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Extended abstracts of the 15th Conference of the European Association of Thermology

Kurt Ammer

Editor in Chief, Thermology international, European Association of Thermology (EAT), Vienna, Austria

Number 3 of this year´s volume of "Thermology international" is completely dedicated to the extended abstracts of presentations at the 15th conference of the European Association of Thermology (EAT). As previously reported [1], all submissions underwent a peer review and almost all authors accepted the proposals of the reviewers to improve their text. The abstracts of the virtually presented presentations represent an interesting collection of short articles, covering six main topics in current thermographic research.

The first topic is "**Temperature measurement by thermal imaging**" and this section includes 3 articles. The English physicist and metrology expert Graham Machin and his colleagues from China, Spain, Slovenia, and Singapore report the aims and progress of an international project to improve human body temperatures on a global basis. Two physicists from Slovenia studied the uncertainties of infrared imagers used for fever screening. A group from the Department of Medical Physics at the University in Brno investigated in a large group of students the variation in temperature readouts from thermal images. The obtained measurement uncertainty was large due to variation in the position of regions of interest.

"Fever detection by thermal imaging" is topic in 3 other articles. Forehead temperatures of afebrile subjects attending a hospital clinic during the COVID-19 pandemic are reported from the Royal Free Hospital in London. The fever screening routine with a thermal imager detected other causes than corona virus infection at a tertiary hospital in Brazil. Ricardo Vardasca discusses the potential of machine learning techniques for fever screening in a pandemic.

Assisting the diagnosis of diseases is one of the traditional applications of thermal imaging. 6 articles are related to this topic. Aderito Seixas appraises critically systematic reviews on infrared thermography in musculoskeletal research. An article from India compares infrared imaging and power Doppler ultrasound in the assessment of knee joints affected by rheumatoid arthritis. Jozef Gabrhel, physiatrist from Slovakia, determines the role of infrared imaging and sonographic imaging in the evaluation of patients with pain in the shoulder region. Peter Plassmann pleas for the use of liquid crystal thermography in podiatry. Magalhaes, Vardasca and Mendes from Portugal report skin cancer detection in thermal images based on machine learning techniques. Prof John Allen from Coventry University explored in a pilot study skin temperature and objective colour measurements in Raynaud´s phenomenon.

5 articles are dedicated to another frequent application in medicine, that is "**Thermal imaging as an outcome measure**". Priego-Quesada and colleagues from Valencia confirmed the value of thermal imaging as a technique to differentiate successful and failed nerve blocks in patients with complex regional pain syndrome. Two articles reported comparison of infrared imaging with indocyanine green fluorescence imaging. A group from the Czech Republic applied both imaging modalities during open gastrointestinal surgery, while the Medical Imaging Research Group at the University of Tromsø extended the comparison with ultrasound Doppler and CT-angiography for selecting dominant perforating blood vessels for autologous breast reconstruction. Research from Russia explored the value of thermal imaging for the assessment and treatment/rehabilitation evaluation of children with cerebral palsy.

The section on "**Thermal comfort, environment and exercis**e" includes 7 articles. Prof George Havenith provides in his invited lecture an overview of the use of infra-red thermal imaging as a tool in our laboratory's studies on thermoregulation, thermal strain, sports performance, thermal comfort, and clothing. Face temperature is the focus of two articles. An article from Brazil/Spain reports changes in facial thermal images after wearing two different military combat jackets. The other article by Brazilian authors observed face temperature of athletes during a triathlon competition with dominant changes after swimming. An international group of authors used two infrared cameras equipped with different detectors responsive to either 3 to 5mm or 8 to 14mm wavelength to collect skin temperature of athletes during a road-race competition. Two articles from Spain report the influence of fatiguing strength exercise or 10km run prior to infrared imaging respectively, on skin temperature recovery after application of a cold stimulus. Prof Urakov from Russia reports the effect of an insulation layer fixed to saxophone buttons on performance and comfort when playing music in a cold ambience.

7 articles are dedicated to "**Animal welfare, veterinary applications and equine physiology**" and the authors of 6 articles originate from Poland. Skin temperature observed after training or exercise testing in horses are reported in 2 articles, and in beagles in another article. The effect of high intensity laser therapy on skin temperature

and vein diameter in various anatomical regions of healthy racehorses is topic of 2 articles. Flank temperature of mares during pregnancy is reported. Skin temperature changes of horsed induced by hydrotherapy are related to various ambient temperatures during the summer period.

Two articles are outside of those six main topics. An article from the Czech Republics reports the range of topics in final theses of health professions students utilizing infrared thermal imaging as main technique for answering their research question. Prof Urakov modified and repeated an experiment of Prof Czerny, who was the first who imaged thermal phenomena associated with chemical reaction applying the principles of evaporography, an early version of infrared photography [2].

The 33 articles in this issue demonstrate nicely the distribution of current research activity in thermology all around Europe and their cooperation with scientists outside of Europe. The contribution of EAT-members to European thermology research is large since the name of an EAT member appears as first author in 16 articles, and as co-author in 10 articles. Only 10 articles do not show any EAT member among their authorship.

References

1. Ammer K.Preliminary report on the evaluation of submissions to the EAT2021 Online Conference. Thermology international 2021, 31(2) 62-64

2. Czerny M. Über Photographie im Ultraroten. Zeitschrift für Physik 1929, 53:1-12

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PROGRESS IN IMPROVING BODY TEMPERATURE MEASUREMENT ON A GLOBAL BASIS

Graham Machin[1], Xiaofeng Lu[2], Dolores del Campo[3], Maria-Jose Martin[3], Igor Pusnik[4], Wang Li[5]

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Introduction

The Covid-19 pandemic has brought into the spotlight something of which clinicians have been aware for some time, namely the general unreliability of body temperature measurement in health services and, more widely, in public health situations such as fever screening.

Although the medical diagnosis of a disease is not exclusively based on a single clinical indicator such as body temperature measurement, nevertheless the unreliability of such measurement could potentially be a contributary factor to inadequate treatment due to the mis-diagnosis of fever.

This situation is being addressed by a multipronged initiative led by the International Bureau of Weights and Measures (BIPM) Consultative Committee for Thermometry (CCT).

A multinational Task Group on Body Temperature Measurement (TG-BTM) was established in June 2020 whose aim is to improve body temperature measurement on a global basis, with the main focus on ear/tympanic thermometry, forehead thermometry and thermal imaging.

Method/approach

The overall objectives of the task group will be achieved through the following actions:

- Lead a global comparison, using internationally agreed approaches, of blackbody calibrators used by National Measurement Institutes for infra-red body temperature thermometers (ear/forehead/thermal imagers). The comparison of ear/forehead calibrators is scheduled to begin in Spring 2021 and take about two years. It will be followed by a comparison of blackbody references for thermal imagers. This will ensure that the metrology foundation for ear/forehead and thermal imager calibration, on a global basis, is sound and in place.
- Collect current best practice/standards of body temperature thermal imaging in a) health services b) airport and other screening situations around the world and develop best practice recommendations. The aim is to have draft best practice guidance by Spring 2021 with the final version issued by end 2021. The identification and initiation of research that needs to be undertaken to implement low uncertainty traceable fever screening is one of the key objectives of this work.
- Collect current best practice of infra-red body temperature measurement (ear, forehead) and develop best practice recommendations. Draft best practice guidance is under review by the group (Dec 2020) and will be circulated to the wider community, including clinicians, for comment with the aim of finalising the document by end 2021. Afterwards, short form (one-page) best practice guidance will be developed in close consultation with clinicians to ensure uniformity of best practice. The identification and initiation of research that needs to be undertaken to determine particularly whether forehead thermometers can even be used to reliably detect fever is one of the key objectives of this work.
- Review standards and work with appropriate standardisation bodies (e.g. ISO/IEC) concerned with producing standards for body temperature measurement devices. A number of Task Group members are joining the clinical standards committees to ensure that rigorous metrology is introduced in any revision of clinical standards regulating body temperature measurement.
- Establish metrology, medical and manufacturer forums within the metrology regions to identify any problems with the current approaches to body temperature measurement, develop practical solutions and establish appropriate links to the World Health Organisation. This work is just beginning and will become more active as the best practice guides are developed.

This talk gives the background to the issues, introduces the activities undertaken and progress made to date by the task group in pursuit of reliable body temperature measurement.

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UNCERTAINTY OF THERMAL IMAGERS FOR TEMPERATURE SCREENING

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Introduction

Application of thermal imagers for mass screening of febrile humans has been present for over two decades. Manufacturers usually specify accuracy far smaller than expected by experts, usually from 0.3 to 0.5 °C. Accuracy of the body core temperature using facial thermogram consists of two main contributions: accuracy of non-contact skin temperature measurement and accuracy of body core temperature calculation. Both, exact measurement uncertainty and calibration traceability are usually not specified by manufacturers. Therefore, a decision was made to document these parameters on typical fever screening systems by means of calibration, by which the measurement accuracy as well as the measurement uncertainty were assessed. The type A and type B uncertainty analysis was performed based on measurements, exploring the literature and measurement equipment specification.

Methods

Modern thermal imagers using FPA micro-bolometers are composed of high number of micro electro-mechanical systems that measure absorbed radiant power. Sensor elements were evaluated statistically for uncertainty of image average and uncertainty of all image elements (fixed and temporal pattern noise, Figure 1) in relation to the image average. Calibration uncertainty of a device is influenced by the thermal stability and homogeneity of the blackbody, its non-ideal emissivity and uncertainty of a reference thermometer, which is calibrated and traceable to ITS 90. Uncertainty of input parameters contributes to the total measurement uncertainty. Manufacturer supplied mathematical model of thermal imager was used to study these influences under indoor measurement conditions. Finally, effect is analyzed, determining the highest expected uncertainty for this kind of measuring equipment deployment. Lastly, biological influential parameters also largely con influence of scaling with distance and the size-of-source tribute to the measurement uncertainty. A search of literature was performed on assessing skin emissivity and temperature correlation between the skin and the body core temperature with specified associated uncertainties. Effect of small target and distance is further discussed, considering the size-of-source effect (SSE) and source down scaling bellow instantaneous field of view (iFOV) with increasing distance to the imager.

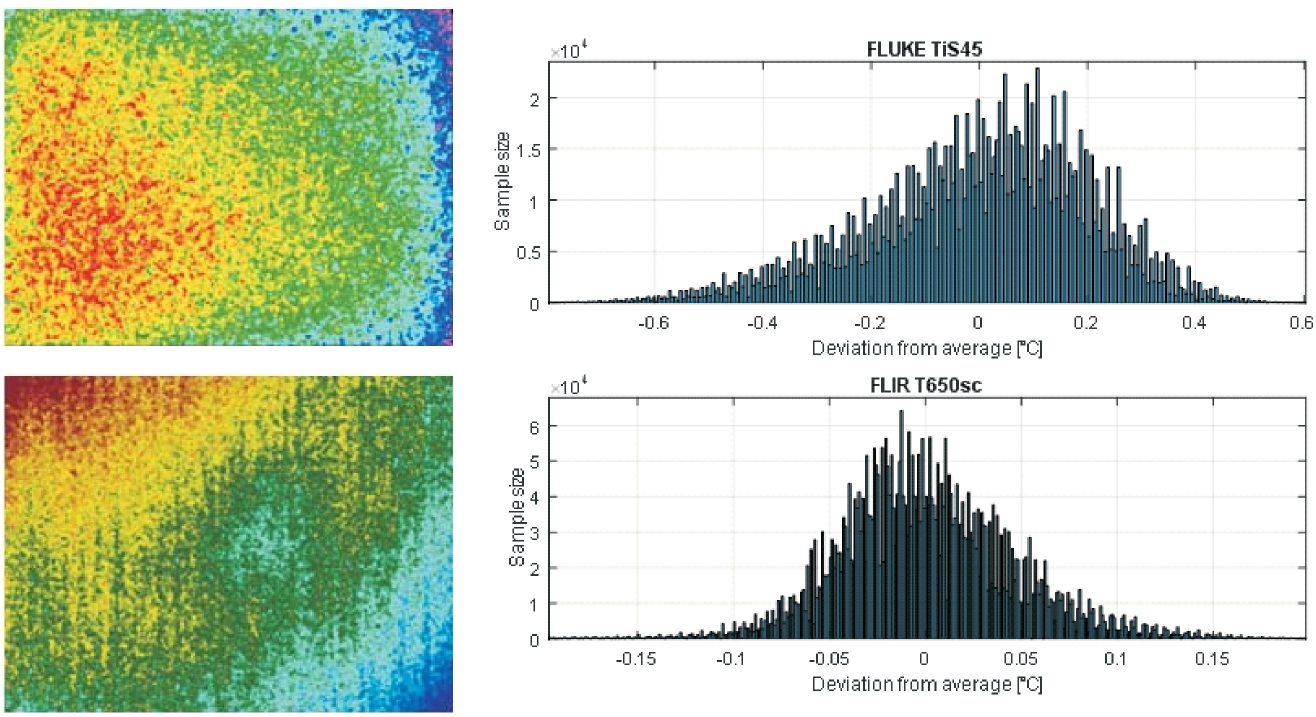
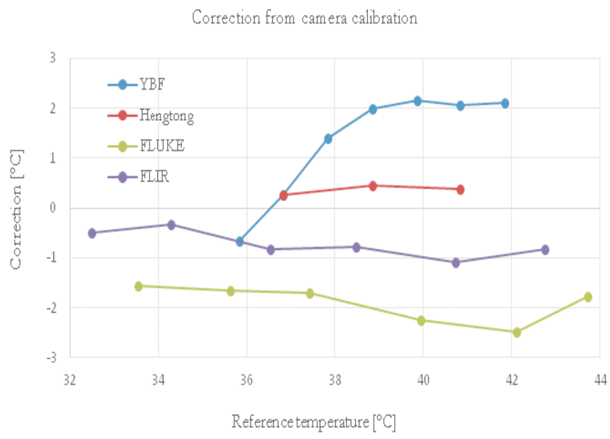


Figure 1
Example and distribution of fixed and temporal noise in a series of thermograms, acquired using FLUKE (top) and FLIR (bottom)

Table 1
Results of skin emissivity measurements by different authors

Author	Year	Spectral range	Emissivity
Hardy [2]	1934	>2 μm	0.989 ± 0.01
Büttner [8], cited in [7]	1937	0,3-50 μm	0.954 ± 0.004
Eckoldt [9], cited in [12]	1960	0.8-12 μm	0.939 ± 0.003
Buchmüller [10] cited in [7]	1961	3-15 μm	0.99 to 1
Gärtner [11] cited in [7]	1964	unknown	0.976 ± 0.015
Mitchell, Wyndham and Hodgson [12]	1967	do 20 μm	0.995 to 1
Patil and Williams [13] in [7]	1969	6-18 μm	0.972 ± 0.041
Patil and Williams [13] in [7]	1969	4-18 μm	0.975 ± 0.043
Steketee [3]	1973	3-14 μm	0.98 ± 0.01
Togawa [7]	1989	8-14 μm	0.969 ± 0.004
Charlton et al. [4]	2020	8-14 μm	0.972 ± 0.010

Figure 2
Correction of the average image temperature, obtained by calibration. Calibrated temperature is to be calculated as sum of measurement and correction.



Results

Literature search was conducted on skin emissivity factor within spectral range of thermal radiation (Table 1). Results were found to mostly agree upon range of skin emissivity factor overlapping in range of 0.97 to 0.99 in most studies [1, 2, 3]. Charlton et al report no effect of ethnicity or pigmentation on skin emissivity, linking statements with relatively short penetration of thermal radiation, as compared to visible light [4]. Maximal skin temperature over temporal artery at inner cantus of the eye was approximated with linear correlation function as a function of body core temperature in studies by Cheung et al. [5] as $T_{skin} = T_{core}$ - 1.7 °C ± 1.9 °C and Ng et al. [6] as $T_{skin} = 0.85\ T_{core} + 4.1972$ °C ± 1.82 °C with uncertainty of used thermal imager, taken into account. Authors state low correlation factor of r^2= 0.189 and 0.5509 respectively, latter values being used in this study.

Accuracy of thermal imagers was unexpectedly low, manifesting in errors of up to and above 2 °C (Table 2). Calibration was conducted with high accuracy laboratory equipment (Figure 2), therefore uncertainty of calibration is within the lowest achievable on the global level (0.2) and should be better than any manufacturer's calibration capability. Uncertainty evaluations, presented in table 2, were conducted under laboratory conditions for four thermal imaging cameras: FLUKE TiS45, FLIR T650sc (general purpose thermal imagers), YBFace and Hengtong optic-electric, purpose built thermal imagers of lower price range.

Table 2
Partial contributions and total measurement uncertainty of fever detection systems when measuring core body temperature, expressed in °C. Thermogram non-homogenity was not measured for the two purpose-made imagers due to data inaccessibility, however it is expected to exceed that of more costly products. The distance effect was assessed based on iFOV specification and SSE measurements due to lack of theoretical understanding.

	Influential parameter	**source**	**FLUKE**	**FLIR**	**YBFace**	**Hengtong**
1	Camera measurement repeatability	Imager	0.90	0.60	0.20	0.63
2	Thermogram non-homogeneity	Imager	0.47	0.11		
3	Thermal stability of blackbody	Calibrator	0.01	0.01	0.01	0.01
4	Thermal homogeneity of blackbody	Calibrator	0.24	0.24	0.24	0.24
5	Emissivity of blackbody	Calibrator	0.03	0.03	0.03	0.03
6	Uncertainty of reference thermometer	Calibrator	0.02	0.02	0.02	0.02
7	Target emissivity	Human	0.17	0.17	0.17	0.17
8	Distance (atmospheric interference)	Air	0.02	0.02	0.02	0.02
9	Relative humidity	Air	0.00	0.00	0.00	0.00
10	Background radiation	Environment	0.02	0.02	0.02	0.02
11	Correlation function	Human	1.82	1.82	1.82	1.82
12	Distance effect (scaling, SSE)	Imager, layout	0.59	0.12	1.18	0.47
	Total expanded measurement uncertainty		**2.18**	**1.94**	**2.19**	**2.00**
	Expanded surface temperature measurement uncertainty		**1.03**	**0.59**	**1.05**	**0.71**

Conclusions

Uncertainty of fever screening systems when calculating the body core temperature based on measured skin temperature is far greater than specified by manufacturers. Evaluations revealed the total measurement uncertainty of about 2 °C, where by far the highest contribution originates from the correlation of temperature between the human skin and the core. Furthermore, accounting for the size-of-source effect, the influence of which is not clearly known or agreed upon, estimations drastically increase the theoretical total measurement uncertainty also for other products with small resolution, high iFOV, high focal distance or wider SSE.

In conclusion, it is highly unlikely that these systems could reliably measure and decide upon small deviations of the body core temperature. The described technology is rarely reliable for finding deviations in the body core temperature unless the body core temperature is elevated by at least 2 °C. Therefore, these systems should only be used as a screening tool for detection of extreme outliers, as also proposed by FDA, however relatively unreliable results should not compare with traditional means of measurement with traceable contact or non-contact clinical thermometers.

References

1. Fernández-Cuevas I. et al. Classification of factors influencing the use of infrared thermography in humans: A review. Infrared Physics & Technology 2015; 71; 28-55.

2. Hardy JD. The radiating power of human skin in the infra-red. American Journal of Physiology 1939;127(3); 454-462.

3. Steketee J. Spectral Emissivity of Skin in Pericardium. Phys. Med. Biol 1973;. 18; 686-694.

4. Charlton M et al. The effect of constitutive pigmentation on the measured emissivity of human skin PLOS ONE 2020; 15(11); 1-9.

5. Cheung BMY, Chan LS, Lauder IJ, Kumana CR. Detection of body temperature with infrared thermography: accuracy in detection of fever. Hong Kong Medical Journal 2012; 18(4) 31-34.

6. Ng EYK, Kaw GJL, Chang WM. Analysis of IR thermal imager for mass blind fever screening 2004; Microvascular research 68(2); 104-109.

7. Togawa T. Non-contact skin emissivity: measurement from reflectance using step change in ambient radiation temperature.Clin. Phys. Physiol. Meas. 1989; 10(1); 39-48.

8. Büttner K. Über die Wärmestrahlung und die Reflexionseigenschaften der menschlichen Haut.Strahlentherapie 1937; 58: 345-360.

9. Eckoldt K. Die Emissions- und Reflexionseigenshaften der menschlichten Haut im ultraroten Spektralbereich. Arch Ges. Physiol 1960; 272; 24-25.

