature reading during the start-up offset drift test and take around 15 to 20 minutes to reach measurement stability with an average difference from the blackbody indicated temperature of 0.9 ºC. In the human body temperature offset drift test there is a higher difference from the calibration source at temperatures below 24 ºC, where the temperature readouts are more than 2.0 °C above the real temperatures set at the blackbody. There is a high interclass correlation between the thermal cameras' readings and the calibration source set temperatures and also between the measurements of the two OEM versions of the thermal cameras studied. The span of limits of agreement (LOA) of the measurements of all FLIR ONE 2nd generation cameras with the blackbody temperature was 2.23 ºC.

CONCLUSIONS: Despite these systems being attractive in price and manufacturer provided features, their operational performance does not comply with the required standards for clinical use. The thermal information provided by these imaging systems should only be taken into account for monitoring purposes, as some previous research demonstrated, and not as an input for diagnostic judgments, if they require absolute temperature values to be correct. It is important to note that the cameras provider does not advertise them as medical devices.

KEY WORDS: Affordable IR cameras, FLIR ONE 2nd gen, Infrared thermography, mobile thermography

EIGNEN SICH DIE INFRAROTKAMERAS DER SERIE FLIR ONE FÜR DEN KLINISCHEN EINSATZ?

HINTERGRUND: Die Infrarot-Thermographie (IRT) wird seit sechs Jahrzehnten für klinische Untersuchungen eingesetzt. Im Jahr 2014 wurden erschwingliche und attraktiv kostengünstige Infrarotkameras auf den Markt gebracht, die einfach an mobile Geräte wie Tablets und Smartphones angeschlossen werden können. Obwohl diese Kameras nicht die für den klinischen Einsatz empfohlenen Mindestspezifikationen erfüllen, wurden sie bereits im klinischen Einsatz verwendet. Daher ist es wichtig, die Leistung dieser Geräte zu überprüfen. In diesem Beitrag werden die Anlaufstabilität und für den Temperaturbereich des menschlichen Körpers die absolute Temperaturabweichung der Android- und iOS OEM-Versionen der FLIR ONE Infrarotkameras (IR) der 2. Generation bewertet und aus Sicht der Endanwender verglichen.

MATERIALIEN UND METHODEN: Vier FLIR ONE IR-Kameras der 2. Generation wurden verwendet, von denen zwei entwickelt worden waren, um an Android- Systeme angeschlossen zu werden. und die anderen zwei für Apple iOS-Systeme. Für 30 °C wurde die Anlaufstabilität getestet und der Temperaturbereich des menschlichen Körpers zwischen von 20 °C und 40 °C in Schritten von 1 °C überprüft. Zur Beurteilung der Temperaturerkennung wurde ein Schwarzkörperstrahler Isotech Hyperion R Model 982 als Temperaturreferenz verwendet (Unsicherheit von 0,1°C). Es wurde zunächst eine Referenztemperatur von 30°C für die Untersuchung der Anlaufstabilität gewählt, dann die Kameras zusammen mit den angeschlossenen Geräten eingeschaltet und Messungen im Fünf-Minuten-Takt eine Stunde lang in einem Abstand von 30 cm vom Schwarzkörper durchgeführt. Für die Überprüfung des Temperaturbereichs wurde die Referenztemperatur des Schwarzkörperstrahler auf 20°C gesetzt. Dann wurden mit allen Infrarot-Kameras Bilder aufgenommen und daraus Messwerte ausgelesen. Dieser Vorgang wurde wiederholt, nachdem der Sollwert des Schwarzkörpers in Schritten von 1°C bis 40°C erhöht und zwischen jedem Schritt 15 Minuten auf die Temperaturstabilität des Schwarzkörperstrahlers gewartet worden war.

ERGEBNISSE: Die Wärmebildkameras der 2.Generation von FLIR One überschätzten den Temperaturwert während des Tests der Anlaufstabilität und brauchten etwa 15 bis 20 Minuten, um die Messstabilität mit einer durchschnittlichen Differenz von 0,9 °C zur Referenztemperatur des Schwarzkörpers zu erreichen. Im Abgleich des Temperaturbereichs des menschlichen Körpers fanden sich höhere Unterschiede zur Kalibrierquelle bei Temperaturen unter 24 °C, wobei die Temperaturwerte mehr als 2,0 °C über den realen Temperaturen des Schwarzkörpers lagen. Es zeigte sich eine hohe Korrelation zwischen den Klassen der Messwerte der Wärmebildkameras und den eingestellten Temperaturen an der Kalibrierquelle, aber auch zwischen den Messungen der beiden OEM-Versionen der untersuchten Wärmebildkameras. Die Spanne der Übereinstimmungsgrenzen (LOA) der Messungen aller FLIR ONE Kameras der 2. Generation mit der Schwarzkörper-Temperatur betrug 2,23°C.

FAZIT: Obwohl diese Systeme im Preis und in den vom Hersteller bereitgestellten Funktionen attraktiv sind, entspricht ihre Leistung nicht den erforderlichen Standards für den klinischen Einsatz. Die von diesen Bildgebungssystemen bereitgestellten thermischen Informationen sollten nur zu Überwachungszwecken berücksichtigt werden, wie einige frühere Untersuchungen gezeigt haben, und nicht als Ausgangspunkt für diagnostische Beurteilungen, die für die korrekte Beurteilung absolute Temperaturwerte erfordern. Es muss betont werden, dass der Kameraanbieter die Geräte nicht als Medizinprodukte bezeichnet.

SCHLÜSSELWÖRTER: erschwingliche Infrarot-Kameras, FLIR ONE 2. Generation, Infrarot-Thermographie, Mobiltelephon-Thermographie

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Introduction

Infrared thermography (IRT) imaging has been employed in medical applications for six decades. It is a quick, non-contact, non-ionizing and safe modality for assessing large areas of skin surface temperature distribution. The information provided is associated with the peripheral blood flow which is influenced by the autonomic nervous system among other factors. It has been employed in the physiological study of vascular, sympathetic, musculoskeletal and locomotor systems [1-3].

To increase the accuracy and repeatability of the imaging modality, recommendations were made [3-6] for standardising it in terms of the examination room, the recording equipment and subject preparation, before and during the appointment as well as the image capture protocol. This resulted in a reduction of the variables that influence thermographic assessments while at the same time improving the exchange of knowledge and understanding.

In 2006, Plassmann et al. [7] proposed a set of low cost and simple tests to assess the performance of IR cameras that are used in medicine. Those tests included verification of start-up drift, long-term drift, offset variation over a temperature range, image non-uniformity and the thermal flooding effect.

Three years later, Howell and Smith [8] proposed guidelines for specifying and testing an IR camera for medical applications.

In the ISO standards for fever screening using IRT imaging [9] minimum requirements were specified as a focal plane sensor array size of 160x120, with a NETD of <50mK at 30º C and a measurement uncertainty of ±2% of the overall reading in Celsius (-20 °C to 120 °C).

The first low-cost IR cameras were introduced into the market by manufacturers in 2014 at a very attractive price of around 300.- EUR. The first known assessment of this type of cameras was made by Curran et al. [14]. It concluded that the FLIR ONE does not appear to be suitable for collecting absolute temperature data even when a calibration procedure is employed.

However, Hardwicke et al. [11] demonstrated that using this inexpensive IR system, it was possible to detect and map perforators, define perforasomes, and monitor free flaps. Preoperative, intraoperative, and postoperative obtained thermograms can assist in the planning, execution and monitoring of free flaps, and the FLIR ONE can provide a low-cost adjunct that could be applied to other areas of burns and plastic surgery.

A group of Japanese researchers [12]) suggested that FLIR ONE can work as an alternative device for assessing subclinical inflammation in pressure ulcers and the diabetic foot in clinical settings. Their results may lead to clinicians accepting the proposed method to use thermal imaging assessment at the patients' bedside.

A research letter from Norway [13] raised the issue that absolute temperature estimation may be unreliable with the FLIR ONE camera. However, in perforator mapping, only relative temperature differences are used. Dynamic IRT can increase the reliability of the FLIR ONE for perfusion imaging in the preoperative, intraoperative, and postoperative phases of perforator flap surgery, in line with previous research [11,14].

Sokol et al. [15] observed that a smartphone-based infrared imaging device was capable of detecting thermal trends during sequential zone 1 (Z1) aortic cross clamping as well as zone 3 (Z3) aortic balloon occlusion procedures (resuscitative endovascular balloon occlusion of the aorta [REBOA]) by using an anatomical 2-point thermal ratio. There were also easily recognized qualitative differences between control and occlusion images that allow immediate determination of adequate occlusion of the aorta. This system presented a potentially inexpensive and accurate tool for assessing perfusion, adequate REBOA placement, and even inspecting the level of aortic occlusion.

A group of US researchers [16] demonstrated that using a FLIR ONE camera it was possible to identify that individuals with focal-onset epilepsy have colder abdominal areas.

Jaspers e t al. [17] in the Netherlands showed that the FLIR ONE thermal imager is highly reliable in terms of patient, observer and random error variance. The mean error of measurement in the burn affected area of interest varied between 0.17-0.22°C. However, despite having moderate validity, it has only been tested as an add-on and not as clinical evaluation plus FLIR ONE versus only clinical evaluation. Although, the FLIR ONE is feasible to use, allowing easy and fast measurements of burns in clinical daily practice.

A research group from Washington [18] demonstrated a high degree of accuracy, reliability, and ease of use for assessing limb perfusion with a FLIR ONE camera. It also allowed for rapid and reliable identification of adequate tourniquet placement that was not affected by major haemorrhage or blackout conditions.

A research paper comparing the FLIR ONE 2nd generation for Android with an Android mobile device attached SEEK thermal camera [10] concluded that the FLIR camera outperformed the SEEK but its images were rich in noise.

A recent PhD thesis [20] showed the importance of having the sensors Focal Plane Array (FPA) stabilized to obtain and ensure the best possible consistent temperature read out.

It is important to mention that the FLIR ONE 2nd generation is not marketed as a measurement device, nor CE marked as a medical device.

Given all of these recent medical applications, it is the aim of this research to assess the accuracy (defined as offset or deviation from a known value) of the FLIR ONE 2nd generation cameras in terms of start-up offset drift and offset variations over the temperature range of the human skin.

Materials and Methods

The study took place in an environmental chamber of 2.5 x 4 m in size (controlled with a mean temperature of 24.0 ± 0.3 °C, relative humidity of 52.8 ± 4.3%, absence of incandescent lighting over all equipment and laminar low air flow) at the Faculty of Engineering, University of Porto. For image capturing four recently supplier-calibrated long wave (8 to 12 μm) thermal cameras FLIR ONE 2nd generation with a focal plane sensor array size of 80x60, a Noise Equivalent Temperature Difference of (NETD) of<100mK at 30ºC and a measurement uncertainty of 5% of the overall reading in Celsius (-20 °C to 120ºC) were used. Two were used with android over a micro-USB connection and the other two with iOS over an apple lightning connection. The first two were attached to a LG V400 Pad tablet and the other two to an iPad mini version 1. A recently calibrated and manufacturer calibration certificated valid blackbody Isotech Hyperion R Model 982 with a temperature range from -10ºC to 80ºC, resolution of 0.01 K, stability of 0.1 K and uncertainty of 0.1 K was used as reference source with an assumed emissivity value of 1.0. To verify the room environmental conditions a thermo-hygrometer Testo 175H1 with a digital display and capacity to store the mean temperature and relative humidity with resolution and uncertainty of 0.1 °C and 1% was used.

The tests of start-up offset drift and human body temperature range offset drift were performed by trained staff experienced in performing measurements from the blackbody source used. The emissivity parameter in the cameras was set to 1.0 value.

The start-up offset drift test consisted of setting the reference source to 30ºC and waiting 2h to ensure its stability. The fully charged mobile devices were then switched on, the FLIR ONE app was executed, the FLIR ONE camera attached and at a distance of 30 cm and perpendicular to the blackbody surface, images were taken at 5 minute intervals for 1 hour. Only one camera could be used at a time, therefore the test was carried out on different days for each camera. Each camera was tested 5 times for the temperature sweep from 20ºC to 40ºC in 1ºC steps, waiting 15 minutes at each step for a stable temperature. The IR cameras were kept on an external power supply during the whole procedure, and switched on 25 minutes before the first image was taken. At every temperature step just before the temperature was increased an image was taken with the software provided by the manufacturer. Each of the four cameras performed this test five times.

Example a thermal image taken from the reference source with the IR camera FLIR ONE 2nd generation is shown in figure 1.

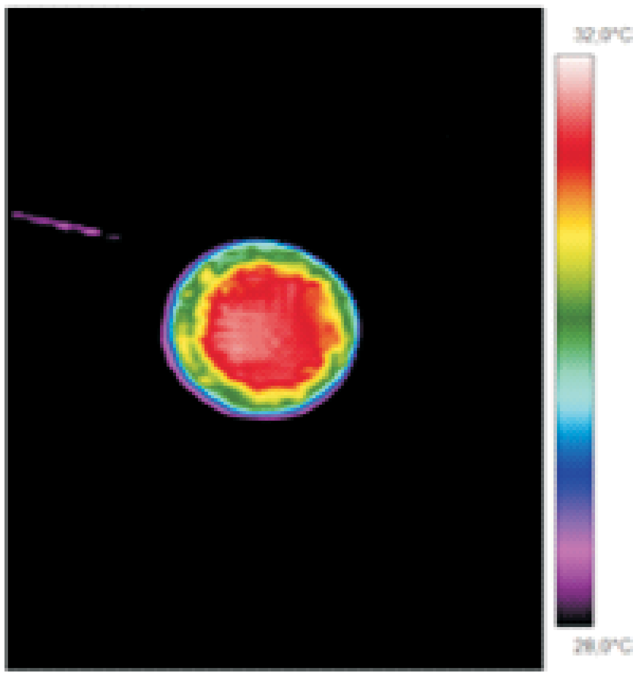


Figure 1
Example of an image taken from the calibration source (blackbody) at 30 °C with the IR camera FLIR ONE 2nd generation.

For assessing the images, a circular region of interest (ROI) was drawn in the images over the reference source circular temperature emission area, large enough for the measurement, in the software package FLIR ThermaCAM Researcher 2.10 pro. The emissivity setting of the cameras was set at 1.0 and the mean temperature of the ROIs was extracted.