10. Buchmüller K. Über die ultrarote Emission, Reflexion und Durchlässigkeit der leben den menschlichen Haut im Spektralbereich $\lambda = 3 - 15\ \mu m$. Pflügers Archiv 1961; 272; 360-371.

11. Gärtner W, Göpfert H. Topographische Untersuchungen über die Strahlungseigenschaften der lebenden menschlichen Haut. Pflügers Archiv 1964; 280; 224-35.

12. Mitchell D, Wyndham CH, Hodgson T. Emissivity and transmittance of excised human skin in its thermal emission wave band. Journal of Applied Physiology 1967, 23(3); 390-394.

13. Patil KD, Williams KL. Spectral study of human radiation Non-ionizing radiation 1969; 1: 39-44.

14. Watmough DJ, Fowler PW, Oliver R. The thermal scanning of a curved isothermal surface: implications for clinical thermography. Physics in Medicine & Biology 1970; 15(1); 1-8.

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IRT IMAGE EVALUATION VARIABILITY - EFFECT OF SUBJECTIVE PLACEMENT OF THE REGION OF INTEREST

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Introduction

Contactless infrared thermography (IRT) is undoubtedly a suitable imaging modality in the hands of a physician. There are several ways to evaluate IRT images - manually, fully automated or a mix between the two. In all cases, the defining regions of interest (ROI) will play a key role. The objective of the study is to determine the variability of IRT image evaluation depending on the subjective selection of the ROI position by different evaluators with no to little experience in the analysis of thermal images. The study establishes to what extent operators are able to be consistent in their analysis

Methods

More than 300 people with the same education and experience (medical students of the same study year) were instructed to evaluate the single set of image pairs as shown in figure 1.

All participants received the same assignment and evaluation instructions: "On this pair of IRT images you see a temperature map of the same person - a right and a left lateral view of the face. The aim is to determine the temperature of the right and left cheeks."

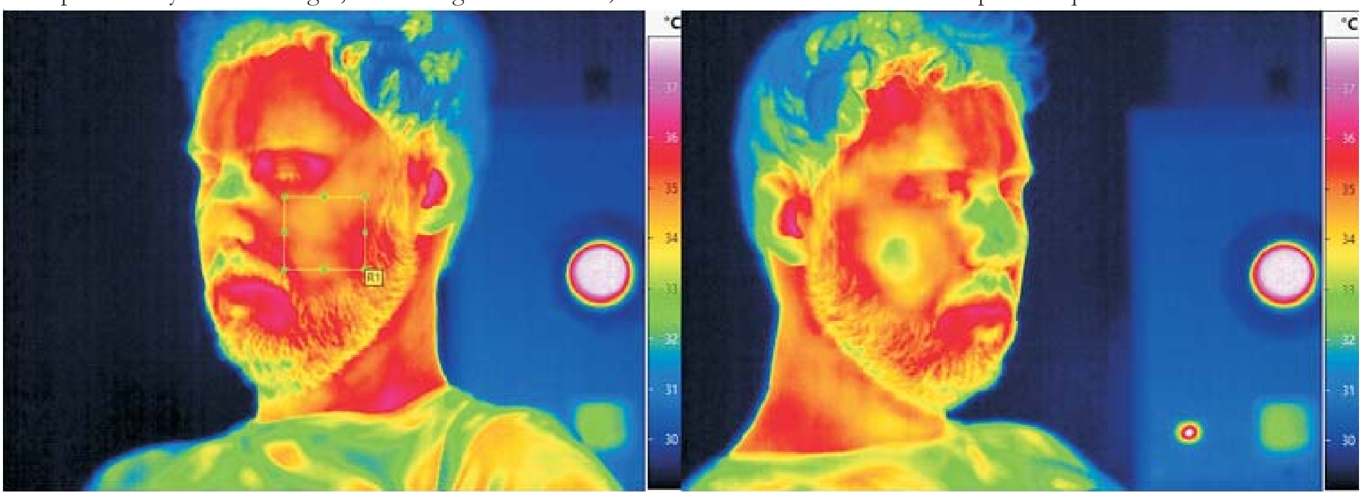
Evaluators were not allowed to change the set parameters such as emissivity and ambient temperature. The data were processed using software IRBIS3 (InfraTec GmbH, Germany), Excel (Microsoft, USA) and Statistics12 (StatSoft, Czech). Part of the surface of the right cheek was intentionally cooled by piece of aluminum logs at room temperature by the authors of the experiment (without deeper physical description, for the sole purpose to induce a real difference in the surface temperature of the right and left cheeks).

Results

Each evaluator determined an ROI in rectangular shape on both of the IRT images (left L, right R) according to the obtained identical instruction (fig. 1 shows an example of evaluation). The minimum (min), maximum (max) and average (avg) temperature was determined in each ROI - L-avg, L-min, L-max, R-avg, R-min, R-max. The obtained temperature data were processed in the form of box-plots graphs (fig. 2) and compared with each other using the nonparametric Mann-Whitney test. The variabilities for minimal, maximal and average values for ROI from left and right lateral view were shown separately.

The obtained data show the variance of temperature values according to the selection of ROI. The smallest variance (including extreme values) is shown for the average value from both lateral view - avg. A similar situation was observed for the distribution of maximum temperature data - max. An interesting situation was shown in the case of the minimum values. The box-plot analysis of the minimum temperature value from right frontal view ROI - R-min shows the smallest variance for 1st-3rd Quartile, but with many extreme values in a very wide range. The Lmin value it also shows a wide range of values, not only extremes but also outliers and 1st-3rd quartile.

Figure 1.
Example of analysed IRT images, left and right lateral view; left lateral view with random examples of square selection of ROI



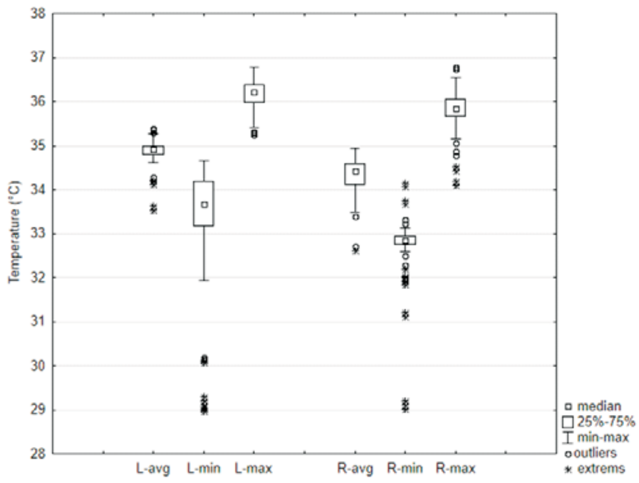


Figure 2
Box-plot analysis of obtained temperature values for both left and right IRT images (left – L and right – R); average (avg), minimal (min), maximal (max) values from selected ROI.

Statistical evaluation showed a significant difference ($p<0.05$) between the average temperature data on the right and left lateral IRT images (L-avg vs. R-avg); it corresponded to the reality determined by the authors of the experiment.

Discussion and conclusion

The initial question of the study is, to what extent evaluators with no to little experience in the analysis of thermal images can be consistent in their analysis. The answer can be found by monitoring the variance of the collected data.

The processed data show satisfactory variability in the evaluated groups: L-avg, L-max, R-avg, R-min, R-max, if we accept a maximum range size of 1st-3rd Quartile as 0.5°C. But only the values L-max were without extremes. A large number of extremes with great scatter were found in the groups L-min, R-min. This indicates a greater agreement between the evaluators in relation to the average and maximum temperature values obtained from the subjectively localized ROIs.

The authors of study tested whether the larger variance of minimal, maximal and average temperature from selected ROI were present on left face with a uniform temperature or on the right face where area with visible reduced temperature was located. The data show the effect of the presence of an area with significantly changed temperature in relation to an incidence of number of extreme values. For example, in the group of minimum temperatures from the right lateral view, more than 10% of all values were extremes.

It is evident that the presence of a distinct area with a different temperature leads many evaluators to reduce their ROI into this area (as indicated by the reduction in 1st-3rd quartile variability). However, the evaluation of such an IRT image is prone to the presence of outliers and extremes if one of the evaluators chooses large ROIs with its edge extending outside the ROIs of other evaluators.

The position of the ROI greatly affects the value of the minimum and maximum temperature. To determine the realistic minimum and maximum temperature, it seems very appropriate to define ROI position standards and use them. This statement is, moreover, consistent with the general recommendations of experts (1). The performed experiment and the outliers and extreme values occurring to a large extent also show that people without sufficient training and knowledge of IRT analysis can perform the analysis incorrectly and obtain error-prone data. Thanks to many evaluators, a significant statistical difference between right and left cheek temperature was demonstrated, even without the standard position of ROI and previous experience with ITR analysis on the other hand.

The authors recommend using standards for IRT evaluation with respect to the obtained data and the observed variability and the existence of extreme values. Ignorance of the method of analysis can lead to the acquisition of unreliable data in extreme situations.

Acknowledgment

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References

1. Ammer K. The Reproducibility of standard positions used for image capturing within the standard protocol for thermal imaging. In: RingF, Jung A, Zuber J. (Eds.), Infrared Imaging. A Casebook in Clinical Medicine, IOP Publishing, Bristol, 2015, pp. 2.1 - 2.3.

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BODY TEMPERATURE MEASURED BY A FOREHEAD THERMOMETER IN AFEBRILE SUBJECTS ATTENDING A HOSPITAL CLINIC DURING THE COVID-19 PANDEMIC

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Introduction

During the COVID-19 pandemic, UK hospitals have screened patients attending outpatient appointments to try and prevent SARS CoV-2 virus entering clinical areas. Screening protocols typically include a questionnaire asking about recent symptoms of COVID-19, and a temperature check at the clinic entrance. Due to concerns about infection control, most clinics screen for fever using non-contact infrared forehead thermometers. The reliability of infrared forehead thermometers has not been established, however, calling into question whether these devices are suitable surrogates for the more established thermometry methods [1,2]. The measurements collected from screening during the pandemic afford an opportunity to explore the performance of forehead thermometry further.

Objectives

We analysed the temperature data from forehead thermometry of self-determined afebrile patients who were screened on arrival at the Microvascular clinic of Royal Free Institute of Immunity and Transplantation, and compared our findings to published data on afebrile subjects employing oral thermometry.

Methods

The screening records of seventy-two consecutive patients who attended the Microvascular clinic were inspected, and anonymised data on gender, age and body temperature estimated by the forehead thermometer were recorded for further analysis. Upon arrival, all patients waited at least five minutes in an indoor environment, but outside of the Institute clinical area, prior to undergoing forehead thermometry. All forehead thermometry was performed by trained health care assistants using the iHealth PT3 forehead thermometer (iHealth Lab Inc, Mountain View, CA, USA). The cut-off temperature for suspicion of fever was set at 37.8ºC, consistent with the "alarm" function of the forehead thermometer.

Results

No patient reported any COVID-19 key symptoms in the previous seven days on their screening questionnaire (fever, continuous cough, anosmia). One temperature reading was excluded from the analysis on the basis that it was not physiologically credible (34.5ºC), leaving 71 measurements included in the analysis. The median age of the subjects was 43 years (range 5 - 86 years). Sixty of the included subjects were female. Temperature across all 71 subjects was not normally distributed ($p<0.01$, Shapiro-Wilk test) (Fig.1), with the normal Q-Q plot (Fig.2) suggesting that the distribution was "light-tailed" i.e., a lower number of temperature readings above the median value than would be expected for normality. The median temperature across all

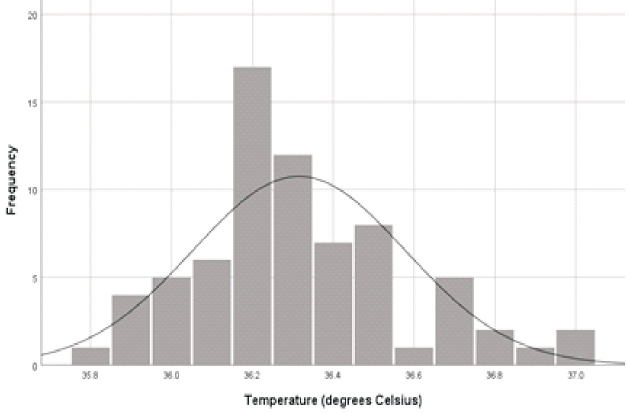

Figure 1
Frequency distribution of body temperature measured by the forehead thermometer from 71 afebrile subjects (normal distribution shown for comparison)

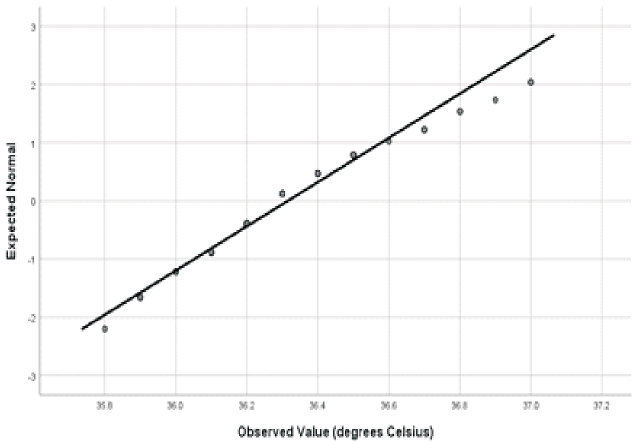

Figure 2
Normal Q-Q plot of temperature from the 71 afebrile subjects.

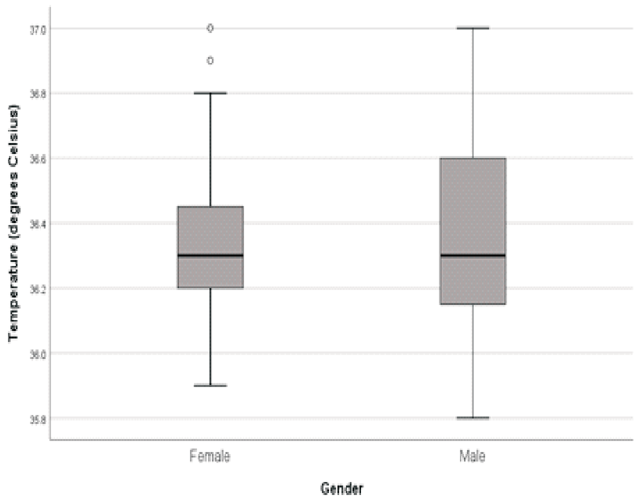

Figure 3
Box and whisper plot showing the temperature of the female (n=60) and male (n=11) subjects.

subjects was 36.3ºC (range 35.8ºC - 37.0ºC). Consequently, no subjects were classified as "febrile" by the forehead thermometer. Median temperature of the females was 36.3ºC (range 35.9ºC - 37.0ºC), and for males it was 36.3ºC (range 35.8ºC - 37.0ºC) (Fig.3). There was no statistically significant correlation between the age of the subjects and their temperature (p=ns, Spearman's rho).

Discussion

The median temperature of our subjects is in close agreement with that reported by Waalen and Buxbaum [3] in their large cohort (n=18,630) of afebrile subjects measured with oral thermometry. The distribution of our readings around the central value differs, however, from the oral thermometry dataset. Whereas Waalen and Buxbaum reported a total of 28% of their subjects with a temperature greater than 36.7ºC, the equivalent figure from our forehead thermometry group was just 14%, and we recorded no temperatures above 37ºC. The Waalen and Buxbaum data also show a clear influence on body temperature from gender (females warmer than males) and age (decreasing temperature with age). We could not identify similar trends for gender or age using forehead thermometry, although our dataset was small.

Our study has some limitations. In addition to the small number of subjects, there was a strong bias toward females in our dataset. Most patients attended our clinic for investigation of peripheral vasospastic disorders such as Raynaud's phenomenon. These disorders affect a preponderance of females, thus skewing the gender balance in our cohort. The possibility that vasospastic disorders may also influence body temperature should also be considered.

Conclusion

Although forehead thermometry of afebrile subjects produces the same median temperature as in published studies of oral thermometry, our results suggest important differences in the distribution of the values about the median value, with no readings above 37 ºC detected by the infrared technique. In addition, we found no evidence from forehead thermometry of any influence on body temperature from age or gender, in contrast to published evaluations of oral thermometry. These findings should be investigated in greater detail with large, controlled studies before forehead thermometry can be considered validated as an appropriate surrogate of established thermometry techniques for screening or clinical monitoring.

References:

1.Aw J. The non-contact handheld cutaneous infra-red thermometer for fever screening during the COVID-19 global emergency. J Hosp Infect. 2020; 104(4):451

2.Fletcher T, Whittam A, Simpson R, Machin G. Comparison of non-contact infrared skin thermometers. J Med Eng Technol. 2018; 42(2):65-71

3.Waalen J, Buxbaum JN. Is older colder or colder older? The association of age with body temperature in 18,630 individuals. J Gerontol A Biol Sci Med Sci. 2011; 66(5):487-492

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THE USE OF THE CAMERA FLIR T530sc TO IDENTIFY PATIENTS WITH FEVER IN TERTIARY HOSPITAL IN BRASÍLIA - BRAZIL

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Introduction

Since the 2003 SARS epidemic, thermal infrared cameras have been deployed as a mass fever screening strategy in strategic border crossing such as airports. In 2020, with the spread of the new coronavirus, several institutions adopted infrared cameras as a fever screening tool, with a vast majority ignoring the recommended protocols. Thus, this study aims to report an experience of using an IR camera in a tertiary hospital in Brasilia, from March to July 2020, as well as confirming the clinical diagnoses of patients who were detected with fever at the screening procedure and subsequently were referred for further medical assistance, underlining the importance of this technology in modern clinical practice.

Image 1
Screening fever station

Methods

This is an observational study intended to register the impact of early fever detection during the first pandemic wave of the Covid-19 virus in Brazil. The Hospital installed 2 IR Cameras, the first one at the main entrance to the hospital and the latter at the Emergency department entrance that is open 24 hours and 7 days of the week. Thermal images were recorded using a thermal camera FLIR T530sc with a 42° mm lens (FLIR Systems, Wilsonville, OR, USA, Focal Plane Array sensor size of 320x240, NETD of 30 mK @ +30°C (+86°F) and a measurement uncertainty of ±2% of the overall reading). An additional Elevated Skin Temperature (EST) screening mode firmware was installed, which can achieve accuracies of ±0.3°C (0.5°F). A screening station (Image 1) consisting of the thermal camera on an adjustable manual height mechanism and a screen, where a virtual human head contour mask is projected on the thermal image, were installed at the main entrance of the hospital emergency department. All entering staff, military personnel and patients, were individually scanned, positioning themselves in front of the camera using a marker on the floor. The screening procedure protocol was designed in accordance to the guidelines IEC 80601-2-59:2017, ISO/TR 13154:2017 and ISO 80601-2-56:2017. A visual and sound alarm was activated. The screening was performed under the supervision of employees trained specifically for this task, who orientated incoming persons to position themselves in order to align the thermal face overlay outline with their faces. All those who were identified by the cameras as presenting fever, were asked for their consent to use their identification data and were separately accompanied for further clinically examination, including fever axillary measurement and a test for SARSCOV2 as an epidemiologic precaution. From the 46 fever detected individuals only data from 42 persons were used in the present study due to lack of sufficient data in 4 of them.

Results

46 individuals were detected by the thermal camera with a temperature > 37.7ºC, consisting of 8 females (17%) and 38 males (83%), with the average age of 33,0 years. The average temperature captured by the camera was 38.2 ºC (standard deviation: 0.46) (Table 1). Of those identified as

Table 1
Demographic and clinical characterization of the population identified by the thermal camera

Age, A (SD)	33,0 (16,6)
Gender, Af (%)	
Male	38,0 (83,0)
Female	8,0 (17,0)
Temperature, A (SD)	38,2 (0,46)

A - Average
SD - Standard deviation
Af - Absolute frequency
% - Relative frequency

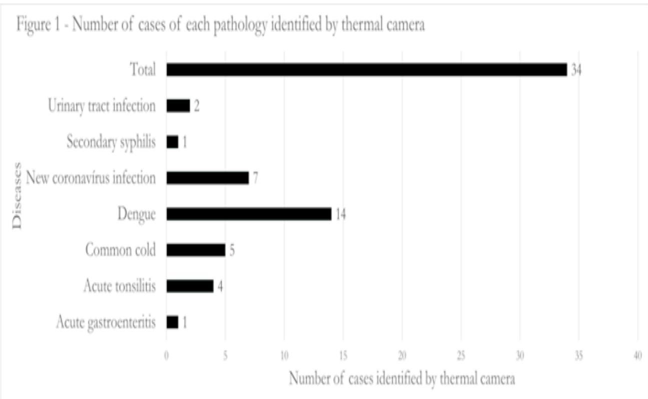

Figure 1 - Number of cases of each pathology identified by thermal camera

febrile, 5 refused to undergo further medical care and 7 did not have a definitive diagnosis at the end of the clinical investigation. The remaining 34 individuals were diagnosed as shown in Figure 1.

Discussion

Using the individual's ID information, a search was made in their medical records to identify the pathology diagnosed after medical care. No false positive fever detection was reported. 14 individuals with high temperature were diagnosed with Dengue, a disease that is highly prevalent in the region where the study was conducted. Fever is a common symptom of this disease and it is crucial to rapidly identify it in order to start treatment. Fever and infection with the new coronavirus were the second most common group with 7 confirmed cases. The fever screening process allowed these individuals who had sought the emergency service, not necessarily for medical care, to be evaluated by a medical doctor and to avoid unwanted contamination of other sectors of the hospital.

This screening method also proved to be useful as an early warning system for urgent treatment of non-covid-19 related diseases. Early fever detection led to early intervention especially in Dengue patients that may have been life-saving. The detection of febrile patients also provided an objective factor to prioritize emergency treatment in all incoming individuals.

Considering the above, the authors suggest that thermographic screening, if properly implemented in accordance to international standards, as a useful complementary strategy not only during the current pandemic crisis but also for the early identification of patients with fewer due to other causes, in particular those of infectious nature, in order to prevent them from contaminating others.

Thus, the importance of investment in thermographic screening technology is evident. Future work should focus on larger population studies that combine this technique with Artificial Intelligence tools and other remote sensors to increase its sensitivity in identifying patients with a specific disease in order to enhance and validate its clinical utility.

References

1.Dey N, Ashour A, Althoupety A. Recent Advances in Applied Thermal Imaging for Industrial Applications - Thermal Imaging in Medical Science 2017; p. 87 - 117

2.Lee I, Wang C, Lin M. Effective strategies to prevent coronavirus disease-2019 (COVID-19) outbreak in hospital, Journal of Hospital Infection 2020; 105: 102-103

3.Malmivirta T, Hamberg J, Lagerspetz E. Hot or Not? Robust and Accurate Continuous Thermal Imaging on FLIR cameras, 2019; p. 1-9

4.Ring EFJ. The historical development of thermometry and thermal imaging in medicine. Infrared Physics & Technology 2007; 30: 192-198.

5.Ring EFJ, Ammer K. Infrared thermal imaging in medicine. Physiol Meas 2012; 33(3) R33-R46

6.Pascoe D, Ring EFJ, Mercer J, Snell J, Osborn D, Hedley-Whyte J. International standards for pandemic screening using infrared thermograph. Biomedical Applications in Molecular, Structural, and Functional Imaging, 2010, Vol. 7626, p. 76261Z.

7.Ring EFJ, Mcevoy H, Jung A, Zuber J, Machin G. New standards for devices used for the measurement of human body temperature. Journal of Medical Engineering & Technology, 2010; 34: 249-253

8.Tirupathamma M, Niranjan V. Telecommunications and Radio Engineering - Principles and Applications of Infrared 2020; 79: 1177-1187.

9.Vardasca R, Magalhaes C, Marques D, Moreira J, Frade R, Seixas A, Mendes J, Ring F. Bilateral assessment of body core temperature through axillar, tympanic and inner canthi thermometers in a young population. Physiol Meas.; 2019, 40(9) 094001

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COMPARISON OF MACHINE LEARNING TECHNIQUES FOR INDIRECT ASSESSMENT METHODS OF BODY CORE TEMPERATURE

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Introduction

Pandemic conditions are once again in great prominence with the recent situation caused by COVID-19, some of these conditions present feverish states that can be detected by means of mass screening at places of great influx of people. There are available different indirect methods to estimate human body core temperature. Being a febrile state considered of a body core temperature higher than 37.5 ºC. This value may differ according to the indirect method used, which can make it difficult to identify febrile cases close to the threshold value, for assisting in this task advanced Artificial Intelligence tools such as Machine Learning (ML) algorithms may be an important aid. The aim of this research is to evaluate which ML technique has the best performance with a certain indirect method of assessing body temperature, considering the reference provided by another method.

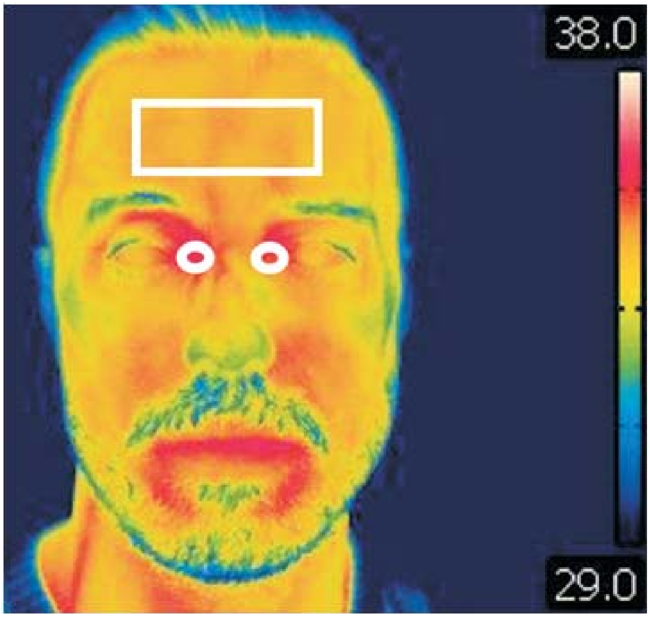

Figure 1
The ROIs at the frontal face thermal images.

Methods

Among the available methods to indirectly estimate human body core temperature are the axillar and tympanic thermometers and the infrared measurements of the forehead and the inner canthi of the eye.

A total of 140 subjects (37±7.1 years old, ranging from 21 to 63, 69 males and 71 females), from which 10 were considered febrile by the axilla thermometer assessment. All were screened with axillar thermometer (Beurer FT09/1 with precision of ± 0.1 °C, Ulm - Germany) and tympanic thermometer (Sanitas SFT 75 with precision of ± 0.2 °C, Uttenweiler - Germany) and facial infrared imaging using a thermal camera FLIR T430 (FPA array size of 320x240, NETD of <50mK @ 30ºC and measurement uncertainty of ±2% of the overall temperature reading) at a health center of Santarem.

To identify the febrile state, it was used the threshold value of 37.5ºC on the axillar thermometer reading as a reference, being the measurements taken in both armpits and considered the average when there was no difference above 0.3ºC between both sides, being the measurement repeated if the difference was higher. In the tympanic membrane thermometer, the two ear canals were assessed and any measurement with a bilateral difference major than 0.3º C was disregarded and the mean between sides was considered. The thermal images were collected using the standard recommendations on room, equipment, and participant preparation. The average room temperature was 22.1±0.2 °C and relative humidity o 47±1.8 %. In each thermogram three ROIs (Fig. 1) were considered, one in the forehead and others at each inner canthi of the eye, being the mean temperatures recorded. For the inner canthi of the eye the average of both sides was considered.

Five ML methods were selected for this research: Multilayer Perceptron (MLP), Support Vector Machines (SVM), Naïve Bayes (NB), k-Nearest Neighbor (kNN) and Random Forest (RF). A Python script was developed consisting of six tests: 5 and 10-fold cross section with 20%, 25% and 30% sample testing. When a 20% test size was used, it meant that the ML model was trained with the remaining 80% sample size. The use of several N-fold cross validation is important to vary the composition of the test and training sets that are selected randomly from the sample.

To verify which ML method would perform better and with which measurement method the overall accuracy (the

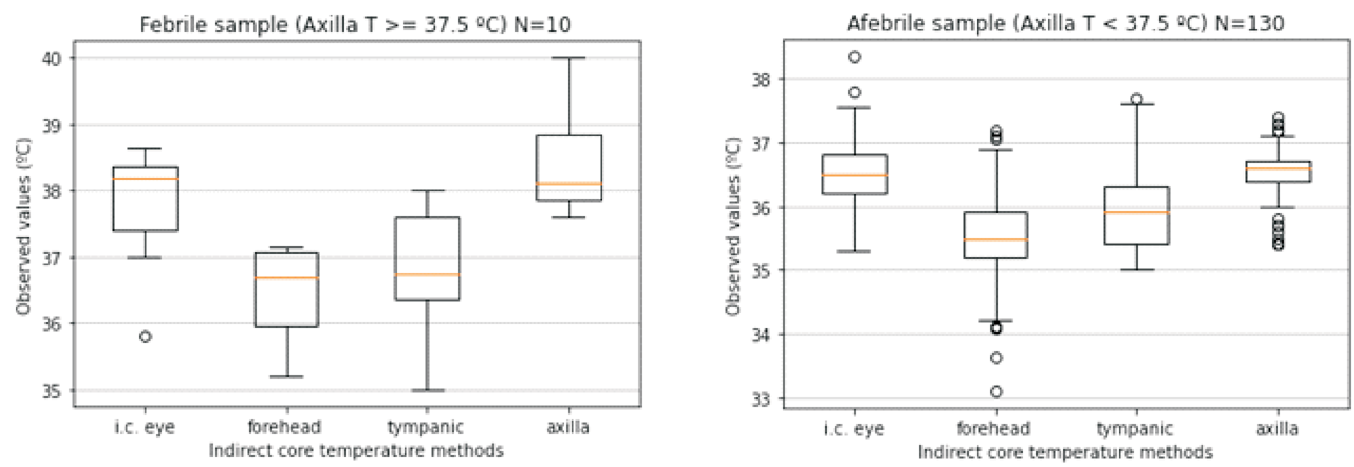

Figure 2
The data sample distribution per indirect core temperature method, left the febrile group and right the afebrile group (based on the axilla thermometer assessment).

ratio between number of correct predictions by the total number of predictions. Being calculated in this experimental work by the ratio of the sum of the true positives and true negatives by the sum of the true positives, false positives, true negatives, and false negatives) of each ML method was calculated.

Results

The sample data distribution of the recorded values with the different core temperature estimation methods is presented at figure 2. The results at the defined tests (sample testing size and fold cross validation) for all ML techniques and temperature assessment methods are showed in table 1, from which it can be observed that the worst results are given by MLP for all tests and methods. All the other ML techniques presented good results (accuracy > 85%), being the SVM the technique that presented better results for the inner canthi of the eye and forehead measurement, being closely followed by the NB algorithm. For tympanic measurements, the ML technique that overperformed was the NB followed by the RF.

Discussion and conclusions

Different indirect methods to assess body core temperature present different temperature values as showed by Vardasca et al., 2019. Therefore, different fever thresholds may have to be considered, which can make hard the life of assessors (humans or systems), to automatize the process ML techniques may be used to help the burden. This research showed that the ML algorithm performance may differ with the temperature assessment method, Artificial Neural Networks (MLP) based systems should be avoided since there is one unique value of entrance to find an output, techniques such as SVM, NB and RF presented better performance (accuracy > 89%) and are more reliable for this kind of implementation. The knowledge base size, for training the ML models, is also an aspect of importance since values may differ from having a 70 to 80% training sample. Although for the suggested methods this variation

Table 1
Accuracy of the Machine Learning techniques on the body temperature assessment methods within the different configuration tests.

Method	Test	5-fold cross validation			10-fold cross validation		
		20%	**25%**	**30%**	**20%**	**25%**	**30%**
I.C. Eye	MLP	63.00	40.00	40.66	50.00	45.20	49.66
	SVM	95.00	96.80	94.00	95.00	94.40	96.00
	NB	95.00	95.20	94.00	94.50	94.00	96.33
	kNN	94.00	96.00	92.00	95.00	90.40	92.00
	RF	92.00	97.60	92.66	95.00	92.00	93.66
Forehead	MLP	39.45	42.70	40.54	75.67	48.10	40.54
	SVM	91.89	93.51	92.97	91.89	95.40	91.08
	NB	91.89	94.05	91.89	91.89	94.86	93.24
	kNN	85.94	88.10	85.40	85.67	91.89	87.29
	RF	89.73	92.97	90.27	90.00	93.51	90.81
Tympanic	MLP	37.83	41.08	40.54	75.67	24.05	31.89
	SVM	90.27	92.97	92.97	94.05	91.08	94.86
	NB	91.89	93.51	93.51	95.40	91.35	96.21
	kNN	89.18	88.64	88.10	88.91	86.75	88.10

is smaller. Nonetheless this experiment should be validated in a larger population size for better understanding.

Acknowledgments

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References

Ring EFJ, Jung A, Kalicki B, Zuber J, Rustecka A, Vardasca R. New standards for fever screening with thermal imaging systems. Journal of Mechanics in Medicine and Biology 2013; 13(02), 1350045.

Vardasca, R.; Magalhaes, C.; Marques, D.; Moreira, J.; Frade, R.; Seixas, A.; Mendes, J; Ring, F. Bilateral assessment of body core temperature through axillar, tympanic and inner canthi thermometers in a young population. Physiological measurement, 2019, volume40(9), 094001.

Vardasca Rn Vaz L, Mendes J. Classification and decision making of medical infrared thermal images. Classification in BioApps 2018. pp. 79-104.

Ammer K, Ring F. The Thermal Human Body: A Practical Guide to Thermal Imaging. CRC Press 2019.

RussellS; Norvig P. Artificial intelligence: a modern approach; 2020.

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SYSTEMATIC REVIEWS AND META-ANALYSIS ABOUT INFRARED THERMOGRAPHY IN MUSCULOSKELETAL RESEARCH - TRENDS AND CRITICAL APPRAISAL

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Introduction

Systematic reviews and meta-analysis are secondary research studies that combine the results of primary research studies, providing a more accurate description of the analyzed phenomenon. This type of research has an important role in evidence-based practice, since well conducted systematic reviews produce high quality evidence on diagnostic accuracy or effects of interventions. Over the years, the number of systematic reviews and meta-analysis reporting the value of infrared thermography is increasing, and musculoskeletal health is one of the most sought research fields. However, little is known about the characteristics of these systematic reviews, concerning the topic, type, and overall methodological quality. Therefore, this study aims to evaluate the publication trends and methodological quality of systematic reviews and meta-analysis reporting the value of infrared thermography in musculoskeletal research.

Methods

A systematic electronic search was conducted up to March 2021 in Pubmed, Web of Science and Scopus using the search string ("thermal imaging" OR "infrared imaging" OR thermog*) AND ("systematic review" OR "meta-analysis" in the title, abstract and keywords. Only systematic reviews with or without meta-analysis reporting the value of infrared thermography in musculoskeletal research were included. The type of systematic review was determined according to Munn et al. criteria [1] and Joanna Briggs Institute Critical Appraisal Tool for Systematic Reviews and Research Syntheses. Comprehensive literature search, assessment of risk of bias for individual studies, appropriate data synthesis methods, and consideration of risk of bias in results are domains often considered as critical in the methodological quality of systematic reviews. Considering these domains, the overall confidence in the results of systematic reviews was classified as "High" (none/one non-critical issue), "Moderate" (>1 non-critical issue), "Low" (one critical issue) and "Critically Low" (>1 critical issue).

Results

Five hundred and thirteen (513) records were found through database searching. After removal of duplicates 323 records were screened. After reading the title and abstract 314 records were excluded for not complying with the eligibility criteria and 9 records were selected for full text analysis. One study was excluded for not being focused on thermal imaging findings and, therefore, 8 systematic reviews were included in the qualitative synthesis. One systematic review (12.5%) [2] focused on methodology, 1 systematic review (12.5%) [3] explored the role of skin temperature (assessed through thermal imaging) as an outcome measure and 7 systematic reviews (87.5%) [3-9] assessed the diagnostic accuracy of thermal imaging in musculoskeletal research. Most systematic reviews (n=5; 62.5%) were considered as being of "Critically Low" quality, 1 (12.5%) was considered as being of "Low" quality, 1 (12.5%) was considered as being of "Moderate" quality and 1 (12.5%) was considered as being of "High" quality.

Conclusion

Consistent methodological quality issues were identified on the included systematic reviews, particularly in the assessment of the likelihood of publication bias, in providing recommendations for policy and/or practice not supported by the results, the absence of methods to minimize errors in data extraction and failing in providing appropriate directives for new research. The existing systematic review quality is low and there is a need to improve the quality of systematic reviews and meta-analysis reporting the value of infrared thermography in musculoskeletal research.

References

1. Munn Z, Stern C, Aromataris E, Lockwood C, Jordan Z. What kind of systematic review should I conduct? A proposed typology and guidance for systematic reviewers in the medical and health sciences. BMC medical research methodology. 2018; 18(1):5.

2. Vardasca R, Magalhaes C, Silva P, Abreu P, Mendes J, Restivo MT. Biomedical musculoskeletal applications of infrared thermal imaging on arm and forearm: A systematic review. Journal of Thermal Biology. 2019;82:164-177.

3. Albuquerque NF, Lopes BS. Musculoskeletal applications of infrared thermography on back and neck syndromes: systematic review. Eur J Phys Rehabil Med. 2020.

4. Hoffman RM, Kent DL, Deyo RA. Diagnostic accuracy and clinical utility of thermography for lumbar radiculopathy a meta-analysis. Spine. 1991;16(6):623-628.

5. Sanchis-Sanchez E, Vergara-Hernandez C, Cibrian RM, Salvador R, Sanchis E, Codoner-Franch P. Infrared Thermal Imaging in the Diagnosis of Musculoskeletal Injuries: A Systematic Re-

view and Meta-Analysis. American Journal of Roentgenology. 2014;203(4):875-882.

6. Bunn PD, Miranda MEK, Rodrigues AI, Sodre RD, Neves EB, da Silva EB. Infrared thermography and musculoskeletal injuries: A systematic review with meta-analysis. Infrared Physics & Technology. 2020;109.

7. de Melo DP, Bento PM, Peixoto LR, Martins S, Martins CC. Is infrared thermography effective in the diagnosis of temporoman dibular disorders? A systematic review. Oral Surgery Oral Medicine Oral Pathology Oral Radiology. 2019;127(2):185-192.

8. Fathima N, Dharman S. Role of thermography in assessment of myogenous temporomandibular disorders-a systematic review. Biomedical and Pharmacology Journal. 2019; 12(3): 1241-1247.

9. Chaudhry S, Fernando R, Screen H, Waugh C, Tucker A, Morrissey D. The use of medical infrared thermography in the detection of tendinopathy: a systematic review. Physical Therapy Reviews. 2016;21(2):75-82.

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THERMAL IMAGING IN RHEUMATOID ARTHRITIS KNEE JOINTS AND ITS CORRELATION WITH POWER DOPPLER ULTRASOUND

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Introduction

Power doppler ultrasound (PDUS) is the current gold standard for quantification of inflammation and disease activity in RA (Rheumatoid arthritis). However, PDUS has several disadvantages including cost of equipment, steep learning curve and interobserver variability. Thermal imaging has emerged as a simple, powerful tool for mapping the heat distribution pattern and has the potential to document and quantify disease activity in RA.

Objective

To study the thermal imaging pattern of inflamed knee joints in cases of RA and its correlation with PDUS.

Methods

This case control study was carried out at the Rheumatology centre of a tertiary care hospital in India including 100 subjects (50 controls and 50 RA patients). A total of 50 recently diagnosed RA patients with features of active arthritis in knee joints were evaluated for disease activity with PDUS (Scored semiquantitatively grade 0 - 3). The controls were asymtomatic and healthy age and gender matched selected from hospital staff. Thermal imaging was carried out in all the participants on the lateral aspect of knee using a high resolution professional thermal camera (Testo - 885 resolution 320 X 240 pixel) with ambient temperature at 25 degree centigrade. The thermal images were taken in sitting subjects from lateral aspect of knees with knee and hip flexed at 90 degrees. The PDUS was carried out on participants and semiquantitative grading system was used for analysis. The mean temperatures in area of interest in knee, thigh and knee - thigh differential were analysed in comparison to PDUS findings in all participants (Fig 1).