Mean temperatures were organized in a Microsoft Excel spreadsheet and the statistical mean and standard deviation were calculated for both offset tests. Separated spreadsheets were also made for each connection type (USB and lightning). The Bland-Altman limits of agreement and Interclass Correlation Coefficient (ICC) were calculated between the average value of all measurements and the blackbody set temperature, each connection type camera average measurement and the blackbody set temperature and between the average measurements of the micro-USB connection type camera with the average measurements of the apple lightning connection type camera for the same blackbody set temperature.

Results

The measured values from the start-up offset drift test of all cameras and the two connection types are presented in table 1. In this section, the micro-USB connection camera is called "FLIR ONE 2nd generation for Android" and the Apple Lightning connection camera is called "FLIR ONE 2nd generation for iOS". Figure 2 shows a graphical representation of the measurement variability during the test. It can be observed that all camera measurements (20 assessments) tend to stabilise after 20 minutes, overestimating the reference source on average by 1.0 ºC. The 10 measurements from FLIR ONE 2nd generation for Android showed an average stabilisation time of 15 minutes, with a

Table1
The start-up drift test results.

Time (min)	All FLIR ONE 2nd generation measurements (4x5)	FLIR ONE 2nd generation for Android (2x5)	FLIR ONE 2nd generation for iOS (2x5)
1	31.4 ± 0.7	32.2 ± 0.2	30.8 ± 0.1
5	30.4 ± 2.6	30.1 ± 3.9	30.6 ± 0.1
10	31.2 ± 0.8	31.8 ± 0.3	30.7 ± 0.6
15	31.2 ± 0.6	31.6 ± 0.3	30.8 ± 0.5
20	30.9 ± 0.4	31.2 ± 0.1	30.6 ± 0.3
25	31.1 ± 0.7	31.6 ± 0.5	30.6 ± 0.4
30	31.0 ± 0.6	31.5 ± 0.1	30.5 ± 0.4
35	30.9 ± 0.6	31.5 ± 0.2	30.5 ± 0.4
40	30.9 ± 0.5	31.3 ± 0.3	30.6 ± 0.4
45	30.8 ± 0.6	31.2 ± 0.5	30.4 ± 0.3
50	30.9 ± 0.5	31.4 ± 0.2	30.5 ± 0.2
55	30.9 ± 0.5	31.3 ± 0.1	30.5 ± 0.3
60	30.3 ± 0.7	29.9 ± 0.9	30.6 ± 0.4

Figure 2
The variation of temperature readings from calibration source by the IR cameras FLIR ONE 2nd gen for iOS (blue), for Android (green) and all FLIR ONE 2nd gen average measurement (grey) during the start-up drift test, the yellow line represents the temperature of the calibration source (blackbody) and the red lines the measurement uncertainty limit.

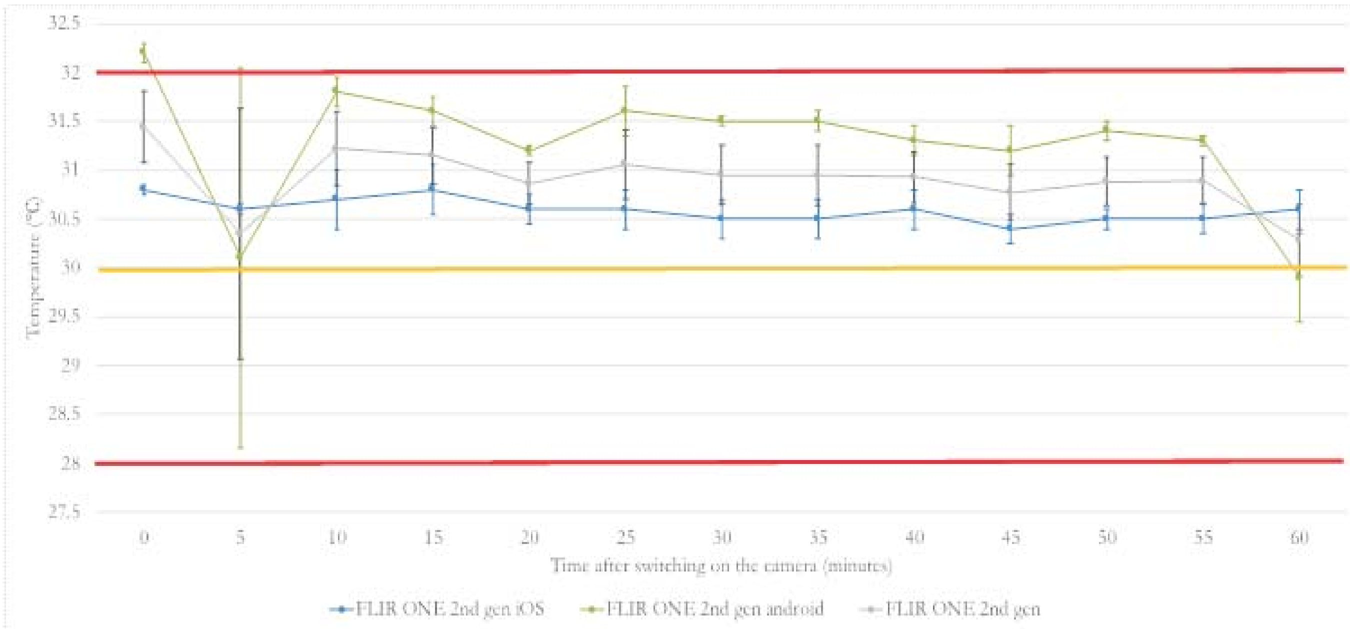
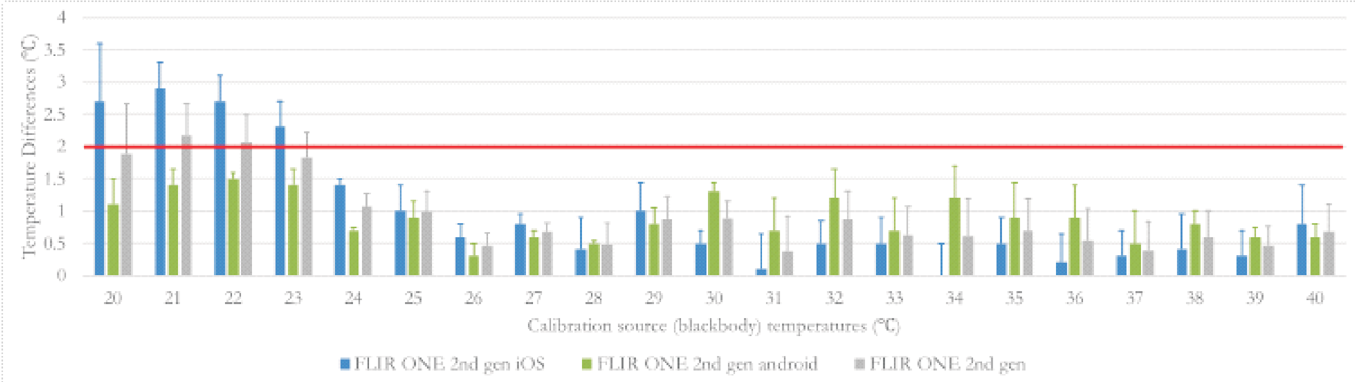


Figure 3
The difference between calibration source(blackbody) temperatures and the reading of IR cameras FLIR ONE for iOS (blue), for Android (green) and all FLIR ONE 2nd gen average measurement (grey) during the offset variation over a temperature range test. In red the 2ºC manufacturer uncertainty.



mean overestimation of 1.4 ºC when compared to the blackbody. The 10 measurements from FLIR ONE 2nd generation for Android showed an average stabilisation time of 15 minutes, with a mean overestimation of 1.4 ºC when compared to the reference source.

The average difference between the FLIR One 2nd generation 20 measurements from the four cameras and the blackbody is 0.9 ± 0.2 ºC for the start-up drift offset test. For the iOS cameras the 10 temperature assessments against the blackbody, the average difference is 0.6 ± 0.1 ºC and for the Android cameras 10 measurements the average difference from the temperature reference is 1.3 ± 0.6 ºC.

Figure 3 presents the difference between the measurements obtained from the four used cameras and the blackbody

Table 2
The offset variation over a temperature range test results.

Calibration Source (Blackbody) Temperature (ºC)	All FLIR ONE 2nd generation measurements (4x5)	FLIR ONE 2nd generation for *Android* (2x5)	FLIR ONE 2nd generation for *iOS* (2x5)
20.0	21.9 ± 1.6	21.1 ± 0.8	22.7 ± 1.8
21.0	23.2 ± 1.0	22.4 ± 0.5	23.9 ± 0.8
22.0	24.1 ± 0.9	23.5 ± 0.2	24.7 ± 0.8
23.0	24.8 ± 0.8	24.4 ± 0.5	25.3 ± 0.8
24.0	25.1 ± 0.4	24.7 ± 0.1	25.4 ± 0.2
25.0	26.0 ± 0.7	25.9 ± 0.5	26.0 ± 0.8
26.0	26.5 ± 0.4	26.3 ± 0.4	26.6 ± 0.4
27.0	27.7 ± 0.3	27.6 ± 0.2	27.8 ± 0.3
28.0	28.5 ± 0.7	28.5 ± 0.1	28.4 ± 1.0
29.0	29.9 ± 0.7	29.8 ± 0.5	30.0 ± 0.9
30.0	30.9 ± 0.5	31.3 ± 0.3	30.5 ± 0.4
31.0	31.4 ± 1.1	31.7 ± 1.0	31.1 ± 1.1
32.0	32.9 ± 0.9	33.2 ± 0.9	32.5 ± 0.7
33.0	33.6 ± 0.9	33.7 ± 1.0	33.5 ± 0.8
34.0	34.6 ± 1.1	35.2 ± 1.0	34.0 ± 1.0
35.0	35.7 ± 1.0	35.9 ± 1.1	35.5 ± 0.8
36.0	36.5 ± 1.0	36.9 ± 1.0	36.2 ± 0.9
37.0	37.4 ± 0.9	37.5 ± 1.0	37.3 ± 0.8
38.0	38.6 ± 0.8	38.8 ± 0.4	38.4 ± 1.1
39.0	39.5 ± 0.6	39.6 ± 0.3	39.3 ± 0.8
40.0	40.7 ± 0.8	40.6 ± 0.4	40.8 ± 1.2

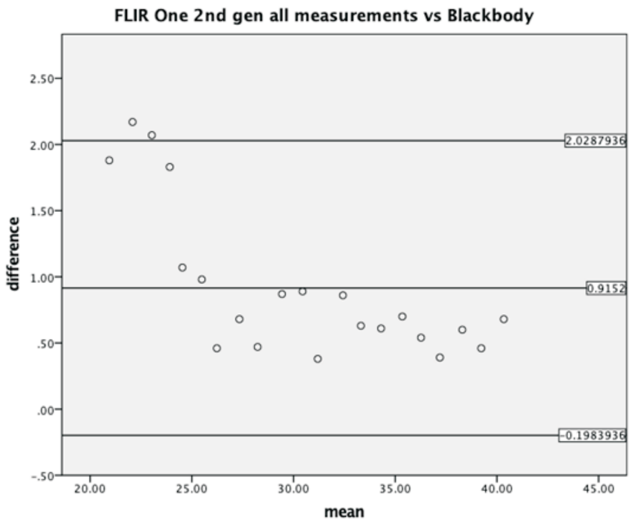


Figure 4
The limits of agreement between the mean values measured by all the FLIR ONE 2nd generation cameras and the calibration source (blackbody) during the human body temperature range.

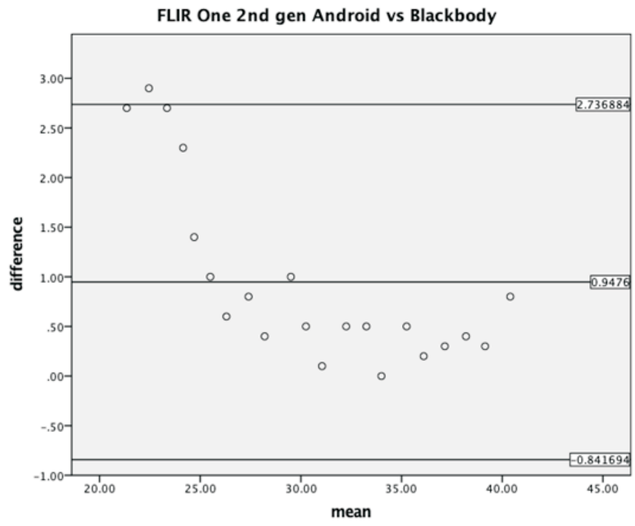


Figure 5
The limits of agreement between the mean values measured by the FLIR ONE 2nd generation camera for android and the calibration source (blackbody) during the human body temperature range.

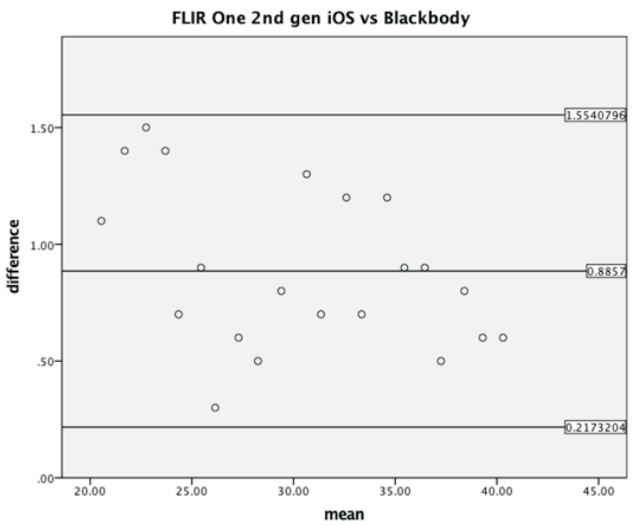


Figure 6
The limits of agreement between the mean values measured by the FLIR ONE 2nd generation camera for iOS and the calibration source (blackbody) during the human body temperature range.