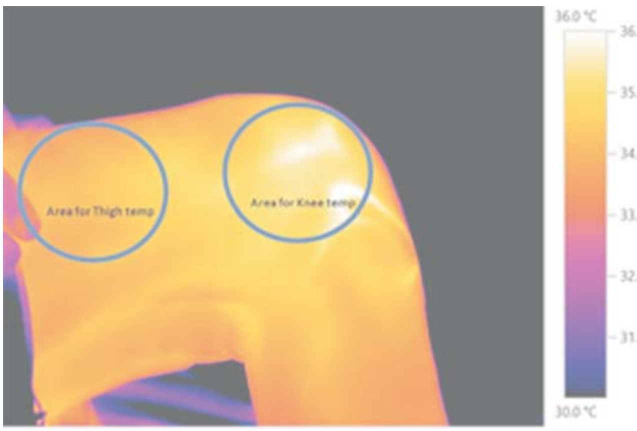

Figure 1
Area of interest for recordeing mean temperature in thigh and knee

Results

There was no significant difference between demographic profile of cases and controls. RA subjects with inflamed knees had significantly higher mean knee temperature and mean Knee-Thigh temperature differential as compared to controls (p value <.00001). The distribution of PDUS grading in RA patients is depicted in Table 2 There was a strong correlation between PDUS grade and Knee-Thigh temperature differential (Pearson's correlation coefficient, r = 0.778)

Table 1
Difference in mean temperatures of knees and knee - thigh differential in subjects versus controls

	Control (n=50)	Test (n=50)	
Mean Knee-Thigh temperature differential (°C)	-0.5	1.1	
Standard deviation	0.5	0.6	
95%CI: lower limit	-0.7	0.9	p<0.05
95%CI: upper limit	-0.4	2.0	
Mean Knee temperature(°C)	31.5	32.7,	
Standard deviation	0.9	1.3	
95%CI: lower limit (°C)	31.2	32.4	p<0.05
95%CI: upper limit (°C)	31.7	33.1	
Mean Thigh temperature (°C)	32.0	31.7	
Standard deviation	0.8	1.4	
95%CI: lower limit (°C)	31.8	31.3	NS

Table 2
Distribution of semiquantitative PDUS Grading in patients with RA

PDUS Grade	No. of cases (%)	
0	50(100)	All controls (n=50)
1	7 (14)	Cases (n=50)
2	15 (30)	
3	28 (56)	

Discussion

The current gold standards for assessment of disease activity in RA have lots of shortcomings. Our study has shown statistically significant differences in mean knee temperature as well as mean Knee-Thigh temperature differential of inflamed versus control knees. There are no previous studies on thermal imaging comparison with PDUS as a tool for assessment of disease activity in RA. Thermal imaging has the potential to become simple, objective, cost effective and reliable tool for assessment of disease activity in inflamed joints. The author is in process of developing a composite scoring system for quantification of disease activity in RA based on thermography of small and large joints.

References

1.Sanchez BM, Lesch M, Brammer D, et al. Use of a portable thermal imaging unit as a rapid, quantitative method of evaluating inflammation and experimental arthritis. Journal of Pharmacological and Toxicological Methods. 2008; 57(3):169-175.

2.McAlindon T, Kissin E, Nazarian L, Ranganath V, Prakash S, Taylor M, Bannuru RR, Srinivasan S, Gogia M, McMahon MA, Grossman J, Kafaja S, FitzGerald J. American College of Rheumatology report on reasonable use of musculoskeletal ultra- sonography in rheumatology clinical practice. Arthritis Care Res 2012, 64: 1625-1640.

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PAINFUL SHOULDER SYNDROME IN THERMAL AND SONOGRAPHIC IMAGING

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Introduction

The shoulder joint is the joint with the greatest range of motion thanks to its anatomical structure and the loose joint capsule. The loose joint socket creates several recesses in which the joint fluid can accumulate, or blood in case of an injury, or even loose bodies. The stability of the joint and the reinforcement of the shoulder girdle are ensured by ligaments. The joint function is made possible by 16 muscles that are clamped into the humeroscapular joint area or other structures of the shoulder girdle (8). Smooth movement during muscle activity is supported by 16 bursas. In places where there occurs a friction of muscles against firm structures and among individual muscles against one another, a specially structured type of interstitial tissue ensures smooth movement (7). In any of the described structures, a pain generator may occur following an injury or disease. At the site of the pain generator, chemical mediators are released that are detected by different types of nociceptors and subsequently activate nociception pathways. There are several basic types of pain according to the type of chemical mediator released. It is assumed that different pain types are associated with specific skin temperature distributions. Local inflammatory processes lead to nociceptive pain, and dependent on the severity of the inflammation to increased skin temperature over the painful area. Pain may also result in a disturbed balance within the autonomous nervous system. Sympathetically maintained pain is defined as pain that is maintained by sympathetic efferent activity or neurochemical or circulating catecholamine action. Affected regions often present with low skin temperature (15). However, thermography is a pathophysiological method. It fails to accurately identify the anatomical structures where activated nociceptors are located.

For these purposes we must use structural imaging methods such as X-ray, MRI, CT, or sonogram. Over the last decade, the quality of ultrasonographic imaging has enormously improved the diagnosis of the musculoskeletal system. It is now possible to display deep-lying structures. The sonographic image is more contrasting, and we can better differentiate the examined structures (9,11).

Objective

The aim of this study was to classify shoulder pain by thermographic findings and providing the diagnostic properties of thermal imaging in relation to the morphological findings recorded by sonography.

Method

Our study is a retrospective study in which, out of the total number of patients admitted to our workplace for shoulder pains between January 2010 and December 2019, we only selected those who had a positive sonographic finding and underwent a thermal imaging examination as well. All patients went through the physical examination, which include inspection with a particular focus on abnormal vascular findings and superficial skin lesions. Palpation of the shoulder included testing for tenderness of insertions of ligaments and tendons, assessment of swelling. Functional tests were performed including range of motion, assessment of joint play, joint stability and joint stiffness. Muscle tone and muscle strength were also tested. For thermal imaging, we used the Fluke infrared camera Ti32, equipped with a 320 x 240 focal plane array, uncooled microbolometer with thermal sensitivity (NETD) 0.05 °C at 30 °C target temperature. The patient was equilibrated in a darkened room at 25° ± 1.0°C for 20 minutes half naked. In addition to the standard positions given by the Glamorgan Protocol (1,3), we also used an additional projection - a horizontal one with a 90° forward bend - to record the AC articulation. The basic criterion for evaluating the thermographic image of the examined area is the description of temperature deviations from the normal temperature pattern. In temperature active findings, we evaluate the total temperature parameters - Tmax., Tmed., and Tmin. We compare them with temperature parameters in the contralateral symmetrical region (if the contralateral temperature pattern is normal) or to the suroudings (1,2). In the area of interest we evaluate both hyperthermia and hypothermia. Thermal findings with Tdif. ≥ 0.5°C are considered positive. We use an Esaote MyLabSeven ultrasound device with a 5-12 MHz linear probe to perform the sonographic examination. We do not focus exclusively on the pain area; but rather are examining the entire shoulder in each patient. Dynamic tests are included in the sonographic evaluation, when necessary.

Results

The total number of patients selected was 332. Of these, 191 were men, and 141 women. All patients were aged between 3 and 91 years, with the average of 49,4 years. In some cases the examinations were completed by use of other imaging methods. 76 of them were also X-ray screened and 57 had an MRI or CT scans done. Biochemical examinations were performed as well if required for

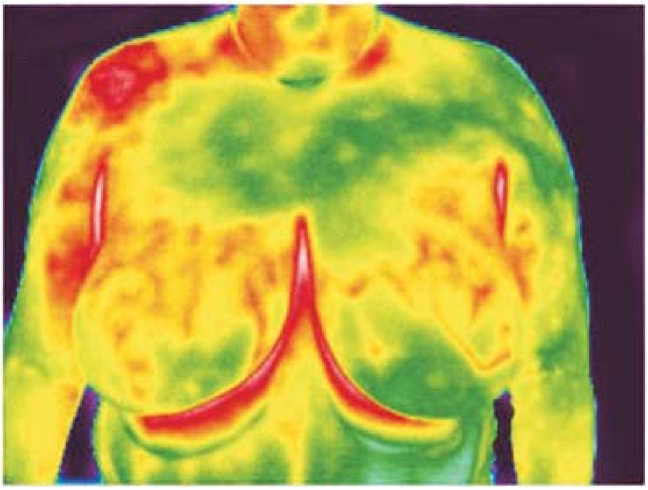

Fig.1.
Increased temperatureon the right side

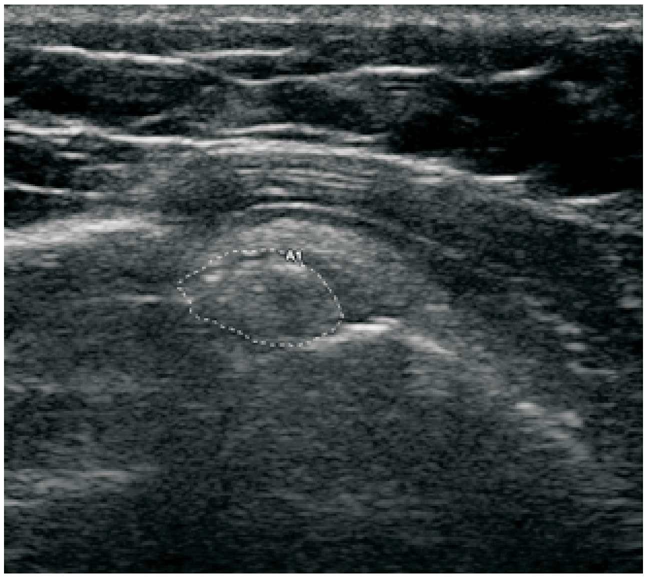

Fig.2.
Calcification in m.supraspinatus on the right side

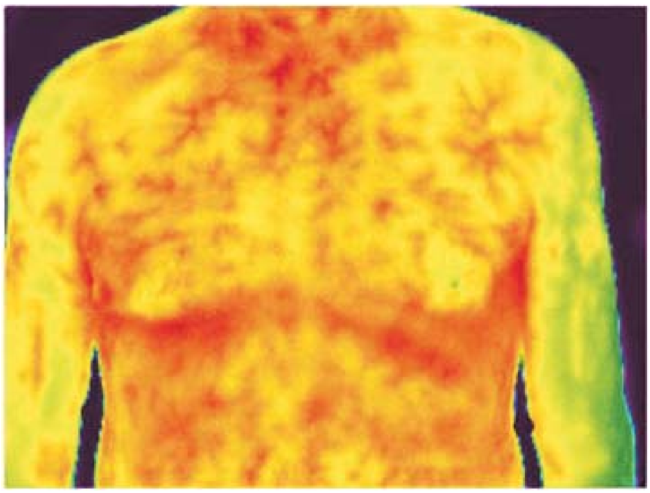

Fig.3.
Normal thermal finding on the left side

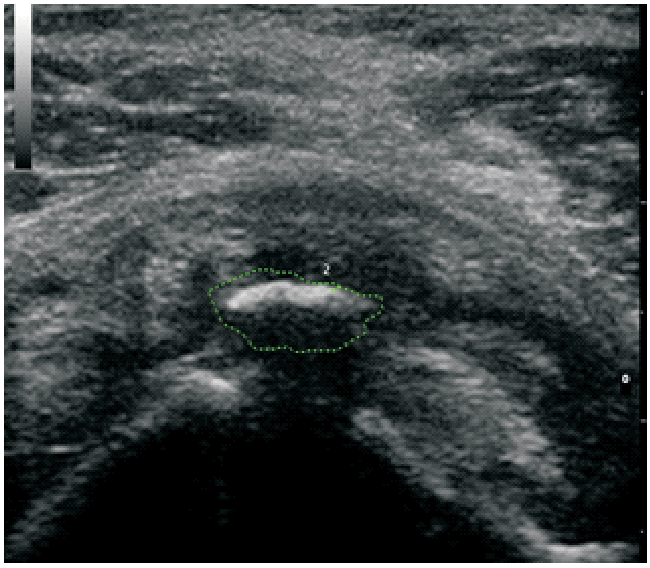

Fig.4.
Ruptura partialis m.supraspinati with calcification on the left side

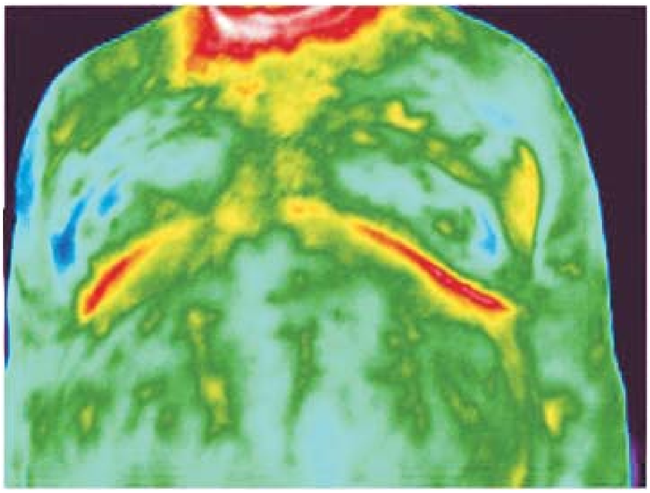

Fig 5
Decreased temperature on the left side

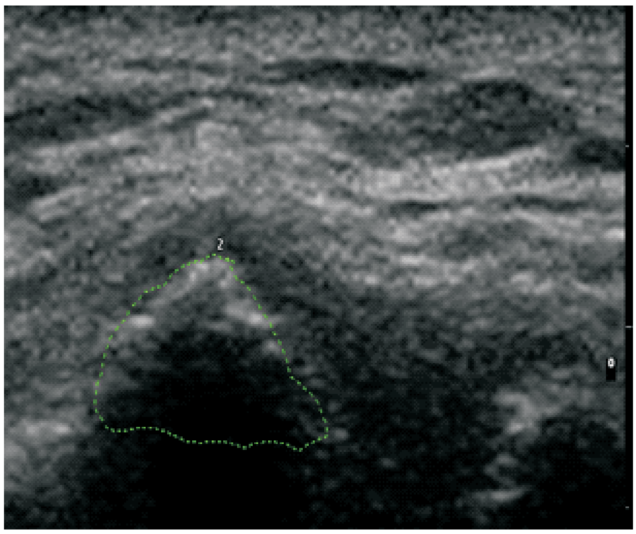

Fig.6.
Calcification in area of AC joint and m. subscapularis on the left side

definite diagnostic decisions. In skin temperature distribution only 57% of the 332 patients with sonographic abnormalities showed a disturbed temperature distribution. 151 patients presented with hyperthermia in the painful shoulder region, while 40 patients showed low temperatures over the symptomatic shoulder. There were 141 patients whose thermal pattern in the painful shoulder region was similar to that of the unaffected side. Combining thermal and physical examination findings has better diagnostic accuracy than just physical examination or thermal findings alone. Since only patients with abnormal sonographic findings were included in this evaluation, all patients presented with at least one pathological finding in sonography resulting in a total of 492 findings in 332 patients. Tendon pathologies were the most frequent observations, followed by joint and bursae pathologies. The ratio tendon to joint pathologies to bursa affections was similar in normal, hyper- or hypothermic thermal patterns. Examples of hyperthermic normothermic, and hypothermic temperature patterns and their corresponding sonographic findings are provided.

Conclusion

Infrared thermal imaging records the temperature distribution on the surface of the shoulder, It provides cues to the pathophysiological processes involved in various pain syndromes. The sonographic image fosters easy differentiation of the examined structures. The allocation to different pain classes based on thermographic and sonographic findings seems to provide a clinical pathway for the selection of treatment with high probability of success.

References

1.Ammer K., Ring EFJ. The thermal human body. Singapore. Jenny Stanford publishing. 2019. ISBN 978-981-4745-82-6. 259 p.

2.Ammer K, Engelbert B., Hamerle S., Kern E., Solar S., Kuchar K. Thermography of the Painful Shoulder, European Journal of Thermology 8/3 (1998), s.93-100

3.Ring EFJ, Ammer K. Infrared thermal imaging in medicine Physiological measurement 2012, 33: p.33-46

4.J. Alencar, M. Freire, R. Cardoso, J. Ferreira Thermographic changes in workers with shoulder disorders, Thermology international 25/3, 2015, p.143

5.I. Rossignoli 1,3 M Sillero-Quintana 1, A. Herrero Infrared thermography and shoulder pain in athletes and sedentary wheelchair users Thermology international 25/3, 2015, p.31

6.Bartonícek J, Hert J: Základy klinické anatomie pohybového aparátu. Maxdorf Jessenius, Praha, 2004, ISBN 80-7345-017-8, p.83-102

7.Synestvedt A.S.D.: Mucous Bursae of the Upper and Lower Extermity. Karolinum Press, Prague, 2010, p.138-145

8.?ihák R. Anatomie 1. Grada Publishinng a.s. Praha 2006, p.20216-234, 236-241, 394-401

9.Bianchi S.,Martinoli C: Ultrasound of the Musculoskeletal System. Springer-Verlag Berlin Heidelberg, 2007, p.189-331

10.Vahlensieck M., Gennant H.K., Reiser M. MRI of the Musculoskeletal system. Thieme Medical Publishers, New York 2000, pp. 47-76.

11.Jacobson J.A. Fundamentals of Musculoskeletal ultrasound. Elsevier 2013, ISBN 978-1-4557-3818-2, p.3-71

12.Wakefield R.J., D´Agostino M.A. Essential aplications of musculoskeletal ultrasound in rheumatology. Sounders Elsevier 2010, 370 p.

13.Helms C.A. Fundamentals of skeletel radiology. Elsevier Philadelphia 2014 ISBN 978-1-4557-5154-9,

14.Dogra V.S., Gaitini D. Musculockeletal ultrasound with MRI correlation. Thieme New York, ISBN 978-1-60406-244-1,

15.Gabrhel J., Popracová Z., Tauchmannová H. Thermographic and sonographic findings in patients with shoulder pain: a retrospective study for the period January 2010 to December 2019. Thermology international 30/2, 2020, s.58-66.

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PLANTAR FOOT ASSESSMENT USING LIQUID CRYSTAL THERMOGRAPHY

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Introduction

Diabetes is one of the world's most common chronic diseases. In 2019 an estimated 463 million people worldwide were living with diabetes, which is expected to rise to 700 million people by 2045.

Diabetes causes vascular complications and neuropathy (loss of feeling) which in turn cause foot ulcers in 2.5% of people with diabetes at any moment in time. In the UK 90,000 people were affected in 2019, 40% of whom will die within 5 years - many as a result of the more than 160 per week (8,500 per year) amputations. Consequently, diabetic foot ulcers are more deadly than some forms of cancer.

A previous three year clinical trial [1] under the clinical lead of King's College, London established that a breach of temperature symmetry between left and right foot and hot-spot development are strongly associated with inflammation and this could be useful to prevent subsequent ulceration.

Using this clinical knowledge the Class I medical device based on thermochromic liquid crystals (TLC) was developed in collaboration with Podiatrists.

This paper describes the outcome of a study with two aims: firstly to assess the usability of the TLC device in podiatric practice and secondly, by generating a set of case studies, to assess if the two main indicators of contra-lateral asymmetry and hot spot development are reliable under the non-standardised conditions that are found in everyday practice.

Methods

In addition to best practice foot care 5 podiatrists assessed a total of 25 patients over a period of 4 months with the TLC device. The protocol followed standard practice with respect to patient enrolment, information and consent.

Addressing the first aim of the study, podiatrists recorded usability experiences in terms of time requirements, intuitiveness of the software, fit into routine workflow, etc. Addressing the second aim the protocol deliberately deviated from established thermography image capture guidelines [2] with respect to patient, equipment and environment preparation in order to assess to what extent the conditions found in reality in daily podiatry practice affect the utility of the device. The hypotheses was that the two main indicators symmetry and hot spots (see example figure 1), together with a third one based on the regular temperature gradient in a "standard foot" shown in figure 2 [3], will be

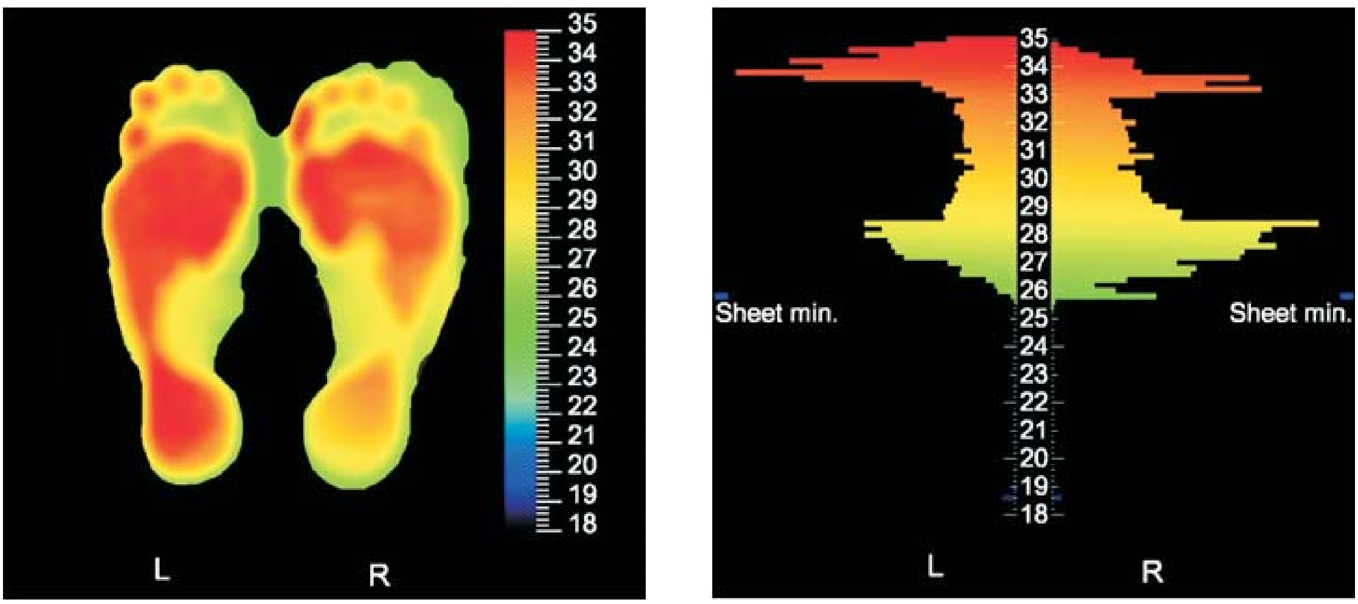

Figure 1
Thermogram of feet with suspected neuropathy (left) and associated symmetry histogram (right). Noticeable are the breach of thermal symmetry between left and right foot, extended hot areas and a poorly developed temperature gradient between medial arch and both toes and heel.

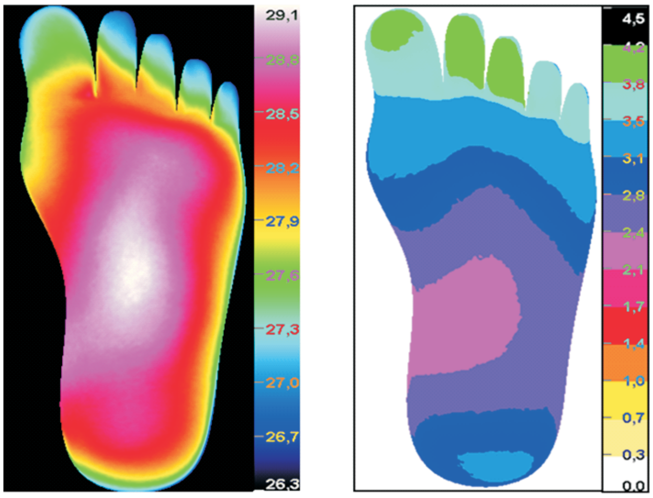

Figure 2
Average plantar foot temperature (left) of 103 healthy subjects, resting at 22°C, 10 minutes after taking socks off. Variation of temperature (right) between the 103 subjects, 1 standard deviation
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sufficiently robust to provide the podiatrist with useful adjunct data to support their standard assessment practice.

As such the study was strongly qualitative, not quantitative, with a view towards informing the design of a subsequent clinical trial.

Results

With respect to the first usability aim the results indicate that the engagement time with the device of between 2- and 5-minutes fits well into a typical podiatry session. Suggestions to change the fixed software guided workflow to a flexible podiatrist determined order were taken on board, implemented and resulted in an overall faster and more intuitive process. Improvements to data presentation, recording and analysis in the associated web portal software were implemented.

With respect to the hypothesis of the second aim that asymmetry, hot-spots and temperature gradient are robust under all practically encountered circumstances the results indicate that this is not the case. Generally, the further a particular image capturing process deviated from thermographic best practice conditions (e.g. very cold or very warm room temperature) the less the observed thermographic image corresponded to the podiatrists' standard, non-thermal, assessment. Overall, foot temperature and hot spots were particularly affected. The temperature gradient between medial arch and toes suffered less while contra-lateral asymmetry was influenced least.

Conclusion

The results demonstrate that for a particular device or methodology to be accepted into routine clinical practice a balance must be struck between practicality of use (time requirement, workflow fit, complexity of operation, training necessary) and scientific rigour (strict adherence to best practice protocols).

Future work will therefore focus on identifying those use cases where a relaxed or simplified protocol is clinically acceptable (e.g. where relevant relative temperatures differences or patterns are only marginally affected by flexible image capture protocol conditions) and those where it is no (e.g. where relevant absolute temperatures are sensitive to those capture conditions). The challenge will be to integrate this knowledge into the user guidance process, hiding and automating complexity while at the same time preserving clinical validity.

References

1. Petrova NL, Donaldson NK, Tang W, MacDonald A, Allen J, Lomas C, Leech N, Ainarkar S, Bevans J, Plassmann P, Kluwe B, Ring F, Whittam A, Rogers L, McMillan J, Simpson R, Donaldson ANA, Machin G, Edmonds ME. Infrared thermography and ulcer prevention in the high-risk diabetic foot: data from a single-blind multicentre controlled clinical trial. Diabet Med. 2020; 37(1):95-104.

2. Ring EFJ, Ammer K. The Technique of Infra Red Imaging in Medicine. Thermology International 2000; 10(1):7-14.

3. Kluwe B. Early detection of diabetic foot ulcers using thermal imaging. PhD Thesis, University of South Wales, July 2018

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IMAGE ANALYSIS AND MACHINE LEARNING CLASSIFICATION FOR SKIN CANCER THERMAL IMAGES USING OPEN SOURCE TOOLS

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Introduction

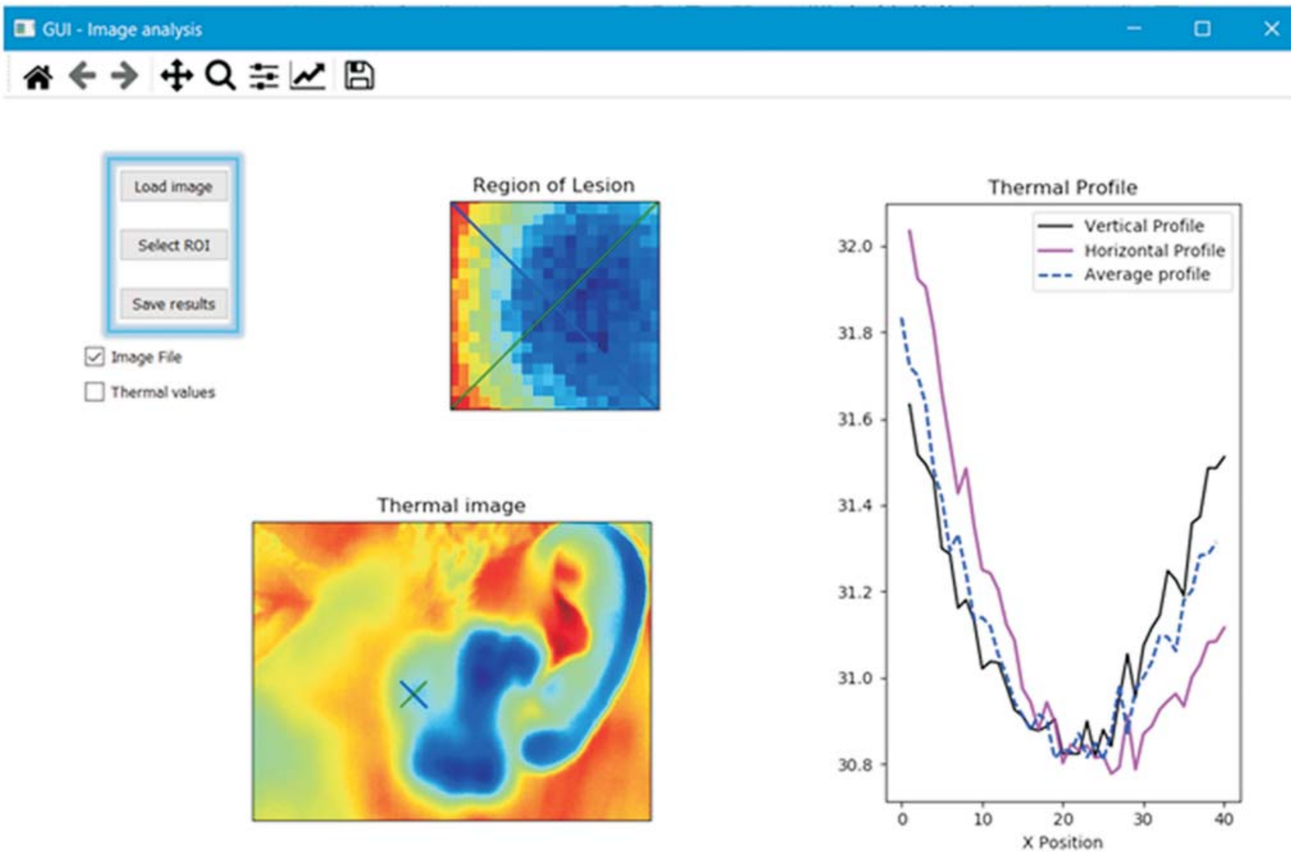
The incidence of skin cancer cases is constantly growing, causing a great burden in health care systems. The interest in using infrared thermal (IRT) imaging to assess atypical skin temperature values associated with skin lesions has grown, as it allows an innocuous and fast evaluation. The processing, collection, and integration of IRT parameters is a challenging task, becoming a tendency to adopt machine learning (ML) strategies. Still, there is not a great number of published research focused on the conception of applications or platforms to perform these tasks. The main aim of this work is the conception and development of two open-source interfaces, using Python programming language, to facilitate and assist in the performance of skin cancer thermograms' image analysis and classification.

Materials and Methods

Static thermograms representative of different skin tumors were analyzed to retrieve features for lesion classification. The infrared thermal images were previously collected at Instituto Português de Oncologia do Porto FG, EPE, including 298 skin tumors (113 benign (29 actinic keratosis (AK), 30 melanocytic nevi (Nevi), 54 other types) and 185 malignant lesions (16 melanoma, 51 squamous cell carcinoma (SCC), 118 basal cell carcinoma (BCC)). The established classification tasks included the differentiation: melanoma vs nevi, SCC vs AK, Melanoma vs Non-melanoma and Benign vs Malignant.

Thermogram manipulation and analysis was performed using the software tools ThermaCAM Researcher Profes-

Figure 1
Image analysis GUI: selected image, region of interest, thermal profile and options for saving.



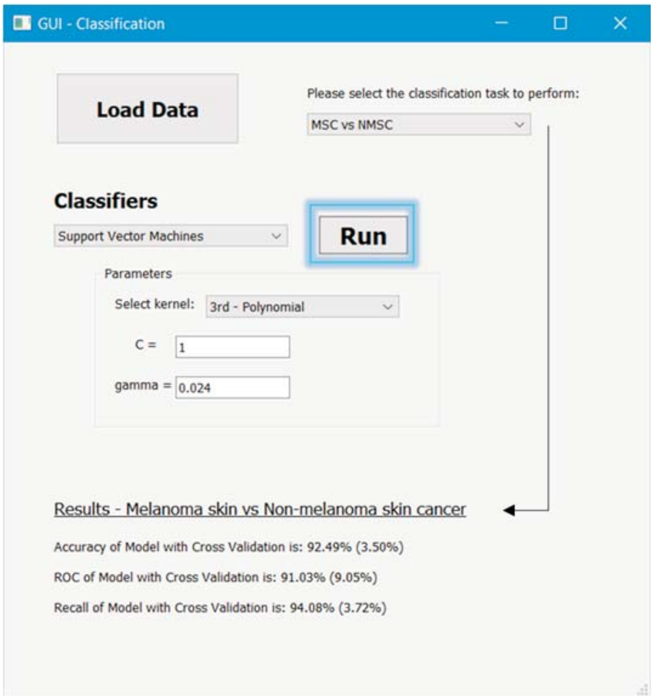


Figure 2
Machine learning classification GUI: classifier run and respective results with label indicating the selected classification task.

sional 2.10 and Anaconda 3 - Spyder 4.0 (Python 3.7), along with QtDesigner for the construction of both graphical user interfaces (GUIs). The Python libraries SciPy, NumPy, OpenCV and Matplotlib were imported to perform tasks concerning file loading, matrix and array manipulation, image processing and plotting and image display, respectively. The GUIs development was performed using the Python library PyQt5 with the modules QtCore, QtGui and QtWidgets. Both GUIs were constructed in a simple manner, being easy to understand and use. Functionality was attributed to each GUI component through the connection of functions and methods to events upon initialization of image analysis GUI (1), the user can load a .mat file representative of the neoplasm of interest, followed by the selection of region of interest. The region of interest (ROI) is process according to Magalhaes et al. 2019 (2), displaying the results, that can then be saved in different format files (Fig. 1). Concerning the classification GUI, the user can load the desired data set, indicate the required classification task, select classifier to use and respective parameters. The classifiers available for selection and respective parameters were chosen based on a previously conducted literature survey for skin cancer images (3). The performance is assessed based on the metrics of accuracy (ACC), Area Under the Receiver Operating Characteristic Curve (ROC(AUC)) and Recall (Fig. 2). A collection of errors is included in both GUIs by pop-windows to inform the user of possible mistakes concerning, per example, image loading, ROI selection, results storage, data set loading and classifier/parameter selection (4).

Results and Discussion

The constructed GUIs were fully operational, allowing the analyses of thermograms in a straightforward manner. In the same line, the classification GUIs eased the testing of different classifier parameters. Promising classification results were achieved with the implementation of a classifier based on Support Vector Machines with a 3rd degree polynomial kernel (SVM - 3rd Poly), specially for the distinction of non-melanoma skin cancer and melanoma (ACC=92.49%, ROC(AUC)=91.03%, Recall=94.08%) and melanoma and nevi lesions (ACC=85%, ROC(AUC)=93.33%, Recall=86.07%) (Table 1). The resemblance of thermal characteristics of SCC and AK complicated its differentiation, since both tumor types presented a decrease in temperature compared to the surrounding tissue (Fig. 3b). The same was verified with the benign and malignant groups. Regardless of the common association of increased temperature with malignant lesions, the malignant group exhibited decreased temperature measurements, due to the integration of non-melanoma skin cancer (squamous cell carcinoma and basal cell carcinoma) in this group (Fig 3c). These neoplasm types were described by a clear hypothermic profile, being mistaken by benign neoplasms by the classifiers.

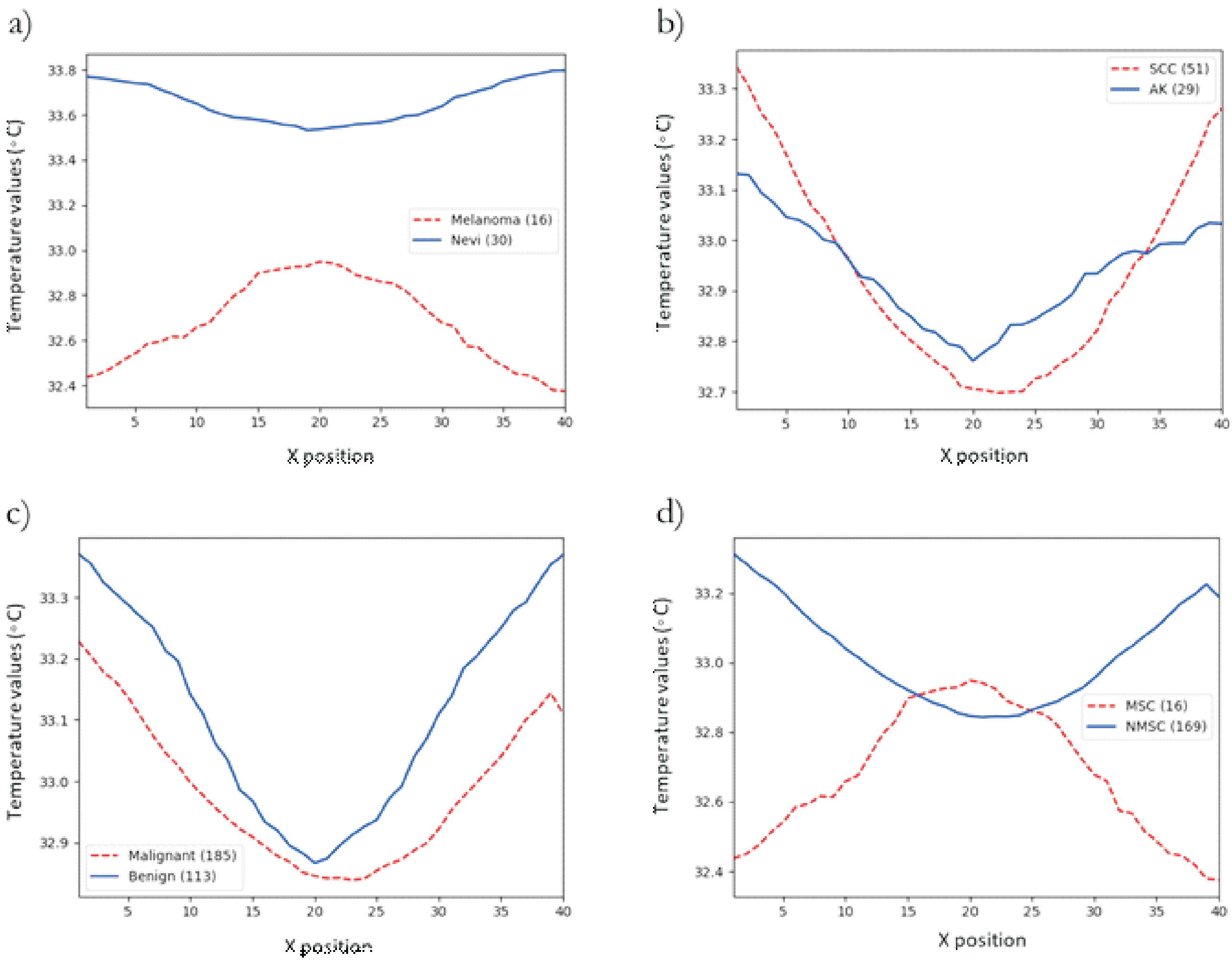
Conclusion

The temperature features retrieved during image analysis proved its potential as input vectors for the constructed ML models, particularly when based on support vector machines. The constructed GUIs eased image analysis and classification. For future work, the use of strategies to deal with class imbalance, perform hyperparameter tuning and

Table 1
Summary of best classification results with top classifier,
average ACC, ROC(AUC) and Recall values and respective standard deviation (std) (results achieved with cross validation 10-fold)

Classification Task	**Best Classifier**	**ACC ± std (%)**	**ROC(AUC) ± std (%)**	**Recall ± std (%)**
t180Benign vs Malignant	SVM – 3^{rd} poly	67.10±7.32	62.63±9.12	100
SCC vs AK	SVM – 3^{rd} poly	67.25±13.05	69±17.64	71±11.36
Melanoma vs Nevi	SVM – 3^{rd} poly	85±3.42	93.33±13.33	86.67±6.33
MSC vs NMSC	SVM – 3^{rd} poly	92.49±3.50	91.03±9.05	94.08±3.72

Figure 3
Average thermal curve: a) Melanoma vs Nevi, b) SCC vs AK, c) Malignant vs Benign, d) Melanoma vs Non-melanoma.



feature selection are suggested, as well as the combination of dermoscopic and thermal features to improve classification results.

Acknowledgments

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References:

1 Fowler, S. GUI Design Handbook; 1997.

2 Magalhaes, C.; Vardasca, R.; Rebelo, M.; Valenca-Filipe, R.; Ribeiro, M., Mendes, J.; Distinguishing melanocytic nevi from melanomas using static and dynamic infrared thermal imaging. 2019; 33(9):1700-1705.

3 Magalhaes, C.; Mendes, J.; Vardasca, R., The role of AI classifiers in skin cancer images; Skin Res Technol. 2019; 25: 750-757.