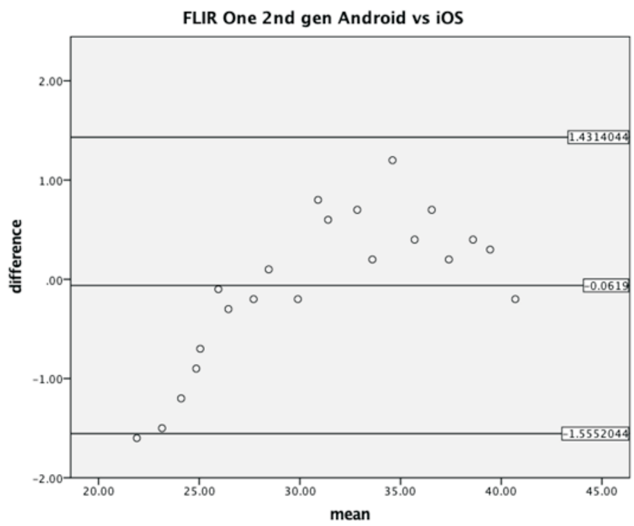


Figure 7
The limits of agreement between the mean values measured by the FLIR ONE 2nd generation camera for android and the calibration source (blackbody) during the human body temperature range.

Table 3
The Interclass Correlation Coefficient between the measurements during the human body temperature range.

Measurements	Cronbach' Alpha coefficient	ICC	ICC (95% c.i.)
All FLIR One 2nd generation measurements and blackbody	0.998	0.996	0.989 to 0.998
FLIR One 2nd generation for *Android* and blackbody	0.994	0.988	0.971 to 0.995
FLIR One 2nd generation for *iOS* and blackbody	0.999	0.998	0.996 to 0.999
FLIR One 2nd generation for *Android* and FLIR One 2nd generation for *iOS*	0.996	0.991	0.979 to 0.996

during the temperature sweep grouped by all 20 assessments of all cameras, the 10 assessments of iOS cameras and the 10 assessments of Android cameras. Table 2 presents all 20 assessments of all cameras, 10 assessments of iOS cameras and 10 assessments of Android cameras of the blackbody referencing the temperatures between 20 ºC and 40 ºC. In the temperature range of 20 ºC to 23 ºC, a maximal deviation of all camera measurements from the blackbody temperature was observed, exceeding 2 ºC. The difference for all iOS was greater than 2.2 ºC and for all Android greater than 1.7 ºC. In the temperature range of 25 ºC to 40 ºC all differences are lower than 1.0 ºC, excluding all the Android camera at temperatures 30 ºC, 32 ºC and 34 ºC.

The maximum deviation between the blackbody temperature and 20 measurements from the four FLIR ONE 2nd generation cameras is 0.9 ± 0.6 ºC, for the temperature sweep being of 2.2 ºC. For the 10 iOS cameras temperature assessments against the blackbody, the average difference is 0.9 ± 0.9 ºC, with maximum of 2.9 ºC. In 10 Android camera measurements the average difference from the blackbody temperature is 0.9 ± 0.3 ºC, with a maximum of 1.5 ºC.

Figure 4 presents the Bland-Altman limits of agreement between the 20 temperature measurements of all the FLIR ONE cameras and the value indicated by the blackbody during the temperature sweep. The mean difference to absolute agreement between the blackbody and all 20 temperature measurements is 0.91 ºC, the limits of agreement (LOA) rank between - 0.2 and 2.03°C. Mean bias to agreement with the calibration reference was 0.95 (figure 5) in the 10 temperature measurements of the android cameras, with a span of LOAs equal to 3.58 °C. The 10 temperature measurements with the iOS cameras obtained a mean difference to the blackbody temperature of 0.89 ºC (Lower LOA: 0.21°C, Upper LOA: 1.55°C; figure 6). Comparing measurements from Android cameras with temperature readings from iOS cameras resulted in a small mean bias of -0.6 °C (Lower LOA: 0.21°C, Upper LOA: 1.55°C; figure 7)

The Interclass Correlation Coefficient analysis (table 3) shows good data consistency (Alpha Cronbach' coefficient > 0.995) and evidence of relationship (ICC > 0.990) between all the 20 measurements of all FLIR ONE cameras and blackbody, all the 10 measurements of the iOS cameras and calibration reference values, all the 10 assessments of the Android cameras and the blackbody temperature and between the 10 measurements of the iOS cameras and 10 assessments of the Android cameras.

Discussion

This study has followed the IRT imaging guidelines (3-6) with respect to examination room and equipment preparation. In the start-up drift test, it is verified that the FLIR ONE 2nd generation cameras stabilised their output only after about 15 to 20 minutes after being switched on. This limits their time of use since their battery lasts about 1 hour. The average difference obtained after 20 measurements of four instruments is 0.9 ºC. When comparing the two imager connection types (micro-USB for Android devices and Apple Lightning for the iOS devices), the iOS version outperforms the Android version. The Android cameras seem to stabilise faster than the iOS cameras. The differences may be related to the software differences between the two devices or due to the sensor itself. The underlying sensor (Lepton) uses a SPI bus to communicate serial data to a microcontroller. This data must then be translated into USB/Lightning or USB/micro-USB connection compatible data which can then be read by the smartphone/tablet. Over the course of the communication, a Cyclic Redundancy Check (CRC) is enforced to ensure that the data does not get corrupted in transit (19). Additionally, it is possible that the software between the smartphone/tablet application is slightly different as well as the microchip that reads out the lepton sensor data. However, without opening the device (which voids the warranty) and attaching the lepton sensor to an SPI bus and reading out the sensor data and settings directly, it is not possible to say where these differences in the data arise. Using FPA stabilisation techniques has shown to provide consistent temperature values (20) on evaluations against blackbodies at the National Physical Laboratory in the United Kingdom.

In the temperature sweep, the 20 measurements of all FLIR ONE 2nd generation cameras presented an average error of 0.9 ºC and a maximum error of more than 2ºC. The two connection type versions of the thermal cameras studied presented similar results, where the iOS version had slightly higher variation, but the high ICC proves the relationship between the measurements through statistical evidence.

It is important to note that these deviations are within the manufacturer provided specifications, being the differences due to random characteristics of the individual cameras rather than systematic connection type or operation system differences.

The finding of this research is in line with those presented by Curran et al. (14), where an average error of 1 ºC is presented by overestimation of temperature.

Based in this finding the claims presented in the clinical studies (11-13,15-18) using this kind of cameras are difficult to be acknowledged. It is important to note that when collecting data with these cameras the uncertainty in the evaluation of thermal images in medicine is not only affected by the camera itself, factors (21) such as individual data of participants and their preparation for thermal imaging; extrinsic factors such as recent physical activity or physiotherapy; wetness of the skin; ambient temperature, humidity and infrared sources in the examination space, acclimation time, camera type, camera settings, emissivity, size of field of view, camera position in relation to the imaged subject and image analysis are sources of uncertainty and to overcome this; IRT imaging guidelines (3-6) should be followed to minimize their effect. However, it is also important to note that this imaging system's operational performance is not in conformity with the required standards for clinical applications (8,9).

The tests presented in this research do not intend to be technical, they are based on an end user with minimal experience but with the capability of repeating it since there is access to a manufacturer calibrated blackbody to perform similar examinations.

Conclusion

Despite these systems being attractive in price (around 300.- Eur) and manufacturer provided features, their operational performance does not comply with required standards for clinical use. The thermal information provided by these imaging systems should only be taken into account for monitoring purposes, as some previous research demonstrated, and not as an input for diagnostic judgments, if they require absolute temperature values to be correct. It is important to note that the cameras provider does not advertise them as medical devices.

Acknowledgements

The authors gratefully acknowledge the partial funding of Project NORTE-01-0145-FEDER-000022 - SciTech - Science and Technology for Competitive and Sustainable Industries, cofinanced by Programa Operacional Regional do Norte (NORTE2020), through Fundo Europeu de Desenvolvimento Regional (FEDER) and the FCT - Foundation for Science and Technology under the project (PEst-OE /EME/LA0022/2013).

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Address for Correspondence:
Ricardo Vardasca, Ph.D., ASIS, FRPS
LABIOMEP, INEGI-LAETA,
Faculdade de Engenharia, Universidade do Porto,
Rua Dr. Roberto Frias S/N, 4200-465
Porto, Portugal
Email: ricardo.vardasca@fe.up.pt

(Received on 11.10.2018, revision accepted on 8.08.2019)

Exploring the association between pressure pain threshold and skin temperature in the upper trapezius of healthy subjects

Adérito Seixas[1,2,] Marlene Soares[1], Sandra Rodrigues[1]

[1] Escola Superior de Saúde, Universidade Fernando Pessoa, Portugal
[2] LABIOMEP, INEGI-LAETA, Faculdade de Desporto, Universidade do Porto, Porto, Portugal

SUMMARY

BACKGROUND: The use of infrared thermography to assess pain is appealing, and the literature suggests plausibility regarding this application. An objective assessment method to analyse a subjective feeling would be of great interest.

OBJECTIVE: To investigate the association between skin temperature (TSk) and pressure pain threshold (PPT) over the upper trapezius in healthy subjects.

METHODS: A cross-sectional study was conducted in 24 healthy subjects. TSk and PPT were assessed in the upper trapezius and the association between the two was tested. Two groups were formed, based on PPT values, a Low PPT group and a High PPT group, and the association between TSk and PPT was tested on both.

RESULTS: No significant association between TSk and PPT was found, neither when considering the whole sample ($p > 0.05$), nor when analysing individual groups ($p > 0.05$). However, the direction of the association was was opposite in the Low PPT and High PPT groups.

CONCLUSION: No significant association between TSk and PPT was found in healthy subjects at the upper trapezius.

KEYWORDS: Skin temperature; Pressure pain threshold; Pain; Upper trapezius

UNTERSUCHUNG DES ZUSAMMENHANGS ZWISCHEN DRUCKSCHMERZSCHWELLE UND HAUTTEMPERATUR AM OBEREN TRAPEZ VON GESUNDEN PROBANDEN

HINTERGRUND: Der Einsatz der Infrarot-Thermographie zur Schmerzbeurteilung ist verlockend, und die Literatur belegt die Plausibilität dieser Anwendung. Eine objektive Bewertungsmethode zur Analyse der subjektiven Erfahrung "Schmerz" ist von großem Interesse.

ZIEL: Untersuchung des Zusammenhangs zwischen Hauttemperatur (TSk) und Druckschmerzschwelle (PPT) am oberen Trapezius bei gesunden Probanden.

METHODE: In einer Querschnittsstudie wurde an 24 gesunden Probanden TSk und PPT am oberen Trapezius erhoben und der Zusammenhang der beiden Parameter getestet. Aufgrund von PPT-Werten wurden zwei Gruppen gebildet, eine Low PPT-Gruppe und eine High PPT-Gruppe, und die Assoziation zwischen TSk und PPT wurde in jeder Gruppe untersucht.

ERGEBNISSE: Es wurde kein signifikanter Zusammenhang zwischen TSk und PPT gefunden, weder bei der Betrachtung der gesamten Stichprobe ($p > 0{,}05$), noch bei der Analyse einzelner Gruppen ($p > 0{,}05$). Allerdings war in den Gruppen Low PPT und High PPT die Richtung des Zusammenhanges entgegengesetzt.

SCHLUSSFOLGERUNG: Am oberen Trapezius wurde bei gesunden Probanden kein signifikanter Zusammenhang zwischen TSk und PPT festgestellt.

SCHLÜSSELWÖRTER: Hauttemperatur; Druckschmerzschwelle; Schmerzen; Oberer Trapezius

Thermology international 2019, 29(3) 103-107

Introduction

Infrared thermography is an image modality able to evidence alterations in skin temperature, rather than anatomical changes in body structures. The skin is a very important effector in temperature regulation, a process mainly controlled by the autonomic nervous system, both with central and peripheral components. Its use in various fields of medicine is well known [1] and its popularity continues to increase.

One of these applications is the study of skin temperature (TSk) in pain medicine, as the idea of having an objective tool to assess a subjective dimension is appealing. There is evidence that regional mean TSk has little variation between the right and left sides of the body [1] and this concept has been considered one of the most important when interpreting thermograms. A dynamic assessment is often used, applying stress tests (mechanical, chemical or thermal) and analysing the TSk dynamics before, during and after the challenge [2, 3]. However, only alterations in skin temperature after thermal stress should be considered as a thermoregulation response.

Chronic pain adversely affects autonomic control [4], which supports the plausibility of using TSk as an outcome measure in pain studies, considering the role of the autonomic nervous system in regulation of cutaneous blood flow.. Previous research has reported a significant association between pressure pain threshold and TSk, measured in the lumbar region, in patients with chronic low back pain [5] and a significant association between thermal symmetry values in the plantar surface of the feet and pain, assessed with a visual analogue scale [6]. These studies suggested that higher TSk values were associated with lower pressure pain thresholds and that higher values of TSk differences in the plantar surface of the feet were associated with higher pain intensity values.

However, these results are not consensual when other conditions are assessed. In patients with complex regional pain syndrome and knee osteoarthritis, no significant association between thermal symmetry in the area of the most severe pain and pain intensity [7], and no significant association between TSk and pain intensity in patients with knee osteoarthritis [8] were found.

Considering that the possible association between TSk and pain is not consensual and that this relationship has not been explored in the literature in healthy subjects, the goal of this research is to investigate the association between TSk and pressure pain threshold (PPT) over the upper trapezius in healthy subjects.

Methods

Participants

Considering that the association between TSk and PPT reported in the study of Haddad and colleagues [9] varied between $0.4 \leq r < 0.7$, considering a correlation coefficient of 0.55, an $\alpha = 0.05$ and a statistical power 0f 80%, a minimum sample size of 24 subjects was determined [10].

The study was approved by the local University ethical committee and followed the recommendations of the Helsinki Declaration. The experimental procedures were explained to the participants and all questions were answered by the research team and all participants signed the informed consent form to participate. Twenty-four young adults (eleven males) agreed to participate (mean ± standard deviation age and BMI: 23.5 ± 3.1 years / 23.8 ± 4.7 kg/m^2). The volunteers reported no musculoskeletal or neurological pathology, no history of surgery in the head, neck, trunk or upper limb, no cognitive deficit and no medication intake.