4 Raschka, S.; Mirjalili, V. Python Machine Learning 2019; 112-180.

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EXPLORATIONS IN SKIN TEMPERATURE AND OBJECTIVE SKIN COLOUR MEASUREMENTS IN RAYNAUD'S PHENOMENON: A PILOT STUDY

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Introduction

Raynaud's phenomenon (RP) is a condition in which the blood supply to the extremities, usually the fingers and toes, is intermittently interrupted. An attack can be triggered by exposure to cold, even from just slight changes in ambient temperature. The affected parts become white, and may turn blue and finally red. There may also be pain, or numbness. RP occurs in approximately 10% of the population. It is often severe when related to other conditions, such as connective tissue diseases (CTD). Traditionally, RP is assessed clinically and based on reported episodic skin colour changes. Specialist centres employ temperature-based measurements to help clinicians to diagnose Raynaud's. Such objective testing, however, is not always reliable since healthy people can have cold hands and feet, without the characteristic episodic skin colour changes ascribed to RP. Since RP is diagnosed on the reported colour changes, it is possible that objective skin colour measurements may aid the assessment process (1). It is interesting to note that in our dedicated microvacular Raynaud's assessment facility the episodic finger colour changes of dark purple, blue, cyan, yellow, orange, red, grey, and white have all been reported by different patients (but never green). Colour changes made by the eye are subjective since they can be influenced by ambient lighting and colour perception (2). The aims of this pilot study were a) to quantify and compare measures of objective skin colour in people without RP to patients having RP secondary to a CTD, and b) to compare measures of objective skin colour with skin temperature.

Method

Measurements were collected by a single operator: 24 healthy Caucasian adult subjects ('non-Raynaud's') recruited from staff working at Freeman Hospital; 24 Caucasian adult patients diagnosed with RP secondary to CTD recruited from Rheumatology clinics at Freeman Hospital. Resting objective skin colour and temperature measurements were measured under normothermic conditions for hand sites including the palm / pads of ring and index fingers on one hand. Measurements were made using a portable reflection spectrophotometer (for 400 'blue' to 700 nm 'red', with percentage reflectance values 10 nm intervals) (Minolta CM-508i) and analogue electronic thermometer (Comark), respectively. The spectrophotometer also determined the Hunter colour space coordinates (i.e., Lab) (L for perceptual lightness, a and b for colours of human vision: opponent pairs of red-green and yellow-blue, respectively). The 95% confidence interval ranges for skin colour data were calculated for the 'non-Raynaud's' group, to which the Raynaud's group was compared (Student's t-test, $p<0.05$ for statistical significance). Skin temperature and colour data were compared using linear regression. If a pa-

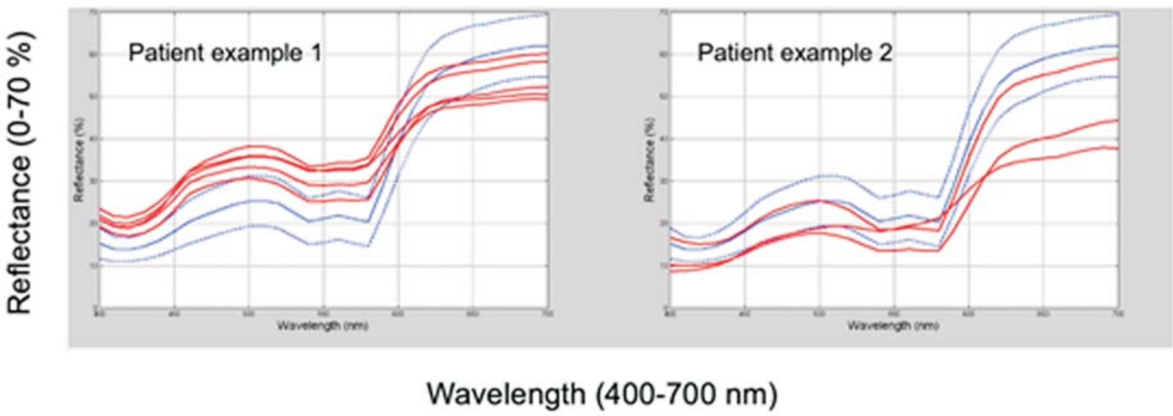

Figure 1
Examples of spectra for RP patients having visible colour changes of some of their fingers at the time of their study, many of their colour traces are beyond the normative range.
Blue lines: normative ranges Red lines: Raynaud´s patient fingers with vissible colour changes

tient had visible finger colour changes during a measurement session then additional exploratory measurements were collected for comparison with the normative ranges of Caucasian skin colour.

Results

There were significant differences in finger temperatures between non-Raynaud's (mean [standard deviation], 31.9 [2.6] °C) and CTD/Raynaud's groups (27.8 [3.2] °C) ($p<0.001$); small but significant differences in reflectance values for 640-700 nm wavelengths only (i.e., relative redness); but no clear associations between skin temperature and colour. Figure 1 shows exemple spectra for 2 CTD/RP patients who had visible finger colour changes at time of testing (red lines), and are compared to our normative reflectance ranges for Caucasian subjects (blue lines), many of these CTD/RP sample traces fall outside the normative range.

Discussion and Summary

CTD/RP group finger temperatures were clearly significantly lower than in the non-RP group, even with one sixth of normals having 'cool' resting finger temperatures (average finger pad temperature <30 °C). For finger skin colour there were small but significant differences in reflectance at the 'redder' wavelengths, although it was interesting that there was no clear relationship with skin temperature overall. Exploratory reflectance plots have illustrated the colour spectra for CTD/RP patients experiencing clear finger colour change episodes, with some traces clearly beyond the normal range at various points. Further work is needed to evaluate the potential added value of spectrophotometry in Raynaud's assessments.

References:

1. Buckley, W.R. & Grum, F. Reflection spectroscopy. Arch Dermatol 1961;83;111-123.

2. Konica Minolta Photo Imaging (UK) Ltd. Precise Colour Communication: Colour control from perception to instrumentation. 1998.

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EXPERIENCE WITH BLOOD SUPPLY VISUALIZATION BY INFRARED THERMOGRAPHY AND INDOCYANINE GREEN FLUORESCENCE IMAGING IN OPEN GASTROINTESTINAL SURGERY

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Introduction

Gastrointestinal surgery is used in the treatment of diseases of body parts involved in digestion. This includes the esophagus, stomach, small intestine, large intestine, and rectum. It also includes the liver, gallbladder, and pancreas [1]. To perform surgical treatment successfully, tissue blood perfusion must be precisely evaluated. An important procedural part of the surgery involves an anastomotic reconstruction, where the visualization of adequate blood perfusion on the free edges of the tissue needs to be verified before suturing the two ends of the tissue. Inadequate perfusion may affect the healing process due to, for example, anastomotic leak. Only a few objective methods for monitoring blood supply of the tissue during surgery treatment are commonly used. The aim of the study is was to integrate non-contact thermography (IRT) as an imaging technique for the detection of tissue blood perfusion during gastrointestinal surgery, in particular during tumor resection and subsequent reconstruction. The IRT method was supported by indocyanine green fluorescence imaging (ICG), which is used as a gold standard method to confirm the blood circulation in tissue.

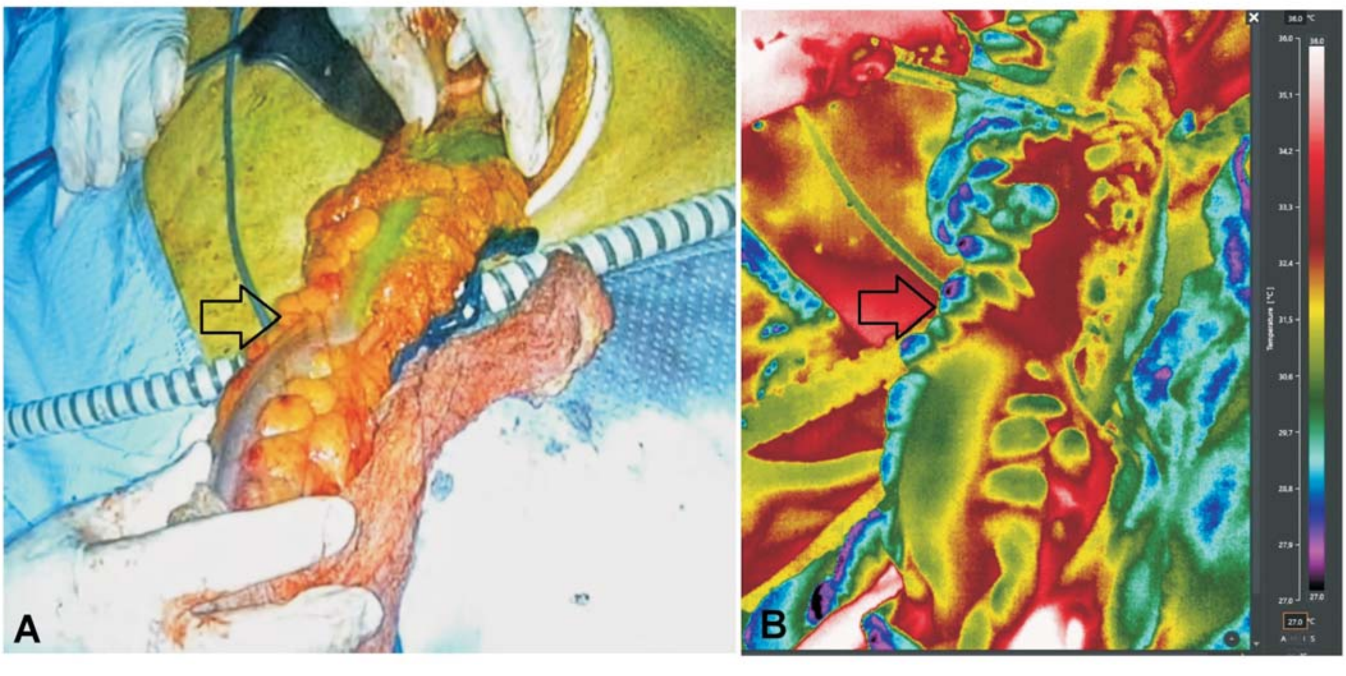
Materials and methods

Infrared images were captured with a Workswell WIC 640 IR camera (resolution 640x512 px, sensitivity 0.03°C /30mK, spectral range 7.5-13.5 μm). ICG images were captured with a near infrared camera. (Novadaq Technologies). For both systems the images were taken simultaneously. The cameras were positioned beside each other at a distance of 0.5 m from the surgical field during open surgery after devascularization of the tissue. Ambient parameters, such as temperature and humidity were recorded. The ischemic part of a specific tissue which could be resected or could not be used for anastomoses were assessed by both diagnostics methods.

Results

First group of 10 patients where both of the imaging methods were performed was indicated for surgery treatment in the resection and reconstruction of large intestine. Second group of 10 patients was indicated for surgery treatment in esophagectomy. Images of both of the groups of patients were qualitatively evaluated as a comparison of images with focus of the temperature different in ROI (IRT) and green color visualization in ROI (ICG) as is shown in Figure 1.

Fig. 1:
ICG (A) and IRT (B) images comparison of the large intestine. An arrow shows resection line.



Discussion

Comparison of both imaging methods was performed during the surgery. The visualization of the blood perfusion was objectively possible by using ICG. This method is very effective as blood circulation is directly visualized using a contrast agent. However, this method is financially demanding and partially invasive due to the use of a contrast agent. Real time evaluation is a huge benefit of both methods. However, the IRT technique, compared to the ICG is noninvasive and cost effective.

Conclusion

Based on the first results and performed records, IRT method may help to visualize blood supply during surgical treatment and may reduce post-operative complications after surgery treatment.

Acknowledgements

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References:

1.Retrieved from https://intermountainhealthcare.org/services/gastroenterology/treatment-and-detection-methods/gastrointestinal-surgery/

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SELECTING DOMINANT PERFORATING BLOOD VESSELS FOR AUTOLOGOUS BREAST RECONSTRUCTION: A COMPARATIVE STUDY USING DYNAMIC INFRARED THERMOGRAPHY, LASER FLUORESCENCE ANGIOGRAPHY OF INDOCYANINE GREEN, ULTRASOUND DOPPLER AND CT ANGIOGRAPHY.

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Introduction

The aim of this study was to compare invasive laser fluorescence angiography of Indocyanine green (LFA-ICG) and computed tomography angiography (CTA) with non-invasive techniques such as dynamic infrared thermography (DIRT) and Ultrasound Doppler for selecting dominant perforators in a DIEP-flap for breast reconstruction.

Methods

Preoperative perforator mapping of the lower abdominal area using CTA and a handheld Doppler Ultrasound was performed in fifteen patients that had been selected for autologous breast reconstruction using the deep inferior epigastric perforator (DIEP) technique. On the day of surgery and under general anesthesia, mapping of perforators in the same abdominal region was carried out using DIRT and LFA-ICG. Their location was classified using a previously published quadrant system. The functionality of the selected perforators was also assessed intraoperatively with DIRT and LFA-ICG. All images were stored for further analysis and post-surgical comparison of the findings using all modalities was made.

Results

From visual assessment of the recorded images, it could be seen that the location the hot spots with surrounding IR radiation using DIRT coincided with the first appearing fluorescence spots and its branching pattern on LFA-ICG and both were closely associated with the location of suitable perforators identified preoperatively and also selected during surgery. While the location of the majority of perforators preoperatively mapped with CTA corresponded with those mapped with DIRT and LFA-ICG, in some cases the thickness of the perforator appearing on CTA could not be related to the intensity of the hot spot assessed with DIRT and the degree of fluorescence pattern with LFA-ICG. Also, preoperative marking on the abdominal wall with Doppler Ultrasound had some degree of inconsistency with patterns of real time perfusion imaging with DIRT and LFA-ICG.

Discussion

The non-invasive DIRT corresponded well with the invasive technique of LFA-ICG for both preoperative perforator mapping and assessment of its quality. Both techniques show clear changes in the perfusion patterns of the skin flaps after perforator dissection. The advantage of DIRT is the continuous visualization of the dynamic activity of a skin perfusion during autologous breast reconstruction, which is short lasting with LFA-ICG.

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USING INFRARED THERMOGRAPHY TO CONFIRM THE CORRECT PLACEMENT OF THE NEEDLE IN THE PERFORMANCE OF LUMBAR SYMPATHETIC BLOCKS FOR COMPLEX REGIONAL PAIN SYNDROME

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Introduction

Complex Regional Pain Syndrome (CRPS) is a chronic rare condition characterized by pain in combination with sensory, trophic and motor abnormalities of the affected limb. It is usually triggered by an injury and can worsen with time. To improve quality of life and function of patients affected by CRPS, achieving pain relief is of paramount importance. However, it remains a major challenge because the syndrome is biomedically multifaceted, comprising both central and peripheral pathophysiology, and frequently it also may involve psychosocial components [1].

Lumbar sympathetic blocks (LSBs) are a therapeutic option in the treatment of pain in patients with CRPS affected lower limbs. Under radioscopic guidance, LSBs are often considered correctly performed when there is radioscopically confirmed contrast dye spread [2]. Even so, the correct placement of the needle is not always ensured. Before administering the medication, a test with lidocaine is performed to produce a vasodilatory effect where a resulting increase in foot skin temperature would confirm correct needle placement. The objective of this study was using infrared thermography to monitor and quantify skin temperature changes to confirm the correct placement of the needle during LBSs.

Methods

46 lumbar sympathetic blocks (LSBs) for the treatment of lower limbs in 12 patients (8 men, 4 women) with CRPS were performed. The lumbar sympathetic ganglia are located on the anterolateral aspect of the lumbar vertebral bodies and when lower extremities are affected, LSBs are performed blocking the lumbar sympathetic ganglia by injecting local anesthetic around the nerves, between lumbar vertebral levels L2 and L4. The technique was guided by fluoroscopy, guiding the needle tip to the anterolateral part of the vertebral body, and aiming for a craniocaudal contrast distribution. Before administering the medication, a test with 2 ml lidocaine 2% was performed, after which infrared images of the feet soles were captured using a thermal camera FLIR E60 (FLIR Systems, Inc., Wilsonvolle, OR) with a spatial resolution of 320 x 240 and thermal resolution of < 50 mK at 30ºC. The camera was mounted on a tripod at distance of 1.5 m from the subjects' feet and perpendicular to them. The emissivity was fixed to 0.98 for skin measurements and the temperature scale was adjusted between 20ºC and 35ºC. When a particular warming thermal pattern (starting as small warmer areas which grow and extend over the sole) in the affected limb within the first five minutes is detected (Figure 1c), the needle placement is considered correct, and the medication is injected. Otherwise, a repositioning manoeuvre should be carried out and the lidocaine test along with the temperature evaluation of the limbs must be repeated. (Figure 1). Number of cases requiring a repositioned manoeuvre using thermal data as a criterion were quantified.

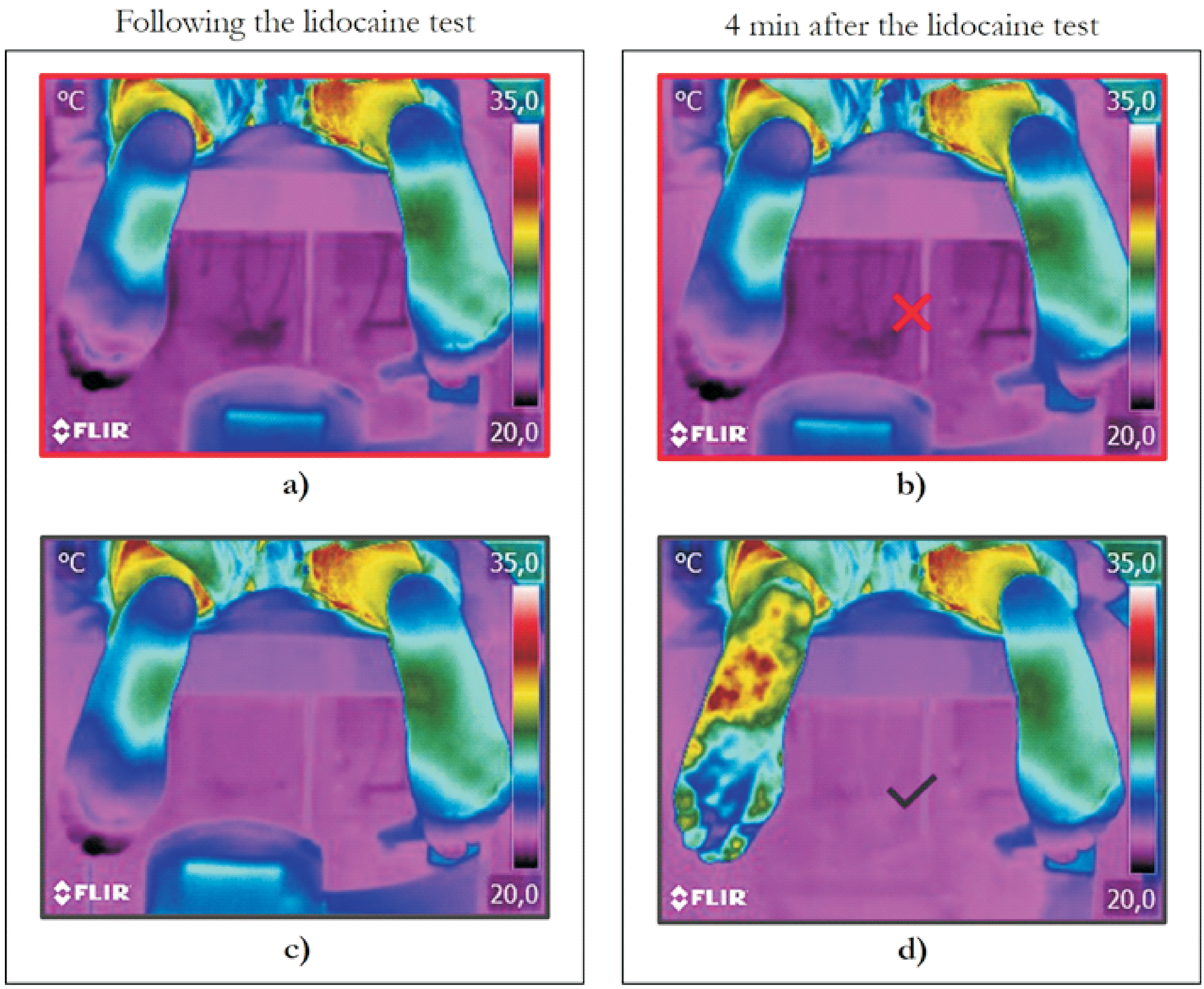
Results

In 80% (24 out of 30) of the LSBs considered correctly performed (with radioscopically confirmed dye spread), thermal pattern changes in the affected limb occurred in the first 4 minutes after injecting the lidocaine test (Figure 1d). However, in 16 out of 46 LSBs, there was no warming thermal pattern within the first 5 minutes after the test (Figure 1b), and therefore a repositioning manoeuvre to achieve the correct collocation of the needle was required. Following the repositioning manoeuvre and the procedure repetition (lidocaine test along with the temperature evaluation), 10 out of 16 BSLs were reassessed as correctly performed, with temperature changes in the affected limb detected.