Skin temperature assessment

At the time of recruitment, participants were asked to avoid physical activity in the day of the assessment and in the day before and to avoid smoking, caffeine, alcohol and heavy meals in the day of the scheduled assessment. Skin temperature data was collected away from airflow and radiation sources after a 15-minute acclimation period, in a room with controlled ambient temperature (22.3 ± 0.8 ºC) and relative humidity (46.2 ± 4.3 %). TSk was assessed with an infrared camera FLIR E60 (FLIR Systems, Wilsonville, OR, USA) with a sensor array size of 320x240, ± 2% of measurement uncertainty of the overall reading, with emissivity set to 0.98, and the camera was turned on at least 30 minutes before the assessments. The camera was positioned perpendicular to the participants trunk at 1 metre distance and all thermograms were captured by the same researcher.

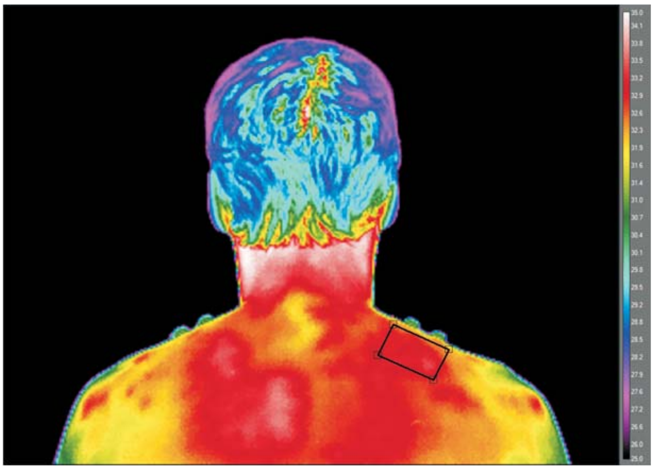


Figure 1:
Region of interest for thermal and algometry assessment.

Thermograms were analysed with FLIR ResearchIR Max (FLIR Systems, version 4.30.0.69). A rectangular region of interest was defined over the upper trapezius muscle (figure 1) of the dominant side, and mean temperature values were extracted for further analysis.

Pressure pain threshold assessment

PPT, the degree of pressure intensity at which the subjects report pain, was assessed in the dominant side with a digital algometer (Wagner Model FDIX, Greenwich, CT. USA). The assessment was made on the upper trapezius at half distance between C7 and the acromion, in the same area of the TSk measurement (figure 1). Three PPT measurements (kg/cm^2) were performed and the mean value was computed for further analysis. Measurements were made in a time interval of 30-60 seconds by the same researcher to avoid methodological bias.

The area of TSk and PPT assessment is a common area of pain [11]. During collection, participants remained seated, with the trunk straight, and with their hands placed on the thighs.

Data analysis

All analysis were performed using Statistical Package for the Social Sciences (SPSS Statistics version 25, IBM Corp., Armonk, N.Y., USA). Data distribution assessment was made applying the Shapiro-Wilk test and visually inspecting histograms and, since not all variables had normal distribution, non-parametric tests were selected for the analysis. Spearman's rho was used to assess the association between Tsk and PPT data and confidence intervals for the correlation were obtained through a bootstrapping approach. PPT data was transformed to a nominal variable considering the threshold of 2.55 kg/cm^2 (below or equal to the threshold and above the threshold), which is used as a

Table 1
Age, BMI, PPT and TSk values for the total sample and for the High and Low PPT groups. Values expressed as median (interquartile range). Results for significance and 95% confidence intervals.

Variables	Total sample (n=24)	High PPT (n=13)	Low PPT (n=11)	*p* value [a]	Median Difference Estimate [b]	95% Confidence Interval
Age (years)	23.0 (3.0)	23.0 (3.0)	22.0 (4.0)	0.424	1.000	[-1.000; 2.000]
BMI (Kg/m^2)	22.7 (4.1)	22.8 (3.6)	21.6 (4.5)	0.361	1.200	[-1.200; 3.500]
PPT (Kg/cm^2)	2.59 (1.72)	3.34 (1.33)	1.67 (0.81)	<0.001	1.870	[1.180; 2.530]
TSk (ºC)	33.1 (0.7)	33.3 (0.9)	33.1 (0.4)	0.277	0.300	[-0.200; 0.700]

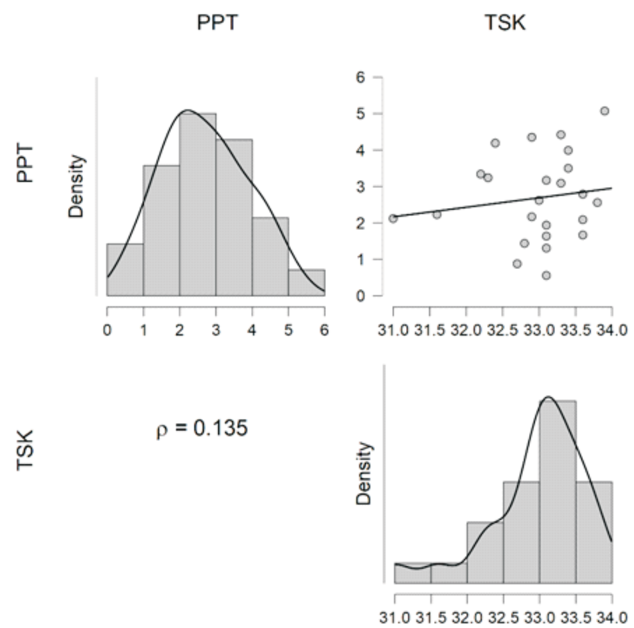
Note: a. Mann-Whitney test; b. Hodges-Lehmann test.

threshold to detect hypersensitive spots [12], to analyse if the association between TSk and PPT is the same in different intensities of pain. The Mann-Whitney test was used to compare age, BMI, TSk and PPT across groups formed considering the mentioned PPT value (High and Low PPT). To estimate the confidence intervals across groups the Hodges-Lehmann estimate was used. The Chi-squared test was used to test if the gender proportions were similar in both PPT groups, since gender influences PPT [13]. The significance level was set at $p \leq 0.05$.

Results

A total of 24 subjects volunteered to participate. Age, BMI, PPT and TSk values are presented in table 1, for the total sample and for both groups based in the PPT vales (High and Low PPT). The groups are homogenous for all variables except for PPT values, which was expected.

Figure 2:
Correlation plots between TSk and PPT and density plots for each variable



The proportion of females in the High PPT group (20.8%; n=5) was not significantly different (p = 0.123) from the proportion of females in the Low PPT group (33.3%; n=8).

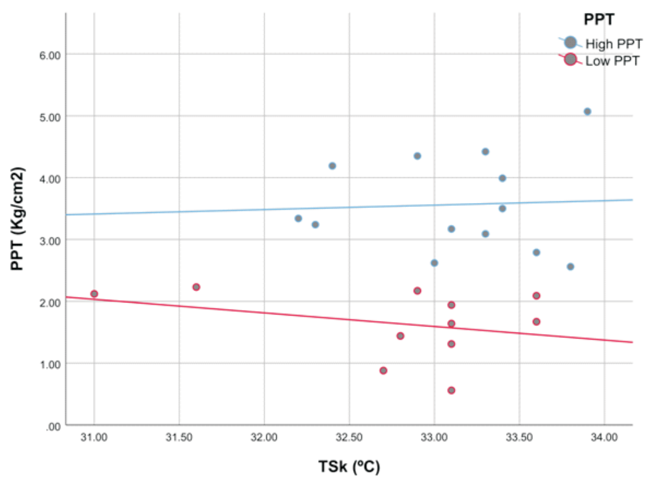
No significant association between TSk and PPT in the upper trapezius (figure 2) was found (rho = 0.135; 95% CI [-0.284; 0.511]; p = 0.529), but the tendency of the association is positive.

When testing the association between TSk and PPT considering the subgroups of High and Low PPT, although no significant association was found, the direction of the association was different (figure 3). In the High PPT group the trend was positive (rho = 0.051; 95% CI [-0.569; 0.610]; p = 0.869), but in the Low PPT group the trend was positive (rho = -0.317; 95% CI [-0.718; 0.624]; p = 0.342).

Discussion

This study analysed the association between TSk and PPT over the upper trapezius in healthy subjects. The results demonstrated a lack of association between TSk and PPT considering the totality of the sample and the same results when subgroups of pain intensity were considered. How-

Figure 3:
Scatter plot evidencing the association between TSk and PPT in the Low and High PPT groups.



ever, the direction of the association was positive in the High PPT group and negative in the Low PPT group.

Previous research has investigated the association between pain a TSk in clinical populations, such as low back pain [5, 14], neck pain [11, 15], complex regional pain syndrome [7] and tennis elbow [16] patients. However, in healthy subjects this relationship has not been broadly explored.

Although TSk and PPT assessments serve different purposes, pain negatively affects autonomic control [4], hinting that TSk may also be altered in the presence of pain. In the present study no significant association between TSk and PPT was found. It is important to emphasize that healthy subjects were recruited, not a clinical population. Nonetheless, in patients with knee osteoarthritis [8] the authors also reported no association between pain and TSk. Even if the association between TSk and PPT was not significant, it showed a positive trend suggesting that higher PPT values implied higher TSk values, which is in line with the findings of a previous study where PPT and TSk were assessed in the temporomandibular area. In that study, Haddad [9] recruited only subjects without history of temporomandibular disorders, assessed the PPT in that area and found the same trend but achieving statistical significance in the correlation analysis. However, the opposite was reported by Alferi [5] and Ammer [16], in patients with low back pain and tennis elbow, respectively, higher TSk values were associated with lower values of PPT. The fact that this study recruited patients with a diagnosed clinical condition may be the reason for the discrepancy in the results.

We have also divided the sample in two groups, a group with Low PPT (more pain), and a group with High PPT (less pain), based in the threshold of 2.55 kg/cm^2, which was used to identify the hypersensitive spots in previous studies [12]. The proportion of females in both groups was not statistically significant. This is important because, according to Fischer [13], females exhibit lower PPT vales than males and this could have an influence in results. The association between TSk and PPT, in both groups was not significant but the direction of the association was positive in the High PPT group and negative in the Low PPT group. Although not significant, the direction of the association between PPT and TSk in the Low PPT group was in line with the study of Alferi and colleagues [5].

Future studies with a large sample, and good methodological basis should provide more definite results regarding the association between TSk and PPT.

Limitations

The study design of this research does not allow to establish a cause-effect relationship. Even if the results of this research are interesting, the limited number of subjects enrolled in the study impairs the ability to fully understand them. Despite this limitation, objective methods of assessment of skin temperature and pressure pain threshold were used, and the findings can provide the background to a more robust investigation.

Conclusion

No significant association between TSk and PPT over the upper trapezius was found in healthy subjects. The use of thermal imaging in pain medicine still needs to be explored in studies with good methodological quality. Research documenting the use of objective assessment methods to analyse subjective feelings is highly demanded.

Conflict of interest

The authors have no conflict of interest to declare.

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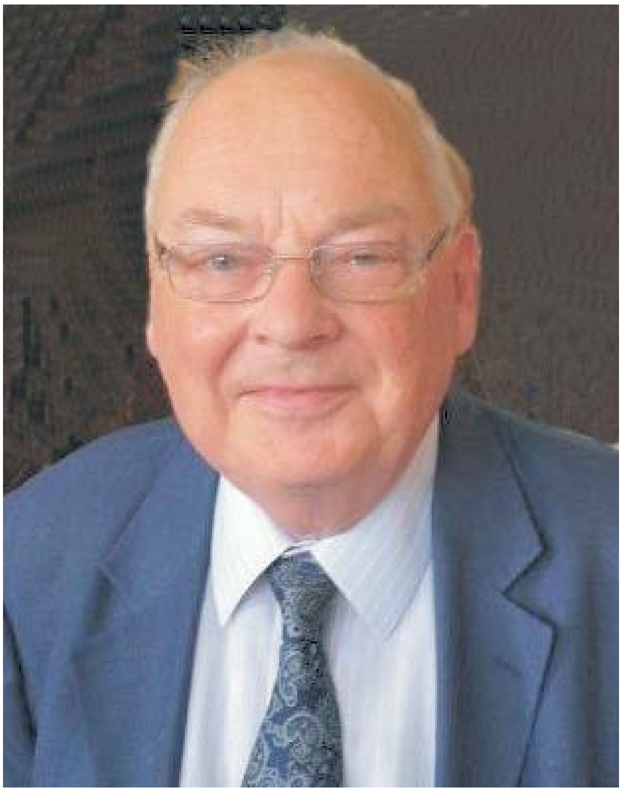
Corresponding author:
Adérito Seixas
Escola Superior de Saúde, Universidade Fernando Pessoa
Rua Delfim Maia, 334
4200-253 Porto
Portugal
Email: aderito@ufp.edu.pt)

(Received: 01.08.2019, revision accepted 10.08.2019)

Prof Edward Francis John Ring 1935-2019



It is my sad duty to inform you that Prof. Edward Francis John Ring, born in Bath, England on 27th November 1935, passed away peacefully in his sleep on the morning of 15th July 2019 at the Dorothy House Hospice in Winsley, England.

Prof. Ring used Edward for formal contacts but preferred to be called "Francis" by the many friends who he found in the plethora of his fields of interests. Thermology, the science of using temperature and heat in medicine and biology, was certainly his main focus. He was not only one of the founders of the European Association of Thermology, and later of the International College of Thermology, he also constructed the basic framework that fostered the understanding of temperature phenomena in medicine. Initially working with an infrared radiometer in a pharmacology department analysing temperature variation in animal experiments and drug trials, he became quickly involved in infrared thermography and had already proposed standards for image capture and analysis in the 1970s. He was also one of the first who understood a thermal imager as a measurement tool and developed consequently procedures for quality assurance. Francis served the EAT three times as President, twice as General Secretary and once as Vice-President. He organised two European thermology conferences, in 1982 and 1994, in his hometown of Bath. Prof. Ring lectured at numerous thermology conferences all around the world, and received six honorary memberships in national thermology societies, including an honorary life membership of the European Association of Thermology.

In 1978, as an accredited clinical scientist Francis Ring was appointed as head of the Department of Clinical Measurement at the Royal National Hospital for Rheumatic Diseases in Bath. Francis regularly published his thermal imaging results and was involved in the promotion and distribution of articles related to thermology. He was an editorial member for all the journals dedicated to thermology such as Acta thermographica, Thermology, ThermoMed, Thermologie Österreich, the European Journal of Thermology and Thermology international. Francis' commitment to check the English of articles submitted to Thermologie Österreich was an essential contribution to the first version of the official organ of the EAT. He edited the proceedings of both conferences held in Bath; these books are landmarks in documenting the development of clinical thermology. Additionally, the book entitled "Human Body Temperature-Its Measurement and Regulation," authored by Francis and the French cardiologist-physiologist Y. Houdas, has served as the basis for clinical thermology since 1982. The book combined, for the first time, principles of physics and thermal physiology in creating a rationale for how the temperature distribution within and at the surface of the human body may develop. In 2003, together with Anna Jung and Janusz Zuber, Francis edited "A casebook of Infrared Imaging in Clinical Medicine," a collection of thermal images that can be found in clinical cases. An update of this book, extended to include chapters on the technique of thermal imaging and with more clinical cases, was published in 2015 by IOP Publishing in Bristol. Francis delegated the organisation of the planned update of the 2015 version to close friends, all experts in clinical thermography, at the beginning of 2019.

Besides his endeavour to establish infrared thermal imaging as a complementary diagnostic tool and outcome measure in clinical trials with arthritis patients, he became involved in osteoporosis research and bone densitometry. Francis developed a bone densitometry service using single photon absorptiometry (one of the first 5 centres in the UK), followed by dual x-ray absorptiometry for whole body scans. He started a series of biennial conferences dedicated to osteoporosis and bone mineral measurement, and he edited the proceedings books of five of these conferences. Prof. Ring joined the National Osteoporosis Society (NOS), became a member of the Scientific Advisory Council and chairman of a national working party to establish NHS training in bone densitometry. He developed the framework for the first UK National training Course in Clinical Densitometry and edited a training manual entitled: "Fundamentals of Bone Densitometry" first published by the National Osteoporosis Society in 1998 and revised in 2000 and 2001. Later, course participants could do their exams online by using software developed at the University of Glamorgan. In 2017, Francis was elected as an Honorary Fellow of the NOS.

While still working as the head of the Clinical Measurement department in Bath, Francis became an external professor at the University of Glamorgan in 1994. At that time, he developed expertise in optical wound measurements while contributing to the MAVIS project, a device developed by Peter Plassmann that was capable of performing volumetric wound measurements utilising structured light. After Francis' retirement from his clinical role in Bath in 2001, he continued at the University of Glamorgan as head of the Medical Imaging Research Unit until 2018, enriching the field with his expertise in thermography and bone densitometry. This unit came to offer a postgraduate PhD degree in thermology and attracted many, now well-known, experts in thermal imaging. Rod Thomas, Rob Simpson, Ricardo Vardasca, Kevin Howell and I were awarded a PhD degree in the period between 2000 and 2005. Initiated by Francis and Prof. Bryan Jones, the University of Glamorgan also offered Short Courses on Medical Thermography from 2001 onward, which were attended by students from all around the world. A set of standard body positions, views and regions of interest developed for the "Atlas of thermograms of the human body recorded in healthy subjects", known as the Glamorgan Protocol, was the basis for image recording and analysis in these teaching activities.

Francis also became very interested in fever screening by infrared thermography. In cooperation with Prof. Anna Jung in Warsaw he investigated a large group of children with suspected fever, obtaining a reference for core temperature at the inner canthus of the eye. These data, and the position of the head as proposed in the Glamorgan Protocol, became the main reference source in the ISO standard document "80601-2-59, Medical electrical equipment - Part 2-59: Particular requirements for the basic safety and essential performance of screening thermographs for human febrile temperature screening".

Foot ulcer assessment by thermal imaging was the last large project in which Francis was engaged. A spin-off company of the medical imaging research unit designed a battery-powered thermal imager using microbolometer arrays operating at 8-14 ?m, aiming for field trials of subjects at high risk for diabetic foot ulcers. The measurement specifications of this device, used in four clinical settings, are published, and first clinical measurements derived from healthy subjects and some patients are now available.

For many years Francis and I had discussed updating the contents of the book "Human Body Temperature." Work was finally started in the week between two medical conferences held in Zakopane in March 2013. Due to our underestimation of the time required for revising the sections on thermal physiology, and Francis' unexpected health problems, it took until June 2018 to deliver the final manuscript. Francis was very pleased with the new book, published in May 2019, and I hope the thermology community will come to appreciate "The Thermal Human Body" as a fitting revision to "Human Body Temperature".

However, listing Francis' impressive scientific contributions to thermology does not completely capture his talents, interests, achievements, and definitely not his personality. I first met Francis in May 1988, interested to learn how medical thermal imaging could be performed. I never experienced him impatient or angry; he was always gentle and good-humoured, open to new ideas and critical discussion, and willing to give supportive assistance. He was fond of music, particularly of classical piano music. He played the piano or, if unavailable, an accordion quite well, performing various music styles on these instruments. He liked to travel, and he had some preferred places to visit such as the south of France, Piestany in Slovakia, Zakopane in Poland or my hometown Vienna in Austria. In Vienna, roasted duck became his favourite meal, in combination with a glass of young white wine (Grüner Veltliner). This traditional dish is served in eastern Austria in November in honour of St. Martin, and we never missed getting this meal at that time of the year.

Over the years, I detected other facets of Francis' interests. He started his career as a Medical Laboratory Scientist and became an Associate of the Institute of Medical Sciences (Bacteriology) in 1958 and a Fellow of the Institute of Medical Sciences (Histopathology) in 1960. Francis took a university course in scientific photography and scientific instruments. His professional life in those early days was filled with images seen through a microscope, describing features and structures that are invisible without the use of magnifying optics. Francis' curiosity, his wish to look behind the scenes and to trace observations back to their source, and his ambition to understand how phenomena are generated was already detectable in this early stage of his scientific life. He was convinced that proper terminology was the essential foundation for understanding and fruitful co-operation. In my opinion, this motivation and interest explains very well Francis' achievements in thermal imaging and beyond. Infrared rays, which are invisible to the human eye but can be sensed by thermoreceptors in the skin, obviously fascinated him, and also the history of the observation and evaluation of heat and temperature in medicine and biology.

His interest in the scientific achievements of the Herschel family resulted in many articles on the history of heat and temperature measurement, and the foundation of The William Herschel Society and the related William Herschel Museum in Bath. As founder and Chairman of the Herschel House Trust, he established a link between The Royal Society, the Royal Astronomical Society and the University of Bath. Prof. Ring was elected to the Fellowship of the Royal Astronomical Society in 1994. For the promotion of the William Herschel Society, Francis edited a small journal named "The Speculum." This published two editions per year, and reported lectures presented at meetings of the Society, progress in international space research, and Society activities. I remember photographs of a partial eclipse taken by Francis, and his pleasure and enthusiasm when we visited together the Air and Space Museum in Washington DC.

The Royal Photographic Society (RPS) was another important field of Francis' activity. He joined the RPS in 1980 and the committee of the Imaging Science Group in 1987, and as chairman of this RPS group he linked the RPS and the EAT in the combined responsibility of organising the 6th European Conference of Thermology in 1994 in Bath. He also inaugurated a series of conferences on infrared and other imaging in forensic science on behalf of the RPS Imaging Science Group. The William Herschel Infrared Bicentenary Conference, held at the Guildhall, Bath in March 2000, attracted international speakers and audience celebrating the 200th anniversary of the detection of infrared rays. Francis served the RPS as a member of the Science Council and Imaging Science Qualifications Board, as Industrial & Academic Liaison Officer, and as a member of The National Awards Committee. He was always eager to find new imaging technologies that deserved an award, and Francis was pleased when his proposed candidate achieved a successful outcome with the awards committee. I was impressed by how carefully Francis developed his proposal that Prof. Dr. Fercher, a medical physicist from Vienna, should be the recipient of the Royal Photographic Society's 2014 Combined Royal Colleges Medal for developing Optical Coherence Tomography, an imaging technique now used widely in medicine, especially in eye examinations. Francis himself received the Royal Photographic Society's Combined Royal Colleges Medal in 2008 for "Advances in Computerised Thermal imaging in Medicine." In 2011 Prof. Ring became an RPS honorary life member and received the Fenton Medal for services to the Royal Photographic Society.

Francis received an MSc. degree in 1975, and the degree of DSc. in 1991, both from the Pharmacology Department of the University of Bath. Although he was not a physician, his contributions to medicine were recognised by the national and international medical community. In 1996, he received Honorary Membership of the Slovak Medical Society in recognition of scientific assistance to Czechoslovakian Medical Science since 1984. In 2012, he became a Fellow of The Royal Society of Medicine. Wisely, he never competed with medical doctors in decisions on patient care, or proposals for further steps in diagnostic or therapeutic interventions. He restricted himself to an accurate and precise description of his thermographic, densitometric or planimetric findings, was aware of the limitations and uncertainties of clinical measurements, and thus carefully avoided overinterpretation.

Personally, I lost a close friend, a companion in promoting thermal imaging in health sciences, and a partner who was convinced that thermography is a scientific discipline and not a fortune-telling crystal ball. I will miss his company during our annual travels from Vienna to Zakopane, and his assistance in editing Thermology International or authoring articles on future developments in thermal imaging. There will be no more chances to listen to his rich experience, his piano playing, nor to chat, drink a glass of wine or a drop of malt whisky. It is comforting that the remembrance of his great personality will never fade away.

Prof Dr. Med Kurt Ammer Ph.D
European Asociation of Thermology

Memory notes from around the globe

E.F.J. Ring RIP

William Hershel discovered infrared radiation in 1800 and his son John produced the first thermogram image. This created the foundation for radiometric determination for skin temperature and the awakening of medical and physiological infrared thermal studies. Since the 1960's. E.F. J. (Francis) Ring has been a leader in the thermology world. He has authored and co-authored numerous books on the topic and published over 300 articles. As a scientist he has developed equipment, research testing protocols, functional imaging programs, and guidelines on the principles for proper use of infrared imaging. His medical and physiological questions pursued a vast number of topics and interests. He was a generous teacher giving his time, knowledge, experience, and expertise and mentor to fellow thermologists worldwide. Francis was a treasured friend to all that knew him and a respected member of the European Association of Thermology, American Society of Thermography, and other international infrared imaging societies. As a leader in the field thermal imaging, he will be greatly missed. His career, work, and contributions have created an indelible mark on the advancement of infrared imaging science and research.

David Pascoe, Ram Purohit, Tim Conwell- American Thermology Colleagues

Charming - is the first word that comes to mind when I think of **Francis Ring**. Francis was not only one of the finest scientists I have had the pleasure to be associated with in my nearly 50 year-long scientific career, but also one of the finest gentlemen I have ever met. As well as being a veritable mine of knowledge in the world of infrared thermography Francis was also, as you can read in the main obituary, an expert in several other fields such as bone densitometry, astronomy and the history of thermometry. I often jokingly referred to him as "Ringopædia". My association with Francis was closely tied to the use of infrared thermography in medicine. Francis was one of the most avid promoters in this fascinating field of science you could ever have met. His enthusiasm for promoting not only the use of infrared thermography in the biological sciences, in particular medicine, but also in promoting the European Association of Thermology, had no bounds. His unique ability to encourage, advise and discuss science with the youngest to the most experienced experts is one of the hallmarks of a World-class scientist. This is also reflected in the incredible amount of text books, review articles and scientific articles he has published in this field, right up to the last months of his life with the publication of a yet another great textbook on thermography with his longtime friend and colleague Kurt Ammer. Francis always enjoyed giving talks on thermography at congresses and symposiums all around the World. His talks were always well prepared and a great pleasure to listen to. Francis was a popular invited speaker.

My association with Francis started when I attended my first EAT meeting, the 9th European Congress of Medical Thermology in Krakow in 2003. At that time, I was interested in thermoregulation in the elderly. Through serendipity I had acquired my first IR camera, a Sony Laird, and had carried out my first study comparing hand and foot re-w arming times following a cold challenge in young and elderly healthy subjects. I was eager to receive feedback from "thermography experts" and, as it turns out for my scientific future at that time, I was lucky to have attended this meeting. I remember it was a lively meeting with many heated discussions between some of the "elderly" members of the EAT. I was somewhat nervous and felt like Daniel in the Lions Den. I actually said this at the start of my talk. Luckily, the talk went well and was well received. After my talk, a man called Francis Ring (I had no idea of his status at that time) came up to me and reassured me that I did not have to fear the Den any longer, which was a very kind comment. Francis asked me later if I would I like to join the EAT, with Kurt Ammer hot on his heals asking me to publish my study in Thermology International, both, of course, which, I did. This was to be the beginning of a long and cherished entry into the EAT and the World of Medical thermography and, not least, friendship with Francis. This small beginning and acquaintance with Francis led to many doors being opened for me in the years to come, eventually leading to my term as president of the EAT and a love for this topic, which I still am lucky to continue experimenting with today, even in retirement.

There are so many stories I could tell about Francis but space limits me to a few. For example, Francis discovered that my wife and I liked a special type of English tea, which we could not get in the Norway, and for many years whenever we met in the World, Francis always had several packets of tea to give us. It became a sort of ritual. Even though Francis always travelled light (hand luggage only) he was always very well dressed in suit and clean shirt and tie. How he fitted his clothes and not least the packets of tea in his small suitcase always amazed us. Francis loved to tell the story of an occasion his suitcase was being inspected by a security officer at an airport. The security man had to open his suitcase and on returning it, the officer commented that he had never seen such a neatly packed suitcase!

Sometime it could be frustrating to talk to Francis. On many occasions I came up with, what I thought were new and original ideas for using thermography in medicine. I would call Francis to discuss them and on most occasions he would say, Oh yes James, I did this many years ago! It seems there was no area in medicine that Francis had not investigated with thermography. Over the years my meetings with Francis were largely related to events revolving around the EAT but also on other occasions such as ISO standards meeting which he got me involved in.