Conclusion

Lumbar sympathetic blocks (LBSs) are often performed in the treatment of pain in patients with CRPS. However, this technique when only under radioscopic guidance is performed, does not ensure the desired efficacy. Almost 35% of the LSBs performed required the repositioning of the needle because even though there were radioscopically contrast dye spread, no temperature changes in the affected limb were detected. Without the repositioning manoeuvre, the medication injection would have probably resulted in a reduction of the LSBs' clinical efficacy. For this reason, evaluating temperature changes by means of infrared thermography after a lidocaine test during the performance of LSBs to verify the correct placement of the needle has been demonstrated to be of great help in the achievement of better outcomes.

Figure 1
Infrared thermographies taken during the performance of a Lumbar Sympathetic Block just after the lidocaine test (a, c) and four minutes after (b, c). An attempt showing no temperature increase (a,b). Second attempt after needle repositioning (c, d).



References

1.Harden RN, Oaklander AL, Burton AW, Perez RSGM, Richardson K, Swan M, Barthel J, Costa B, Graciosa JR, Bruehl S. Complex regional pain syndrome: Practical diagnostic and treatment guidelines, 4th edition; Pain Medicine 2013; 14(2), 180-229.

2.Gofeld M, Shankar H, Benzon H. Fluoroscopy and Ultrasound-Guided Sympathetic Blocks. In Essentials of Pain Medicine; 2018

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THERMAL IMAGING SIGNS OF SPASTIC FORMS OF CEREBRAL PALSY IN CHILDREN 4-7 YEARS: PRELIMINARY RESULTS

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Introduction

Cerebral palsy (CP) affect on the neuromuscular system is manifested in spasticity, contractures, pain syndromes, muscle weakness, loss of selectivity, impaired postural control, pattern, and impaired standing balance. One of the promising diagnostic methods for motor disorders is the measurement of skin temperature using thermal imaging. The more detailed description of the temperature manifestations of spasticity in CP is still required. There is not enough data on the mechanisms of the formation of pathological thermal patterns with the relation to the degree of movement disorders.

Hypothesis

We assumed that with long-term spastic disorders in the motor sphere characteristic of CP, the IR radiation from the suffering muscle groups will be reduced, and their response to the motor load differs from the reaction of healthy muscles.

The aim was to study the stationary distribution of thermal fields on the body surface and their dynamics after moderate physical activity in children with spastic forms of cerebral palsy.

Methods

The study includes 31 patients with CP and functioning at Gross Motor Function Classification System (GMFCS) levels I or II aged 4-7 years old. CP was identified using ICD-10 codes G80.1 - spastic diplegia (17 children: 12 patients with lower paraparesis, 5 with upper paraparesis), G80.2 - hemiplegic form (14 children). 9 children without disabilities of the same age served as the control group. The study was approved by the local ethics committee of the PIMU (protocol No.4 from 03/29/2017). Informed consent was obtained from parents and/or the legal guardians.

The thermal image was observed by a thermo-tracer (NEC TH-9100) with a temperature resolution of 0.06K. The measurements followed the protocols of thermal imaging studies [1], with our modification of the positions. Our own active infrared thermal mapping technique has been applied [2]. The technique includes the registration of thermal maps of 67 regions of interest (ROIs) on the trunk, upper and lower limbs, and face, before and after the motor load. Standard protocol complex biomechanical testing served as a functional motor load for all groups of children consisted of: 1. Holding a vertical posture on the ST-150 stability platform, the test duration is 60 s. 2. 2 passes along the track of the Tekscan Walkway podographic system, the duration is 2-5 minutes. 3. 2D video analysis of movements on the Simi Reality Motion Systems GmbH motion capture system (2 passes of 3 m on the left and right sides), the test duration is 10-15 minutes. 4. Performing the Nine-hole Peg Test [Smith et al., 2000] with dominant and non-dominant hands, the duration of execution is 5-15 minutes. The time to complete tests 2-4 varied depending on the capabilities of each child. The total time, taking into account pauses for the transition from one task to the next, was 30-45 minutes. The condition was the mandatory completion of each task and a clear sequence of tests.

For data processing and analysis, were used MS Excel 2010, Statisitica 12 software, and RStudio integrated development environment. The type of distribution of the studied parameters was determined by the Shapiro-Wilk test. The level of significance of differences for indicators with a nonparametric distribution was assessed by the Mann-Whitney test (w), for indicators with a normal distribution - by the Student's t-test for unrelated samples (t). The statistically significant p value was set as p?0.05.

Results and discussion

The distribution and dynamics of temperatures on the face and the trunk proved to be uninformative. An analysis of thermal patterns of back revealed a distinction of the diplegia group from the control and the hemiparesis groups in the form of a temperature difference between the thoracic and lumbar regions ?0.5°C; the greater temperature difference, the more severe paresis at the corresponding level.

Absolute temperatures and distal-proximal gradient (DPG) on the limbs. In the control group in all ROIs, thermal maps were typical of children of this age both initially (before the load) and after the load. In the diplegia group, initially, there was a distinctive DPG inversion in the front surface of the lower limbs, namely shin/foot segments with increase in temperature to distal direction, and on the inner surface of the upper limbs in the shoulder/forearm segments. In the hemiparesis group, there are significant differences in initial absolute temperatures on the following ROIs: hemiparesis and the control - the back of the wrists; hemiparesis and diplegia - the back of wrists and the projection of the ankle joints. After the load, there are significant differences in the following ROIs: diplegia and control - the back-inner surface of the shin; hemiparesis and diplegia - the projection of the ankle joints and the back-inner surface of the shin. The dynamics at the stages is useful for evaluating the compensatory muscle resources.

Thermal asymmetry (TA). Both initially and after loading, TA in the control group did not exceed 0.4°C in all segments and in all pairs of symmetrical ROIs. There were no significant differences in TA in the diplegic group from the control group. In the hemiparesis group observed a decrease in temperature on the affected side, emphasized in the projection of the most suffering muscle groups. After the load, an increase in TA was recorded in these patients, while in a number of ROI with initial values within typically normal limits, the compensation was disrupted. The pattern of these changes is promisingly correlated with problem muscles, which is especially important in the demanding conditions of activity and the environment.

Conclusion

Thermal imaging is an objective method for assessing the functional state of the thermoregulatory system, reflecting the degree of motor impairment in the form of deviations from the normal thermal pattern of the skin over affected muscle groups and temperature reactions to moderate dosed motor loads. The study revealed thermal imaging markers of the functional state of spastic muscles determined by the adaptive-compensatory reserves of their blood supply and thermoregulation. Patients with hemiparesis (G80.2) have characteristic TA on the affected side. For diplegia (G80.1), the inversion of normal DPG on the limbs is present. The intensity of thermal anomalies is individual, the general pattern is the decrease in temperature on the affected side at the corresponding level. Moderate motor load enhances thermal anomalies in both groups by further decrease in temperature in the projection of the affected muscles.

Knowledge of the thermal reactions of the skin in the projection of spastic muscles in response to stress tests opens up a potential opportunity for using the method in solving problems such as the selection of target ("key") muscles in botulinum therapy, and in general in assessing the course of treatment and rehabilitation of patients with CP. The search and analysis of thermal imaging signs of normalization of peripheral thermoregulation in the process of rehabilitation is a priority for further research in this direction. To achieve this, it is necessary to strive to increase the sample of patients and to increase the homogeneity of the groups.

References

1. Ammer K. The Glamorgan Protocol for recording and evaluation of thermal images of the human body // Thermology International. 2008; 18(4), 125-129.

2. Volovik M.G., Polevaia S.A. Dynamic Infrared Mapping of Human Skin. 14th Quantitanive InfraRed Thermography Conference (QIRT-2018). Berlin, Germany, June 24-29, 2018. DOI: 10.21611/qirt.2018.p11

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DYNAMICS OF THERMOGRAPHIC AND NEUROLOGICAL DATA IN ASSESSING THE EFFECTIVENESS OF REHABILITATION OF CHILDREN 5-8 YEARS OLD WITH SPASTIC FORMS OF CEREBRAL PALSY

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Introduction

Spasticity is one of the leading clinical symptoms of spastic forms of cerebral palsy (CP), which can also lead to the development of secondary musculoskeletal problems. Thermal imaging has indisputable advantages allowing this technique to occupy its own place among the methods for motor disorders objectifying [1]. Search and analysis of thermal imaging signs of normalization of peripheral thermoregulation - a promising area of research on the effectiveness of rehabilitation of children with CP.

Hypothesis

comparison of the initial status and response to standard motor load before and 1 year after treatment shows the direction of changes and may indicate the effectiveness / ineffectiveness of therapy.

The aim was to search for predictors of a positive rehabilitation prognosis for children with cerebral palsy based on a dynamic study of their thermal imaging characteristics in comparison with a neurological assessment.

Methods

20 children aged 5-8 years with spastic forms of cerebral palsy and functioning at Gross Motor Function Classification System (GMFCS) levels I or II participated in the study. CP was identified using ICD-10 codes G80.1 - diplegia (10 children) and G80.2 - hemiplegia (10 children). The research had first been approved by the local ethics committee of the PIMU (protocol No.4 from 29.03.2017). Informed consent was obtained from parents and/or the legal guardians. Rehabilitation measures were carried out on the basis of the University Clinic of the Federal State Budgetary Educational Institution of Higher Education "PIMU" of the Ministry of Health of Russia in accordance with the Standards for the provision of specialized medical care to children with cerebral palsy of the Russian Federation (rehabilitation phase) [2]. Rehabilitation course included two planned hospitalizations for inpatient treatment per year, as well as outpatient observation of patients. The average duration of hospital stay was 14 days (±4). The average time of outpatient follow-up of patients between hospitalizations is 6 months (±7 days). Treatment included pharmacotherapy (muscle relaxants, botulinum therapy, neurotropic drugs, cholinomimetics, general tonic drugs), physical (exercise) therapy, mechanotherapy, physiotherapy, massage, reflexology. Orthopedic shoes were recommended for 12 patients. A neurologist, a pediatrician, a child psychologist, a physiotherapist, a reflexologist and a massage therapist participated in the rehabilitation process. Consultations of doctors of other specialties were carried out as necessary. Parents were consulted to improve their compliance. Continuous scheduled exercise therapy and massage courses were mandatory for patients between hospitalizations.

To objectify the evaluation points of the determinants, specialized questionnaires and scales were used: GMFCS, MAS (Modified Ashworth Scale for Grading Spasticity), GMFM-88 (Gross Motor Function Measure-88), MACS (Manual Ability Classification System), visual analogue scale (VAS). The thermal image was observed by a thermo-tracer (NEC TH-9100). The measurements were carried out before and 1 year after the start of rehabilitation in accordance with the protocols of thermal imaging studies [3], with our modification of positions. Our own method of active infrared mapping was applied [4]. The technique involves recording thermograms of 67 regions of interest (ROI) on the torso, upper and lower limbs before and after motor load. The standard motor load for all groups of children was biomechanical testing of 4 tasks: 1. Holding a vertical pose on the ST-150 stability platform, the test duration is 60 s. 2. 2 passes along the path of the Tekscan Walkway podographic system, duration 2-5 min. 3. 2 passes of 3 m on the left and right sides on the Simi Reality Motion Systems GmbH motion capture system (2D video analysis of movements), test duration 10-15 min. 4. Performing the Nine-hole Peg Test with dominant and non-dominant hands, test duration 5-15 min. Tests 2-4 varied depending on the child's abilities, the total time was 30-45 min. The condition was the mandatory completion of each task and a clear sequence of tests.

MS Excel 2010, Statistica 12 software, and the RStudio integrated development environment were used for data processing and analysis. The type of distribution of the studied parameters was determined using the Shapiro-Wilk test. The level of significance of differences for indicators with a nonparametric distribution was estimated by the Mann-Whitney test (w), for indicators with a normal distribution - by the Student's t-test for unrelated samples (t). A statistically significant p value was established as p≤0.05.

Results and discussion

The neurologist criteria for classifying improvement/no improvement in the evaluation were developed by us based on [5]. The rehabilitation effect was determined based on the dynamics of domain ratings for the components "functions", "activity and participation" 12 months after the start of rehabilitation activities. The criterion for improvement was considered to be the positive dynamics of the child's condition in at least 3 domains with a change in the score by at least 1 point. 12 months after the rehabilitation measures, according to our proposed criterion for evaluating the effectiveness of medical rehabilitation, improvement was observed in 14 patients with CP.

Thermal imaging assessment. The normal distal-proximal gradient (DPG) on the extremities in children is within the following limits: hip/foot ≥0,5≤3°C with thermal asymmetry (TA) on all three segments of the lower extremities ≤0.8°C; forearm / hand ≥0,5≤2,5°C (TA on all three segments of the upper extremities ≤0.5°C) [6, 7]. Improving the symmetry of the temperature distribution on the extremities is positively correlated with improving the functional characteristics of the body, in particular, the balance function, and is a useful indicator of the effectiveness of rehabilitation interventions [1, 8].

Table 1 demonstrates the comparison of treatment results according to clinical questionnaires and thermal imaging.

The criteria for improving the functional state (group "improvement", 4 patients) were considered the following changes for the second period of the study ("after 1 year of treatment") compared to the first period ("before treatment"): 1) reduction of thermal asymmetry (TA) in the projection of muscles and muscle groups at least at one stage - initially or after exercise (in the hemiparesis group - G80.2), 2) a decrease in the inversion of the DPG on the extremities at least at one stage (in the diplegia group - G80.1).

The group "no tendency" (9 patients) included cases where thermal imaging registered indicators that did not have significant differences from the first stage.

The group "without improvement" (7 patients) included cases of deterioration (registration of an increase in TA and DPG and/or the phenomenon of "multiplication" of pathological signs: the appearance of signs of TA in the group with diplegia, and violation of DPG - in the group with hemiparesis).

Intra-group comparison before and after treatment revealed trends in a number of characteristics, but significant differences in the pre-load stage were found only in two characteristics (Fig. 1 A, B) and in the post-load stage - in one characteristic (Fig. 1 C).

The discrepancy between the results of clinical and thermal imaging analyses can be explained by the use of a large number of rating scales taking into account subjective assessment of contextual parameters of life. The observed temperature dynamics trends before the rehabilitation and after one year of treatment provide objective ground for their proof in subsequent studies.

Table 1
Comparison of treatment results according to clinical questionnaires and thermal imaging.

Patient ID	Diagnosis	Side / Paresis Level *	Improvement (●) / Without improvement (■) / No Tendency (●/■) MAS	GMFCS	Neurologist Report	Thermal Imaging
101	G80.2	Right	■	■	■	■
102	G80.2	Right	■	■	■	■
105	G80.2	Right	●	■	●	●
106	G80.2	Left	■	■	●	●/■
108	G80.2	Right	●	●	●	■
109	G80.2	Right	■	■	■	■
113	G80.2	Right	●	■	●	●/■
118	G80.2	Right	■	■	■	■
120	G80.2	Left	●	■	●	●
124	G80.2	Left	■	■	●	●/■
110	G80.1	Lower limbs	■	■	●	■
111	G80.1	Lower limbs	■	●	●	●/■
115	G80.1	Lower limbs	●	■	●	●
116	G80.1	Lower limbs	●	■	●	●/■
119	G80.1	Upper limbs	■	■	■	●
122	G80.1	Lower limbs	●	■	●	●/■
125	G80.1	Lower limbs	●	●	●	●/■
126	G80.1	Upper limbs	■	■	●	●/■
127	G80.1	Lower limbs	■	■	■	■
128	G80.1	Lower limbs	■	■	●	●/■

*a child with G80.1 (diplegia) can have spasticity in both the lower and the upper limbs. Here the diagnosis was established in limbs where spasticity prevailed before the treatment.
Note: for thermal imaging evaluations, 'without improvement' rather means worsening of metrics.

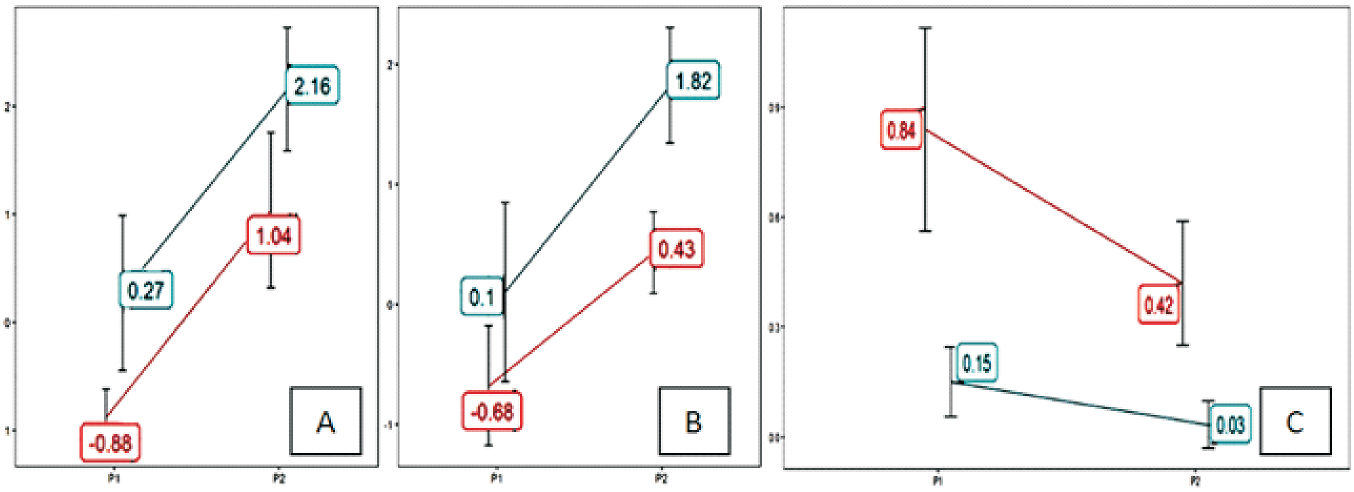

Figure 1.
Dynamics of indicators (deltas - the difference between the stages before and after treatment) by groups and visits with the significance of intra-group differences $p<0.05$: A - hip/foot PDG (left/pathology) before load,
B - hip / foot PDG (right/norm) before load, C - TA (wrist joint, outer surface) after load.
Blue color - diagrams for the group with diplegia, red color-with hemiparesis.
P1 - visit before treatment, P2 - visit after 1 year of treatment.

Conclusion: The possibilities of thermal imaging as a method for assessing motor disorders in children with spastic forms of cerebral palsy, which has the potential to create a reliable, convenient, non-invasive and high-precision method for monitoring the course of rehabilitation, are demonstrated. Increasing the sample size and further data analysis open up prospects for clarifying the objectification of neurological practice and improving the accuracy of the prognosis of the disease, as well as correcting complex rehabilitation programs for this pathology.

References

1. Zanona A. de Freitas, de Souza R.F., Aidar F.J. Use of virtual rehabilitation to improve the symmetry of body temperature, balance, and functionality of patients with stroke sequelae. Ann Neursci 2018 ; 25(3):167-174.

2. Standard for specialized medical care for infantile cerebral palsy (phase of medical rehabilitation). Appendix to the Order of the Ministry of Health of the Russian Federation of June 16, 2015, N 349n.

3. Ammer K. The Glamorgan Protocol for recording and evaluation of thermal images of the human body . Thermology International. 2008; 18(4), 125-129.

4. Volovik M.G., Polevaia S.A. Dynamic Infrared Mapping of Human Skin. 14th Quantitanive InfraRed Thermography Conference (QIRT-2018). Berlin, Germany, June 24-29, 2018. DOI: 10.21611/qirt.2018.p11

5. Sheiko G.E., Belova A.N., Kuznetsov A.N. et al. Application of the International Classification of Functioning, Disability and Health (Children and Youth Version) in the evaluation of rehabilitation Measures of Patients with Cerebral Palsy. Vestnik Vosstanovitelnoy Meditsiny. 2020;5(99):38-45. 5 [in Russian]

6. Dragun V.L., Filatov S.A. Computational thermography. Application in medicine. Minsk: Navuka I Tekhnika, 1992. 232 p. [in Russian]

7. Kolosovas-Machuca S., González F.J. Distribution of skin temperature in Mexican children.Skin Res Technol. 2011; 17(3): 326-331.

8. Karaszewski B., Carpenter T.K., Thomas R.G.R. et al. Relationships between brain and body temperature, clinical and imaging outcomes after ischemic stroke // J Cerebral Blood Flow Metabol. 2013;33:1083-1089.

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COMFORT, THERMAL STRESS, AND CLOTHING

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In this talk I will provide an overview of the use of infra-red thermal imaging as a tool in our laboratory's studies on thermoregulation, thermal strain, sports performance, thermal comfort, and clothing.