Francis's historical interest in thermography of course, included his deep involvement in the William Herschel Society and museum in Bath. My wife and I have had the pleasure of been personally shown around the museum by Francis - an unforgettable experience. As mentioned in the main obituary, Francis was a fellow of the Royal Photographic Society (RPS) and in 2008 he received The Combined Royal Colleges for "an outstanding contribution to the advancement and/or application of medical photography or the wider field of medical imaging". The award was presented at a meeting in London which my wife and had the honour of being invited to. At the presentation Francis presented a talk entitled "Making Invisible Light Visible" - one of the best talks I have ever heard him present. Later in 2011 Francis was awarded the Fenton Medal with honorary life membership of the RPS for his outstanding contribution to the society. In October 2010 Francis organized a one day seminar of the Royal Astronomical Society on The Development and General Applications of Infrared Imaging as part of the RPS Infrared 100 seminar series. I was privileged to be one of the invited speakers and held a talk on the Thermal Behaviour of the African Elephant. In the September 2010 issue of the RPS journal a thermographic image of an African elephant, which I had taken, was published as part of an advertisement for the Infrared 100 seminar series. I am extremely proud of having this image published in this very prestigious journal. Francis, of course, organized this.

Through time my wife Liz also became a good friend of Francis as well as with many other of our dear colleagues in the EAT. We feel privileged that Francis had been to visit our home in Tromsø, on several occasions, for example, when he was an external examiner for one of my PhD students. Francis was enthralled with the special Arctic light we have here in the far north, taking many photographs, photography being one of his hobbies.

Francis's scientific interests had a wide span, ranging from the historical development of thermometry to the use of modern scientific technology. With regards to the latter Francis recently made use of modern genetic research tools to trace the routes of his dear wife Anthea. Anthea, was abandoned as a baby and had no idea of who her parents were. Using this modern technology, they were, after much work, successfully able to trace her routes back to Ireland. Incredibly, a key link was the isolation of DNA from the back of a postage stamp on an old letter. This amazing achievement of Anthea's being able to find who her mother was, was a true scientific endeavour carried out by Francis's with typical dedicated involvement. The story received large cover in the popular press. After this discovery my wife Liz, who is also Irish, would jokingly tell Francis that Irish women make the best wives!

Like many others, my wife and I cherish the many fond memories we have of Francis Ring. I personally will always be grateful to Francis for being a good friend and colleague and especially for all he has done in helping me to "see" the invisible light.

Professor emeritus James B. Mercer, Tromsø, Norway-past president and life time honorary member the EAT

Receiving the news of **the passing of Francis**, even being prepared for that, was very difficult, I met him firstly in May 2005 when I was looking for a PhD opportunity, through Peter Plassmann, we had a conversation for 30 minutes where we discovered shared interests. He introduced me to the Medical Infrared Thermography world, being my adviser, become a close friend, which I liked to call him 'family'. In 2006 he gave me comfort when I received my grandfather death news, somehow, I like to think that he took that place by being my confident and provide me his wise advises until recently. During our scientific collaboration we authored several scientific contributions and shared wonderful and memorable moments together in 11 different countries (UK, Poland, USA, Austria, Germany, Portugal, Brazil, Argentina, Spain, France and Ireland), most more than once. We also shared interests in football, supporting Chelsea FC, photography, cinema, music and drinks.

Francis Ring is one of those persons who never die for all that they have given to persons like myself, who had the fortune to walk by his side. The heaven got richer with him.

Rest in peace my dear friend and mentor, you'll be missed but never forgotten.

Ricardo Vardasca, EAT General Secretary,Portugal

Francis Ring in 1964

A Life Scientific

When I joined the Royal Free Hospital in London in 1992, with a new physics degree from the University of Birmingham, I was immediately set the task of helping the Rheumatology Department develop their fledgling clinical measurement service.

The department was fortunate to possess some rudimentary infrared thermography equipment, with the intention that this would help us to assess conditions such as Raynaud's phenomenon in both clinical and research settings. At the time of my arrival, we had made only limited progress with the apparatus, and it certainly wasn't clear to me how we could use the technique reproducibly and reliably. The Head of Department in those days, Dr. Carol Black (now Dame Prof. Carol Black), suggested I travel to Bath in the west of England to seek the advice of a Consultant Clinical Scientist who already had around 30 years of experience in thermography. This was how I came to meet Francis Ring for the first time.

When I arrived at the Royal National Hospital for Rheumatic Diseases for my appointment with Francis, I was amazed to discover that he had cleared most of his diary commitments for the next two days in order to ensure I could receive personal tuition from him about every possible aspect of infrared thermography. Every question I asked was answered patiently by supplying reading material from Francis' vast collection of published research, or directing me to the work of others. I returned to London with a bag full of books and papers, and a new confidence that we could develop a successful thermography service in London.

Many of us in thermology have stories like this to share about Francis. He had the rare quality in a busy person of finding the time to help everyone. He was a true polymath, with passionate interests which included astronomy, music, photography and the history of science (in particular, the life of infrared discoverer William Herschel).

Away from the field of thermology, Francis developed notable professional expertise in other areas of clinical measurement. He ran a well-regarded and successful bone densitometry service in Bath, for example. But, of course, within the EAT we remember best of all his lifetime of contribution to the discipline of infrared thermography.

Francis and his team in Bath were the first to demonstrate that thermography could be a reliable outcome measure in studies of anti-inflammatory medication, and also performed some of the earliest work in the quantitative evaluation of peripheral vascular disorders such as Raynaud's phenomenon.

It was Francis who fully recognised the need for good quality-assurance and reproducible protocols, and normative data in thermography. Without these elements in place, he understood that the technique would not be accepted by the medical profession. He served two terms as President of the EAT, and his experience in evidence-based thermological methods, and ability to communicate to both scientists and clinicians, was vital to the success of our organisation.

At an age when many consultants turn permanently to gardening, the ever-energetic Francis moved from the NHS to found the Medical Imaging Group at the University of Glamorgan with Peter Plassmann. Here was an environment where many of the outstanding research questions in thermography could finally be addressed. Many of us benefited from the PhD programme at Glamorgan, and Francis was rightly proud of the huge impact the Group had on the training of the next generation of thermologists. Just a few weeks ago, Francis wrote to me to point out (politely, as always) that what we now call the "EAT Short Course in Medical Thermography" was really a syllabus developed and refined at Glamorgan.

In later life, Francis was still traveling regularly to congresses: many of you will remember his presentation in London in July 2018, reinforcing the important message that fever screening could only be performed reliably by adhering to the ISO standards he had played such a large role in developing. Despite his obvious failing health, he was as full of anecdotes and good humour at the congress gala dinner as always.

Francis' first book, "Human Body Temperature" written with Y. Houdas and published in 1982, grew to be recognised as a key textbook on thermal physiology. His last, "The Thermal Human Body" written with his friend of many years, the EAT's Kurt Ammer, was published just last month and will definitely come to be regarded as highly as the work with Houdas. A copy arrived at my laboratory on the morning I heard from Peter of Francis' passing.

Francis death, peacefully on 15th July at the age of 83, is a loss to the EAT of our greatest scientific influence and closest friend. He would probably be proud of some comparison of his career to that of his beloved William Herschel, but I would personally prefer to liken Francis to an even earlier British thinker, the scientist, architect and astronomer Sir Christopher Wren. Wren's masterpiece, St. Paul's Cathedral in London, bears the inscription "si monumentum requiris, circumspice" - "if you require his monument, look around."

The next time we all meet at a thermology congress, look around. The researchers from across the world who are working to produce quantifiable, evidence-based medical thermography are Francis' legacy.

Kevin Howell,
Clinical Scientis in Microvascular Diagnostics,
Royal Free Hospital, London, UK
President of the EAT

On the passing of our mentor, colleague and friend, Francis Ring

His passing leaves a void that will be a real challenge to fill and gives us a great deal to do**.** E Francis J Ring, DSc. was an icon of scholarship and responsible practice of medical thermology. His passing ends an impressive tome of contributions but leaves a legacy that will continue to inspire and guide those of us fortunate to have known him and generations of thermologist to come. I knew him as a deep and thoughtful man, generous with his knowledge and an unexpected sense of humor. I will miss him.

Phil Hoekstra, Phoenix, AZ, USA

Dear relatives and friends of Francis Ring !

It was with great sadness that I, my family and my colleagues learned of the death of Francis Ring in the morning on 15 July 2019 . The death of Francis Ring is certainly a great loss for everyone involved in biomedical Infrared Thermography. Especially hard to realize the death of Francis Ring us living on the Eastern outskirts of Europe (near the Ural mountains). The fact is that for a long time we were isolated from the whole world and did not have the opportunity to communicate with scientists from other countries and travel to other countries. We could only read scientific articles published by scientists. The fact is that for a long time we were isolated from the whole world and did not have the opportunity to communicate with scientists from other countries, to travel to other countries, to participate in scientific conferences, to make scientific reports and to publish our data in international journals. We could only read scientific articles published in these journals by scientists from different countries. Therefore, we were essentially outside observers of scientific progress, not its participants. But fortunately, Russia has recently opened its borders to its citizens and researchers. Thanks to this, and at the invitation of the Polish scientist Antonio Novakovsky, my wife Tatiana Urakova and I in 2013 for the first time went outside Russia and was able to participate in a scientific conference on biomedical thermology in Warsaw. During this conference I first saw Francis Ring and heard his scientific report.

I want to admit to you that Francis Ring with his appearance, manner of communication, deep knowledge of the history of infrared thermography and warm location to the participants immediately attracted my attention. And the subsequent time confirmed my first impressions. After this first meeting, I met with Francis Ring annually. Most often this occurred in Poland, namely in Zakopane, where we visited all the friends of thermology at the invitation of Professor Anna Jung. Today I can say that all this time Francis Ring was a living legend for me ! He embodied both the dignity of a great scientist, a wise leader, a proud British citizen and a reliable family man.

I would also like to inform you that thanks to Francis Ring I have formed very favorable ideas about the British and the UK. And this opinion will remain in me forever, because Francis Ring had on me indelible impression. It so happened that at first the first impression of Francis Ring I had another. At first it seemed to me very similar to Churchill. And so it seemed to me that Francis Ring should be very important and prim. However, the time spent together and the attitude that Francis Ring showed to all others and to me showed the opposite: Francis Ring was a well-mannered, very modest and VERY FRIENDLY PERSON ! Although he certainly knew his worth.

The way of life that Francis Ring has passed, his faith and devotion to his chosen ideals, determination, perseverance and courage shown before our eyes, are an example to follow not only for me, but also for my students and colleagues. I can tell you that I want to be like him.

The bright memory of Francis Ring will forever remain in our hearts ! May he rest in peace ! Please accept our deepest condolences in the passing of a GREAT COMPANION and a devoted family MAN.

Aleksandr Urakov
[Prof., Head of Dep. General and Clinical Pharmacology, Izhevsk, Russia]

Prof. Ring was the "master" in medical thermology

I am one of the old friends. Or, it may be better to be a Prof. Ring's pupil in thermology. There are many Japanese colleagues who think Prof. Ring is their "master" in medical thermology.

Just after I received the grieving e-mail from Prof. Kevin Howell, I informed this to the directors in Japanese Association of Thermology. All of them are grief-stricken by the utmost sad news, and they showed their mourning. Some colleagues say they wanted him to look the results of their researches in process.

Many Japanese members of thermology were taught much knowledge from him. We read his reports and studied the way of thinking. Some of them participated the international thermological meeting, spoke with him and were taught many things directly.

I am one of them. I may be a member participating in the conferences and meeting him most frequently in Japanese Society. Now, I remember many scenes I met him, discussed with him and got valuable knowledges in the venues of many thermological meeting. I participated in the meeting of European Association of Thermology held at London in July 2018. It was my happiness that I met and talked with Prof. Ring in the conference venue. At that time, he told me his disease and the treatment. I was surprised about it and that he looked to lose weight. But his eyes were shining without change. I never forget his shiny and pellucid eyes at the time we talked.

I respectfully offer my condolences. I also pray his more happiness in heaven.

Hisashi Usuki
Chief Director of Japanese Society of Thermology

The **15th July was very sad day** due to the news that Prof E F Ring, our friend Francis, passed away. We knew about his severe disease, nevertheless his death filled our minds and hearts with grief and sadness.

The history of our association with Francis has more than 25 years and started at one of the European Congresses of Medical Thermology. After that we met him very often during various thermology conferences.

Prof. Francis Ring was a great source of information with enormous knowledge in thermography. He was one who introduced thermal imaging into a clinical setting. As a leader on the field thermal imaging he supported us in our investigations. Our scientific cooperation was long and fruitful, for example, data from research s of fever screening by infrared thermography in children became the main reference source in the ISO 80601-2-59 standard document.

We had the great honour to edit together with Prof F. Ring two books: " A Casebook of Infrared Imaging of Clinical Medicine"(Warsaw 2003) and its updated version published in 2015 by IOP Publishing in Bristol.

We enjoyed several visits of Francis in Warsaw , where we're working together in the Thermology Laboratory of the Military Institute of Medicine. Besides performing research in Warsaw, Francis loved to attend concerts, he preferred especially Chopin music. At one of his last visits he was very pleased about the opportunity to attend the performances of the International Chopin Festival competition and to listen to the final laureate's concert.

Francis attended almost all annual conferences of the Polish Society of Thermology in Zakopane. He presented main lectures, chaired sessions and discussions as long as his health allowed it. He loved Zakopane, where he started the work about last book" The Thermal Human Body", written with his best friend Kurt Ammer. Fortunately, the book was ready in spring 2019 and Francis was very pleased with that. Peter Plassmann, a close and caring friend, helped him to distribute this new book to his friends. Personally, we received a hardcopy of that book in May, with last hand-written greetings from Francis

Thank you Francis for your friendship and we will see you in better world!

Janusz Zuber and Prof Anna Jung,
Vice President of European Society of Thermology & Vice President of Polish Society of Thermology

Hooshang Hooshmand, M.D. 1934 -2019

Dr. Hooshang Hooshmand passed away Friday August 9, 2019, age 84, at his home in Vero Beach, Florida with his family by his side. He was born November 16, 1934 in Tehran, Iran to the late Hassan and Zahra Hooshmand.

He received his doctorate of Neurosurgery and Neurology from the Mayo Clinic in Rochester, Minnesota, and then became an Associate Professor at the Medical College of Virginia. He was the first to establish Neurology and Neurosurgery in Vero Beach area.

Dr Hooshmand used routinely thermal imaging as complementary information source of pain syndromes, particularly in patients suffering from complex regional pain syndrome (CRPS). His articles "Infrared Thermal Imaging as A Tool in Pain Management-An 11 Year Study. Part I and Part II" published in 2002 in Thermology international are among his most quoted articles related to thermology. Eric Phillips, who worked with Dr Hooshmand in Vero Beach, Florida, informed the editor of Thermology international about the passing away of Dr. Hooshmand. Eric mentioned, that "Hoosh" really enjoyed working with the editorial staff of Thermology International over the years. His input and promotion of thermal imaging in the field of neurology will be missed, but not forgotten.

The Thermal Human Body

Review of the book "The Thermal Human Body: A Practical Guide to Thermal Imaging" by Kurt Ammer and Francis Ring (Jenny Stanford Publishing, Singapore)

Kevin Howell

Clinical Scientist in Microvascular Diagnostics, Royal Free Hospital, London, UK,
President, European Association of Thermology

Francis Ring's first book, Human Body Temperature, written with Y. Houdas and published in 1982, came to be recognised as a seminal textbook on thermal physiology. His last, The Thermal Human Body, written with his friend Kurt Ammer, is now available in hardback and e-book versions, and is a comprehensive update to the original work.

Kurt and Francis had long discussed producing a major revision to Human Body Temperature to reflect both the significant increase in knowledge of human thermal physiology since 1982, and also the great improvements in infrared imaging technology. The Thermal Human Body will now serve as the most important educational resource available on the topic of thermal imaging in medicine for the foreseeable future.

Chapter one gives a brief historical overview of thermal imaging technology development. The authors wisely keep this section brief, as it is not the main focus of the book, but many good references are included for those who seek further reading.

Chapter two addresses basic thermal physics. Whilst this may not be a section that easily holds the attention of clinicians, it is essential reading in order to form an understanding of the methods of heat transfer that underpin thermal physiology. There is an enormous amount of reference information in this chapter. Some of these data, such as the tables on SI units and SI prefixes, may not be strictly relevant to the subject of the book, but the authors are to be commended for their detailed approach to this section.

Chapter three discusses thermal physiology and its influence on skin surface temperature. This is the longest and most significant section of the book, and forms a meticulous review of the current understanding of the physiological processes governing human body temperature. This is undoubtedly the section of the book which will come to be cited most, since it stands alone as the ideal primer in thermal physiology. Over 150 references are included, guiding the reader to all the most important research on the topic

Chapters four and five discuss the practicalities of operating a thermal imager, and performing adequate quality assurance on the device. These sections are generally excellent, although the authors give a rather curious definition of thermal resolution in chapter five. Disregarding this one minor controversy, there is everything the reader could need in these sections to ensure the correct operation of infrared equipment for clinical and research use.

Chapter six looks at imaging protocols, focussing on the Glamorgan Protocol for thermal image capture and the selection of regions of interest. The full protocol image set is beautifully reproduced in colour in this section. This is an importance reference chapter that many thermographers will turn to regularly, for guidance on how a specific body part should be reliably imaged.

The final chapter (seven) discusses how thermal images should be recorded and evaluated. There is some overlap here with the concepts addressed in chapter six, but the descriptions of provocation tests and image reporting are certainly of value.

As with all first editions of a textbook, a few minor errors have crept in. Superscripts in one or two equations have been printed incorrectly, and a few sentences would benefit from revision to improve the clarity of the English. The small format of the book also makes some figures hard to interpret: the colour figures such as 3.12 are a particular challenge to my presbyopic eyes!

These very minor criticisms apart, the authors should be congratulated on a comprehensive and beautifully-crafted textbook. I think any work such as this should be judged on how well it brings clarity to complex concepts for the student. Kurt Ammer and Francis Ring have succeeded beyond all expectation in this regard.

2019

29th-30th August 2019

2nd International Symposium on Sensors and Instrumentation in Internet of Things Era (ISSI) in Lisbon, Portugal

Special Session_TG
Thematic session on thermal measurements

This session will welcome presentations about thermal IR sensors and cameras, as well as the use of IR technology in medical and industrial applications. This Special Session is mainly focusing on:

- IR technology applications both, medical and industrial
- Thermal sensors
- Thermal simulation software
- Electromagnetic thermal effect
- IR based Maintenance
- Non-destructive tests
- IR Spectroscopy
- Image processing software
- Security and Surveillance
- Remote sensing
- Drones sensing

Session Chairs:

Joaquim Mendes & Ricardo Vardasca,
University of Porto, Portugal

furter information at https://sens-in-net.tech
or contact

Octavian Postolache
ISCTE-IOL and Institute de Telecomunicacoes
Email: opostolache@lx.it.pt

6th-8th September 2019

9th Annual Scientific Session of the American Academy of Thermology in Atlanta, Georgia plus Physician`s Interpretation Course on 6th September

Venue: Emory Conference Center & Hotel, Atlanta, Georgia

Registration via https://annualmeeting.aathermology.org

Programme

Day 1 , September 6th, 2019

Pre-Meeting Physician Member Interpretation Course (separate registration required):

Day 2 - Saturday, September 7th, 2019

GENERAL SESSIONS

8:00 am Registration

08:30 am Welcoming Remarks by Jeff Lefko, MHA, AAT Exec. Director, Greenville, SC

08:45 am Keynote Address:
Clinical Applications for the Management of Complex Pain by Marcos Brioschi, MD, PhD, Sao Paulo, Brazil

09:30 am Pain, Central Sensitization, and Dysautonomia From a Thermographic Perspective by Robert Schwartz, MD, AAT COB, Greenville, SC

9:50 am Thermology Validation: QSART vs Sympathetic Skin Response (SSR) Thermography by Tashof Bernton, MD, AAT Board, Denver, CO

10:10 am False Negative Autonomic Studies Validated By Cold Stress Thermology by David Reinhard, MD, Aurora, CO

10:30 am Break

11:00 am AAT Professional Development: Revised AAT Veterinary Guidelines by Tracy Turner, DVM, President, AAT, Elk River, MN

11:20 am Thermal imaging to Monitor Equine Exercise Endurance by Ken Marcella, DVM, Canton, GA

11:40am Veterinary Thermography Cases,
by Ronald Riegel, DVM, Marysville, OH

11:50am Veterinary Thermography Cases
by John Godbold, Jr., DVM, Jackson, TN

12:00 pm Lunch (provided)

1:00 pm CLINICIANS CORNER 1:
THERMOGRAPHY TIPS AND TECHNIQUES

01:00 pm Physics of How Thermography Cameras Work by Robert Schwartz, MD, AAT COB, Greenville, SC

01:20 pm What Matters and Why by Philip Getson, DO,
AAT Past President, Marlton, NJ

01:45 pm Creating The Optimal Patient Experience
by Liesha Getson, Marlton, NJ

2:05pm Validating Patient Complaints in Pain Management by Matthew Terzella, MD, AAT Board, Greenville, SC

02:20 pm Break

02:50 pm CLINICIANS CORNER 2: BREAST THERMOGRAPHY RISK ASSESSMENT VALIDATION

02:50 pm Study Proposal 1: TH Score True Positive, False Positive and False Negative Rates by Raghava Bhaskaran, MD, Atlanta, GA

03:05 pm Study Proposal 2: TH Score True Positive, False Positive and False Negative Rates by Christine Horner, MD, AAT Board, San Diego, CA

03:20 pm Study Proposal 3: TH Score True Positive, False Positive and False Negative Rates by Alex Mostovoy, DHMS, BCCT, Thornhill, ON

3:35pm Study Proposal Comments, Q & A
by Robert Elliott, MD, Past AAT President, Baton Rouge, LA

03:50 pm THERMOGRAPHIC FORENSICS

03:50 pm Use of Thermography in Forensic Medicine by Marcos Brioschi, MD, PhD, Sao Paulo, Brazil

04:10 pm The Need for Thermography as a Domestic Violence Screening Tool by Brian Bennett, Columbia, SC

04:30 pm Police Force Experience With Thermography in Domestic Violence by William Smock, MD, Lexington, KY, James Campbell, MD, AAT Board, Clemmons, NC

04:50 pm INNOVATIONS & PAPER PRESENTATIONS IN MEDICAL THERMOLOGY

4:50 pm Thermography Integration into PM&R Residency Training Programs by Bryan O'Young, MD, AAT Past President, Danville, PA

5:00 pm Use of Thermography in Critical Care Units by Lokendra Thakur, MD, Danville, PA

5:15pm Glycocalyx, Microvascular Disease, and Medical Thermology by Hans Vink, PhD, Maastricht University, Maastricht, The Netherlands

5:30pm Use of Infrared Thermography In The Measurement of Brown Fat Metabolism by Franciele De Meneck, PhD, Sao Paulo, Brazil

5:45 pm Integrating Thermography Into a New Surveillance Paradigm For Early-Stage Breast Cancer by Mark Nathaniel Mead, MSc, Durham, NC

6:00 pm Saturday Session Ends

6:30 pm Meet and Mingle Reception, Hickory Room, Emory Conference Center

Day 3 - Sunday, September 8th, 2019

General Sessions and Annual Business Meeting:

8:00 am Special Session: ORAL SYSTEMIC THERMOGRAPHY PRESENTATIONS

8:00am AAT 2019 Oral-Systemic Guidelines Update by Robert Schwartz, MD, AAT COB, Greenville, SC

8:15 am Use of Thermography for Face-Ear Temperature Screening of Febrile Airport Travelers by Ho Yeol Zhang, MD, PhD, NHIS Ilsan Hospital, Seoul, Korea

8:45 am Facial Studies for Migraine by Marcos Brioschi, MD, PhD, Sao Paulo, Brazil

9:15 am Use of Thermography in Systemic Dentistry
by Denise Haddad, PhD, Sao Paulo, Brazil

9:45 am Oral Systemic Thermography Cases
by Alex Mostovoy, DHMS, BCCT, Thornhill, ON

10:00 am Oral Systemic Cases by James Campbell, MD, AAT Board, Clemmons, NC

10:15 am AAT ANNUAL BUSINESS MEETING

10:15am Innovations For The AAT Newsletter by George Schakaraschwili, MD, AAT Board, Denver, CO

10:30am Network And Information Exchange

11:00 am General Session Ends

11:00 am Board of Directors Meeting
(Board Members Only)

16th -19th September 2019

AITA 2019- Advanced Infrared Technology and Applications in Florence, Italy

In the 15th AITA edition, special emphasis will be given to the following topics:

- Advanced technology and materials
- Smart and fiber-optic sensors
- Thermo-fluid dynamics
- Vibrational spectroscopies
- Biomedical applications
- Environmental monitoring
- Aerospace and industrial applications
- Nanophotonics and Nanotechnologies
- Astronomy and Earth observation
- Non-destructive tests and evaluation
- Systems and applications for the cultural heritage
- Image processing and data analysis
- Near-, mid-, and far infrared systems

For details, please refer to the workshop website: http://ronchi.isti.cnr.it/AITA2019.

16th -18th October 2019

International Conference VipIMAGE 2019 - VII ECCOMAS THEMATIC CONFERENCE ON COMPUTATIONAL VISION AND MEDICAL IMAGE PROCESSING in Porto, Portugal.

Chairs: João Manuel R. S. Tavares & Renato Natal Jorge, Universidade do Porto

Venue: Axis Vermar Conference & Beach Hotel, Porto, Portugal.

Topics

- Signal and Image Processing
- Computational Vision
- Medical Imaging
- Physics of Medical Imaging
- Tracking and Analysis of Movement
- Simulation and Modeling
- Image Acquisition
- Industrial Applications
- Shape Reconstruction
- Segmentation, Matching, Simulation
- Data Interpolation, Registration, Acquisition and Compression
- 3D Vision
- Machine Learning, Deep Learning and Big Data
- Virtual Reality
- Visual Inspection
- Software Development for Image Processing and Analysis
- Computer Aided Diagnosis, Surgery, Therapy, and Treatment
- Computational Bioimaging and Visualization
- Telemedicine Systems and Applications

Invited Lecturers

- Aurélio Campilho, Universidade do Porto, Portugal
- Danail Stoyanov, University College London, UK
- Daniela Iacoviello, Sapienza University of Rome, Italy
- João Paulo Papa, Universidade Estadual de São Paulo, Brazil
- Jos Vander Sloten, KU Leven, Belgium
- Wafa Skalli, Arts et Métiers ParisTech, France

Thematic Sessions

Proposals to organize Thematic Sessions under the auspicious of VipIMAGE 2019 are welcome.

The proposals should be submitted by email to the conference co-chairs (tavares@fe.up.pt, rnatal@fe.up.pt).

Accepted Thematic Sessions

- Cardiovascular, Cerebrovascular and Orthopaedic diseases: Imaging and Modelling
- Advances and Imaging Challenges in Micro and Nanofluidics
- Intersection between Image Processing and Machine Learning in Biomedical Applications
- Direct Digital Fabrication in Medicine: from digital data to physical models
- Computer Simulations and Visualization Applied to Tissue Engineering
- Parameterization of Reconstructed Organ Models
- Computational vision and image processing applied to Dentistry
- Network Neuroscience
- Applications of Ontologies for Medical Image Analysis and Computer-Assisted Interventions

The contributions should be submitted using the conference management system at: http://conference.mercatura.pt/vipimage2019

For further details, please, have a look in the conference website at: www.fe.up.pt/vipimage

30th November 2019

1st INEF-EAT Symposium on Thermography in Physical Activity and Sports in Madrid

Venue: INEF Madrid c/ Martin Fierro 7, University City of Madrid, 28040 Madrid, Spain

More information on page 120

2020

17th - 19th April, 2020

24th Conference of the Polish Association of Thermology Combined with the European Association of Thermology in Zakopane

Conference venue:
HYRNI Hotel, Pilsudskiego str 20, Zakopane

Further information:

Prof Anna Jung
a.jung@spencer.com.pl or
Prof. Armand Cholewka
armand.cholewka@gmail.com

6th - 10th July 2020

The 15th Conference on Quantitative InfraRed Thermography in Porto, Portugal

For further information and updates, please visit the website: **http://www.qirt2020.com** or

contact the organizing committee at **qirt2020@fe.up.pt**

See pages 121 and 122

Aim of the Symposium:

The INEF of Madrid and the European Association of Thermology (EAT) have organised this international symposium for connecting professionals who work in the area of Sports Thermography.

The main idea is to create a forum that is repeated periodically in the future, in which the participants have an active role.

We hope that during the symposium contacts can be established between professionals that allow collaborative working, or in a complementary way, to fill the gaps in knowledge in this innovative application of thermography.

See you at INEF on November 30th!

Manuel Sillero Quintana, on behalf of the organization of the symposium.

Sponsored by:

FLIR ThermoHuman

Venue of the Symposium:

INEF Madrid. C/ Martín Fierro 7
University City of Madrid
28040 Madrid. Spain

BUS: 46 (from Moncloa and P. Pio)
Walking: from metro Moncloa 15-20', from Metro C. Universitaria 10-15' or from Metro Principe Pio 25-30'

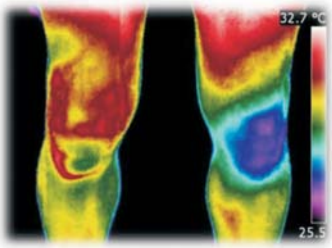
Contact:
Manuel Sillero: +34-687044034
termoinef@gmail.com

1st INEF-EAT Symposium on Thermography in Physical Activity and Sports

INEF POLITÉCNICA

Applications of Thermography in Sports and Physical Activity

Faculty of Physical Activity and Sport Sciences
INEF Madrid, 30th November 2019



Registration process:

The attendees should complete an on-line **pre-registration** form (**deadline 20th September**):

https://forms.gle/CoZJDmQe4FmwpXoA7

All pre-registrants will be asked by email to pay the symposium fee only after 20th September, or once the number of pre-registrants is over 30. Then, they will be able to book their flights and accommodation without any risk.

If, after the deadline for pre-registration, the number of intended attendees is not over 30, the symposium will be cancelled.

Instructions for paying the symposium fees, a special offer of recommended hotels for attendees, and the final schedule of the symposium will be sent in the email of confirmation by 20th September.

Proof of payment will be provided by email.

Registrations after the pre-registration deadline will be accepted, but they will be more expensive (See the **Symposium Fees** section).

Draft Programme:

Schedule (DRAFT)	
9:00	Accreditation and reception of information (Main Hall of INEF) Welcome Coffee.
9:15	
9:30	
9:45	
10:00	Lecture 1. **Óscar Celada** (The Medical Team experience)
10:15	
10:30	
10:45	Lecture 2. **J.I. Priego-Quesada** (Sport Thermography Research)
11:00	
11:15	
11:30	**Coffee Break 1**
11:45	
12:00	Lecture 3. **Adérito Seixas** (Thermography and Physical Therapy)
12:15	
12:30	
12:45	**Presentation of the attendees in alphabetical order** "Visit Cards" from pre-registration (30s each)
13:00	
13:15	
13:30	
13:45	**Lunch at the Cafeteria of INEF** (included in the symposium fee).
14:00	
14:15	
14:30	
14:45	
15:00	Lecture 4. **Maria Soroko** (Equine Physical Therapy)
15:15	
15:30	
15:45	Lecture 5. **Paolo Minafra** (Combining Imaging Techniques)
16:00	
16:15	
16:30	**Coffee Break 2**
16:45	
17:00	**Presentation of the sponsor** (15 mins) ROUND TABLE considering the ideas provided by the attendees (*)
17:15	
17:30	
17:45	
18:00	
18:15	
18:30	WORKSHOP: **Data Collection during Sport Practice (Main Hall of INEF)**
18:45	
19:00	
19:15	
19:30	
19:45	
20:00	CLOSING

* In the pre-registration form the attendees will suggest challenges to be addressed by Sport Thermographers in the near future. These ideas will be integrated and discussed in the round table.

Invited Lecturers:

Adérito Seixas

Portuguese physical therapist and active researcher in thermography.

Maria Soroko

Polish expert in equine infrared thermography.

Óscar Celada (assisted by Ismael Férnandez)

Sport Medicine Physician in a Spanish First Division club of soccer (Atlético de Madrid SAD).

José Ignacio Priego-Quesada.

Spanish lecturer in the University of Valencia and one of the most prolific scientific publishers in sports thermography.

Paolo Minafra.

Italian Sport Medicine Physician, who works with teams of the Italian Calcio. As a musculoskeletal radiologist, he integrates thermography with other imaging techniques in the diagnosis of sport injuries.

SYMPOSIUM FEES:

INEF and EAT Members:
70 Euros (with pre-registration)

Other Participants:
90 Euros (with pre-registration)

NOTE: Without pre-registration, after 20th September, the general fee will be **120 €**

Call for Papers

Since 1992, the Quantitative InfraRed Thermography (QIRT) conference is a biannual international forum which brings together specialists from industry and academia, who share an active interest in the latest developments of science, experimental practices and instrumentation, related to IR thermography.

Following conferences in Paris (1992), Sorrento (1994), Stuttgart (1996), Lodz (1998), Reims (2000), Dubrovnik (2002), Brussels (2004), Padova (2006), Krakow (2008), Québec City (2010) and Naples (2012), Bordeaux (2014), Gdansk (2016) and Berlin (2018), QIRT 2020 will take place in Porto, Portugal. Since 2015, due to the growing QIRT community, a sister conference series, QIRT-Asia, was established. Chennai (India) 2015, Daejon (Korea) 2017 and Tokyo (Japan) 2019. All conference proceedings are available through the QIRT Conference Open Archives at www.qirt.org.

QIRT 2020 will cover, but will not be limited to, the following topics:

- State of the art and evolution in the field of IR scanners and imaging systems allowing quantitative measurements and related data acquisition and processing.
- Integration of thermographic systems and multispectral analysis. Related problems like: calibration and characterization of IR cameras, emissivity determination, absorption in media, spurious radiations, 3D measurements, certification and standardization.
- Thermal effects induced e.g. by electromagnetic fields, elastic waves or mechanical stresses.
- Application of IR thermography to radiometry, thermometry and physical parameters identification in all fields such as: industrial processes, material sciences, thermo-fluid dynamics, energetics, non-destructive evaluation, cultural heritage, environment, medicine, biomedical science, food production…

Important dates

- **Abstract submission deadline: November 30, 2019**
- **Acceptance notification: February 29, 2020**
- **Paper submission deadline: April 30, 2020**

Abstract and Paper Submission

The participants are invited to submit to the QIRT 2020 Web Site (http://www.qirt2020.com) by November 30, 2019 an **extended abstract** of 2 pages (a template is provided at the website), either for oral or poster presentation, including key figures and main results. A book of abstracts will be distributed at the conference.

Following acceptance notification, **camera ready, full paper** of 6-10 pages including colour figures should be submitted to the QIRT 2020 web site by April 30th, 2020.

All submissions for oral or poster presentation will be handled electronically via the conference website **http://www.qirt2020.com**

A Word template to be used for both abstracts and full papers is downloadable at the website.

Authors are requested to propose the thematic section in which the paper should be included.

Web-Based Proceedings and possible publication in QIRT Journal

Presented papers (oral and posters) will be published online in the QIRT Open-Archives, which can be found at the website: **www.qirt.org**. A USB flash drive with all conference papers will be also distributed to the conference participants.

After the conference, the Scientific Committee will carry out a pre-selection of the most prominent presented papers for a possible publication in Quantitative InfraRed Thermography Journal after a subsequent review by two experts.

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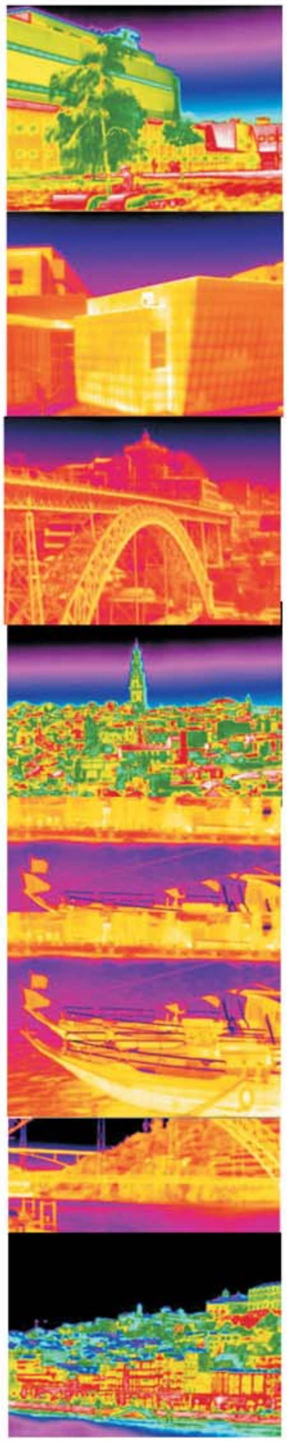


Pre-Conference short courses

QIRT short courses

In addition to the main technical program, the conference will include one-day short courses (Monday, July 6).

It will include:

- Non-destructive testing using active thermography
- Non-destructive testing using lock-in thermography
- Passive and active thermography in civil engineering
- Thermal problems in fluid dynamics
- Analytical solutions for passive and active thermography
- Biomedical thermography applications.

The fee to attend the short course will be 200 € (VAT, coffee breaks and lunch included).

Awards

During the conference, the best scientific paper will be honoured by the Grinzato Award and the best student paper by the Student Award.

Application for the Student Award is indicated at abstract submission. The nominees for the Grinzato Award will be announced by the steering committee according to the rating of the submitted abstracts.

Conference fees (VAT included)

Regular participants

• Early rate (deadline: May 30, 2020): 700 €
• Late rate (deadline: June 30, 2020): 750 €
• Desk registration rate: 800 €

Students & over 66<

• Early rate (deadline: May 30, 2020): 350 €
• Late rate (deadline: June 30, 2020): 400 €
• Desk registration rate: 450 €

Fee covers: Book of abstracts, Conference USB Proceedings, Welcome reception, Conference dinner, 4 lunches and coffee breaks. Accommodation is not included.
For regular participants only, **fee includes also a subscription to QIRT Journal for 2 years** (Standard personal subscription rate).

Accompanying persons

• Rate (deadline: June 30, 2020): 160 €
This amount includes the Porto visiting card (with free transport for 4 days and discounts in touristic places), Welcome reception and Conference dinner.

Venue

QIRT 2020 will be held at the Faculty of Engineering, University of Porto. The city of Porto has been recognized as the best European destination in 2014 and 2017.

A list of hotels will be given in the conference website. Booking of hotel is not assumed by the conference organization.

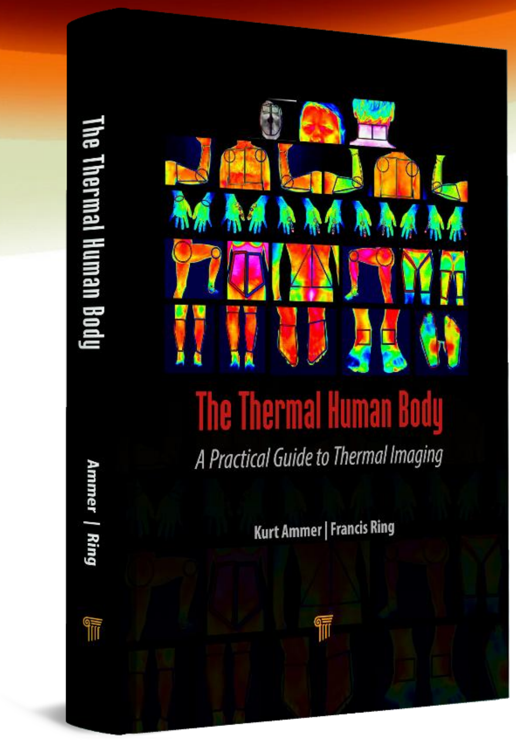
Host organization

Faculty of Engineering, University of Porto, Portugal

For further information and updates, please visit the website: **http://www.qirt2020.com** or contact the organizing committee at **qirt2020@fe.up.pt**

The Thermal Human Body

A Practical Guide to Thermal Imaging



978-981-4745-82-6 (Hardback)
978-0-429-01998-2 (eBook)
US$149.95
260 Pages – 19 Color & 38 B/W Illustrations
May 2019

Key Features

- Combines the physics of heat transfer with thermal physiology to understand skin temperature distribution
- Provides a framework for standardized recording and analysis of medical thermal images
- Includes an atlas of body positions of proven reproducibility for infrared image capture
- Proposes regions of interests for reliable quantitative analysis

How to Order

SAVE 20% with FREE standard shipping when you order online at **www.crcpress.com** and enter Promo Code **PAN01.** Alternatively, you can contact your nearest bookstore, or our distributor as follows:

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Boca Raton, FL 33487, USA
Tel: +1 800-272-7737
Fax: +1 800-374-3401
Email: **orders@taylorandfrancis.com**

by
Kurt Ammer & Francis Ring

Reviews

"There is no way to study thermal imaging and not learn from the writings of Francis Ring and Kurt Ammer. Pioneers of the application of infrared thermography in medicine, the authors unveil the direction for a sensible use of the method. Luck for us—students, professionals and enthusiasts—because we can be grateful to receive a differentiated material that shortens the learning path. No doubt a remarkable book."
- Prof. Danilo Gomes Moreira, Science and Technology of Minas Gerais, Brazil

"This book is set to become essential reading for anyone who wants to perform reliable thermal imaging of the human body, whether it be in medicine, clinical practice, sports science or research."
- Prof. Graham Machin, National Physical Laboratory, UK

"This book is a wonderful practical guide that takes the reader through all the main stages required and will be of special interest for those interested in entering the fascinating field of clinical thermal imaging."
- Prof. James B. Mercer, UiT—The Arctic University of Norway, Norway

Description

This book is a guide for the constantly growing community of the users of medical thermal imaging. It describes where and how an infrared equipment can be used in a strictly standardized way and how one can ultimately comprehensively report the findings. Due to their insight into the complex mechanisms behind the distribution of surface temperature, future users of medical thermal imaging should be able to provide careful, and cautious, interpretations of infrared thermograms, thus avoiding the pitfalls of the past. The authors are well-known pioneers of the technique of infrared imaging in medicine who have combined strict standard-based evaluation of medical thermal images with their expertise in clinical medicine and related fields of health management.

JENNY STANFORD PUBLISHING