In our studies we looked at various aspects of heat exchange with the environment, and a core topic in our work is 'body mapping'. When we started this work, most studies only considered the person as a unit, e.g., looking at whole body sweat rates, mean skin temperatures, whole body comfort. Initiated by our interest in clothing, we worked with several sports clothing companies to investigate heat exchanges, sweat rates and temperatures at a regional level across the body with the intention to provide a more detailed physiological bases on heat transfer distribution across the body with the aim of improving clothing design.

This led to several applied and basic research studies on body sweat mapping, but in parallel we also looked at regional body surface temperature mapping and the interlink between the two. Starting with PhD projects looking at skin temperatures during cold exposures [1, 2], other projects created body sweat maps and associated temperature maps for young male and female athletes [3], older people [4], and pre and post pubertal children [5]. Also, we investigated possibilities to detect moisture absorbed by clothing through thermal imaging [6]. More recently, we looked at temperature mapping of exposed skin during competition events (Doha world championships athletics), where movement artefacts and unstable environments complicate the data collection.

In this talk I will touch on the techniques used and consider issues with the use of infra-red cameras for such measurements. Further I will show how the information obtained can inform clothing design and provide insights into thermoregulatory control.

References

1. Fournet D, Redortier B, Havenith G. A Method for Whole-Body Skin Temperature Mapping in Humans. Thermology International 2012, 22(4), 157-159.

2. Fournet D, Griggs K, Redortier B, Havenith G. Sex differences in thermal strain induced by a typical hiking scenario in a cool environment. In: CotterJD, Lucas SJE, Mundel T, eds, Environmental Ergonomics XV. International Society for Environmental Ergonomics. 2013, pp. 200-201.

3.H avenith G, Fogarty A, Bartlett R, Smith C, Ventenat V. Male and female upper body sweat distribution during running measured with technical absorbents. European Journal of Applied Physiology 2008; 104:245-255.

4. Coull NA, West AM, Hodder SG, Wheeler P, Havenith G. Body mapping of regional sweat distribution in young and older males. European Journal of Applied Physiology 2021, 121: 09-125

5. Arlegui L, Smallcombe JW, Fournet D, Tolfrey K, Havenith G. Body mapping of sweating patterns of pre-pubertal children during intermittent exercise in a warm environment, submitted to Eur. J. Appl. Physiol., 2021.

6. Raccuglia M, Heyde C, Lloyd A. Hodder S, Havenith G. The use of infrared thermal imaging to measure spatial and temporal sweat retention in clothing. Int J Biometeorol 2019; 63, 885-894

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INFLUENCE OF TWO DIFFERENT MILITARY COMBAT JACKETS ON FACE TEMPERATURE

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Introduction

Military uniform properties can influence the body's mechanisms of homeostasis and thermoregulation. Physical exercise in thermally challenging environments can lead to physiological disturbances that may compromise the performance and increase the risk of heat illness. The aim of this study was to compare the face's skin temperature (TskF) after a walking test, using two different types of combat jackets.

Methods

39 male militaries from Physical Education College of Brazilian Army (27.42±2.38 years old) were assessed in three sessions, with an interval of 48 to 72 hrs. In the first session, body composition was recorded using DXA (double X-ray absorptiometry). During the second and third sessions, Tsk_F of militaries was registered using an infrared camera E75 FLIR under thermoneutral environment (Temperature 22.7 ± 3.8ºC; Humidity 55.5 ± 5.5%) in the same position (sitting and wearing only swimming trunks): (a) after a 15' acclimatization for recording baseline Tsk (PRE Tsk_F); (b) after walking 20' on a treadmill at 6 km/h with complete uniform weighting 20 kg. (ballistic vest, helmet, 15kg backpack, jacket, pants, soaks and boots), wearing randomly the Traditional Combat Jacket (TCJ) and the Light Combat Jacket (LCJ), for recording post-exercise Tsk (POST Tsk_F); (c) after 15' of passive recovery for recovery Tsk (POST-15 Tsk_F). In the chest area, the LCJ is made of 100% polyester, while the TCJ is made of 67% polyester and 33% cotton. Tsk_F were collected using the Delphi study recommendations and the images were processed using FLIR Tools software (Figure 1). The data were analyzed by SPSS® 25.0 for Windows, running a repeated measures ANOVA with two factors (time and jackets) using the Bonferroni test for multiple comparison setting the significance level at $\alpha = 0.05$.

Results

The mean results indicate significant differences for the time ($F_{(2,164)} = 98.838$, $p < .001$, $\eta^2 = 0.547$), and lack of differences for the jackets ($F_{(1,82)} = 0.002$, $p = 0.962$, $\eta^2 < 0.001$) or the interaction of time and jackets ($F_{(2,164)} = 1.189$, $p = 0.305$, $\eta^2 = 0{,}014$). Similar results were obtained for maximum TskF with significant differences only for time ($F_{(2,164)} = 23.509$, $p < .001$, $\eta^2 = 0.223$). Both in maximum and mean values (Table 1), it can be observed that Fsk_F significantly decreases ($p < 0.05$) after walking 20' completely uniformed at 6 km/h without significant differences for the type of jacket ($p > 0.05$).

Conclusion

A 20' walking with the whole equipment promotes a significant descent of the face skin temperature of the militaries, turning back to baseline levels after a 15' recovery. There was no association between the course of facial temperature and the type of jackets studied in the military volun-

Figure 1.
Example of the processed images using FLIR Tools

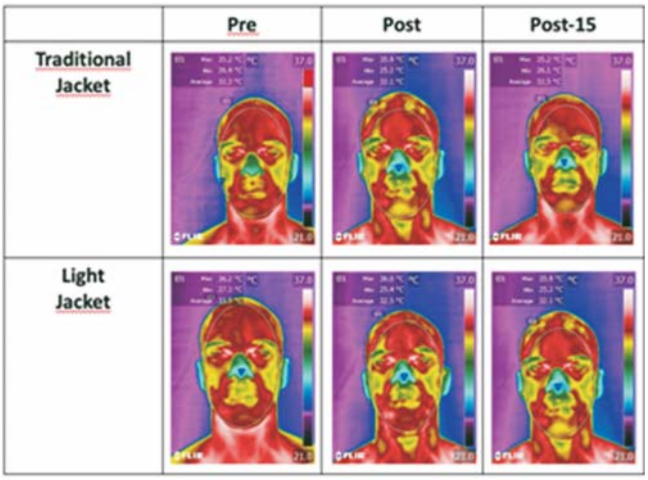

Table 1
Descriptive statistics (mean and standard deviation) of the mean and max for PRE TskF, POST Tsk_F and POST-15 Tsk_F wearing the two types of clothing (Traditional and Light Jacket). Data in ºC.

	TIME	Traditional Jacket (n = 42)	Light Jacket (n = 42)
		M ± SD	*M ± SD*
Mean Tsk_F	PRE	33.1 ± 0.7	33.0 ± 0.7
	POST	32.1 ± 0.7	32.1 ± 0.9
	POST-15	33.0 ± 0.7	33.1 ± 0.8
Maximun Tsk_F	PRE	35.9 ± 0.5	35.7 ± 0.4
	POST	35.5 ± 0.4	35.5 ± 0.5
	POST-15	35.8 ± 0.5	35.7 ± 0.4

teers. Future research with long distance simulated military march, overweight equipment and different environment should be carried out.

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References

Da Silva W, Machado ÁS, Souza MA, Kunzler MR, Priego-Quesada JI, Carpes, FP. Can exercise-induced muscle damage be related to changes in skin temperature? Physiological measurement, 2018; 39(10), 104007.

Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJ, Costa CMA et al. Thermographic imaging in sports and exercise medicine: A Delphi study and consensus statement on the measurement of human skin temperature. Journal of Thermal Biology 2017. 69: 155-162

Viegas F, Mello MTD, Rodrigues SA, Costa CMA, Freitas LDSN, Rodrigues EL, Silva A. The use of thermography and its control variables: a systematic review. Revista Brasileira de Medicina do Esporte 2020, 26(1), 82-86.

Wilusz E. Military Textiles. Cambrigde: Woodhead Publishing Limited, 2008.

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APPLICATION OF DYNAMIC THERMOGRAPHY AFTER A FATIGUING STRENGTH EXERCISE

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Introduction

Dynamic thermography allows analyzing the vascular thermoregulatory response after applying thermal stress (cold or heat) to the skin to alter deeper structures. Although its application is extended in investigations in medical field, its use in sport science is anecdotic. In this sense, it was observed that the use of dynamic thermography is interesting to assess the effect of muscle damage after a marathon [1]. Higher reduction of skin temperature after the application of a cold stress was observed 24 hours after a marathon [1]. However, it is unknown if strength exercise could result in an acute effect of the thermal response after a cold stress.

Objective

To assess changes in anterior thigh skin temperature in response to a cold stress test after a strength exercise fatiguing protocol. We hypothesize that strength exercise can alter skin vascular thermoregulatory response, which may alter the rewarming process after the application of cooling stress.

Material and methods

21 physically active adults (15 males and 6 females; age 27 ± 4; height 173 ±13 cm; body mass 67 ± 11 kg) performed a familiarization session and two strength exercise sessions one with dominant and the other with non-dominant leg (previously randomized), separated by one week. Participants performed bouts of 10 concentric and eccentric contractions of leg extension with 1' rest at 120°/s in an isokinetic device until reaching around a 30% of force loss. Infrared thermographic images (Flir E60bx, Flir Systems Inc.) were taken the familiarization day (basal condition) and after the fatigue level from both thighs, before and after being cooled using a cryotherapy system (GameReady GRPro 2.1; CoolSystems Inc) during 3 min (Temperature: 0-3°C; pressure: moderate). Infrared camera was located 1 m away from the participant, with the lens parallel to the thigh. Emissivity was set at 0.98. TISEM checklist was used to avoid internal or external factors that may affect thermal assessment. ROIs included vastus medialis, rectus femoris, adductor and vastus lateralis (Fig 1), obtaining their mean temperature values (ThermaCAM™ Researcher Pro 2.10, FLIR Systems AB, Sweden). Skin temperature rewarming was assessed before cooling, 15, 30, 45, 60, 90, 120, 150 & 180 s after the cooling process. Tests were performed in a 23 ±1.08 °C room. Logarithmic equations of each ROI, leg and condition were adjusted and slope and constant coefficients were obtained. For each slope and constant coefficients, a repeated-measures ANOVA was made relating each ROI and condition (basal, intervention, control). As a post-hoc a Bonferroni correction was made, stablishing a level of signification of 0.05. Cohen effect size (ES) for pair-comparisons was also calculated.

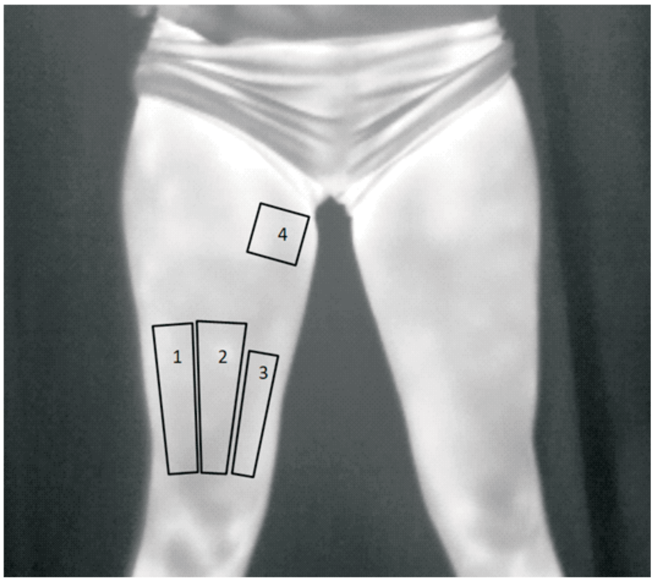

Figure 1
ROI used for the analysis: 1: vastus lateralis; 2: rectus femoris; 3: vastus medialis; 4: adductor.

Results

Skin temperature before cooling were similar in all the conditions ($p>0.05$; e.g., data vastus lateralis: Intervention 32.3 ± 1.2ºC vs. Control 31.6 ± 0.9ºC). Table 1 shows the coefficients of the logarithmic equations obtained. Intervention leg presented higher slope coefficients than basal condition in vastus lateralis (ES=0.96; $p=0.04$), rectus femoris (ES=0.95; $p=0.00$) and adductor (ES=0.92; $p=0.01$) while

Table 1
Coefficients of the logarithmic equation obtained for vastus lateralis (VL), rectus femoris (RF), adductor (ADD) and vastus medialis (VM) in basal, intervention and control lower limb. Results are showed in mean ± standard deviation.

	Skin temperature variation = Constant + Slope * ln (time after the cold stress test in seconds)		
	Constant		
	Basal	Control	Intervention
VL	-4.7 ± 2.21	-6.47 ± 3.35	-7.97 ± 4.63
RF	-5.58 ± 3.70	-6.97 ± 3.57	-9.06 ± 3.63
ADD	-5.30 ± 4.05	-7.10 ± 2.74	-8.79 ± 3.56
VM	-6.18 ± 3.31	-6.96 ± 3.22	—8.47 ± 4.21
	Slope		
	Basal	Control	Intervention
VL	0.78 ± 0.35	0.78 ± 0.35	1.05 ± 0.49
RF	0.76 ± 0.38	0.76 ± 0.38	1.09 ± 0.41
ADD	0.83 ± 0.35	0.83 ± 0.35	1.10 ± 0.40
VM	0.86 ± 0.33	0.86 ± 0.33	1.05 ± 0.54

constant coefficients showed differences only in vastus lateralis (ES=0.64; p=0.03) and rectus femoris (ES=0.84; p=0.01). Intervention leg presented higher slope (ES=0.84; 0.00) and constant (ES=0.58; p=0.01) coefficients in rectus femoris than in control leg, meanwhile no differences were observed in the other ROIs analyzed. No differences were observed in slope nor in constant when comparing basal and control conditions for all the ROIs studied.

Discussion

The lack of changes in constant coefficient may indicate that the peripheral vascular thermoregulatory response is not altered, but the greater slope coefficient could mean that the muscle is warmer and therefore the heat transfer to the skin is faster [2]. However, it is important to clarify that we have measured skin temperature in regions over muscles, but of course not muscle temperature. This result encourages further investigation about the use of cold stress test to assess athlete's fatigue state.

Conclusion

Strength loss in anterior thigh resulted in an increment of slope coefficients in the rewarming process after cold stress test.

References

1.Priego-Quesada, J.; Pérez-Guarner, A; Gandia-Soriano, A; et al. Effect of a marathon on skin temperature response after a cold-stress test and its relationship with perceptive, performance, and oxidative-stress biomarkers; 2020. 15(10);. 1467-75.

2.Percival JM. nNOS regulation of skeletal muscle fatigue and exercise performance . Vol. 3, Biophysical Reviews. Springer Verlag; 2011

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ATHLETES' FACE TEMPERATURE RESPONSE DURING AN ENDURANCE TRIATHLON RACE

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Introduction

The physiological responses of the human body during a triathlon race can vary according to the sports' modality disciplines or individual's physical condition [1]. Understanding the different moments of a combined race and its skin temperature variation may increase the chances of avoiding an athlete's thermal imbalance [2,3,4]. As the type of clothing used in distinct modalities (swimming, cycling, and running) compromise the exposed skin area, the temperature of face was the selected region of interest due to strong correlation with the core temperature4. So, the aim of this study was to compare the face skin temperature (TskF) responses of triathlon athletes during an Olympic simulated race.

Methods

The sample consists of 22 experienced triathlon athletes (19 male and 3 female), 29.73 ± 6.58 years old, 173.6 ± 6.9 cm and 71.1 ± 7.7 kg, members of the Armed Forces team who volunteered for this study. The evaluation occurred in four moments during a simulated Olympic distance (swimming 1.5 km, cycling 40 km and running 10 km) triathlon race: (M1) pre-swimming, (M2) post-swimming, (M3) post-cycling and (M4) post-race. Swimming was performed in open water with a temperature of 20.9° C, in two laps of 750 meters. Cycling was performed outdoor in athletics track on the static roller and running performing 25 laps on a 400m athletics track. Free hydration and colling off. The ambient temperature was 26,6 ± 0,7°C and relative ambient humidity 64 ± 6%. The TskF evaluation was with E75 FLIR® infrared camera and the data collection occurred outdoor, in the competition environment, in a closed tent with a dark background. M2, M3 and M4 evaluations were performed immediately after each completed stage, without acclimatization and rest. The TskF were collected using the Delphi study [5] recommendations and the images were processed using FLIR Tools software (Figure 1) and data analyzed by SPSS®. Descriptive statistics and Friedman's test were used with Dunn post-hoc and significant level of p< 0.05.

Table1
Face's skin temperature during Olympic simulated triathlon race

Moments	Median [Minimum - Maximum]	Median [Minimum - Maximum]	p-value
M1 x M2	33.9 [31.2-35.8]	30.4 [27.2-34.7]	0.002*
M1 x M3	33.9 [31.2-35.8]	33.6 [30.6-35.9]	0.107
M1 x M4	33.9 [31.2-35.8]	34.9 [31.2-36.1]	0.052
M2 x M3	30.4 [27.2-34.7]	33.6 [30.6-35.9]	0.001*
M2 x M4	30.4 [27.2-34.7]	34.4 [31.2-36.1]	0.001*
M3 x M4	33.6 [30.6-35.9]	34.4 [31.2-36.1]	0.016*

Legend: *significant level (p<0.05). Values in °Celsius

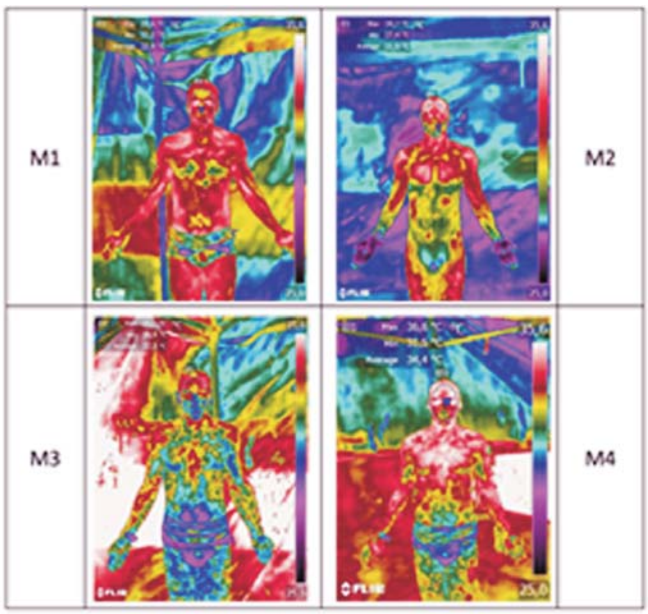

Figure **1.**
Example of the processed outdoor images using FLIR Tools.
Legend: (M1) pre-swimming, (M2) post-swimming, (M3) post-cycling and (M4) post-race.

Results

Tsk in triathlon athletes showed differences in all variables related to swimming (Table 1), which suggests a face skin temperature reduction influenced by water temperature (Figure 2). A significant difference was observed between cycling and running phases (p=0.016), suggesting that the speed of travel in cycling favors thermoregulation by convection in relation to the ambient air.

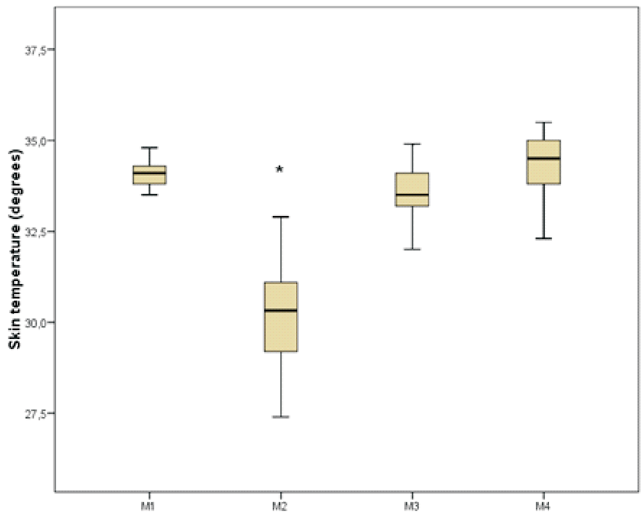

Figure 2
Athlete's face's skin temperature response during a simulated triathlon race.
Legend: * $p<0.05$ M2 vs. M1, M3 and M4. Values in °Celsius.

Conclusion

It can be concluded that the triathlon athletes finish the swimming phase with a significantly lower face temperature than in the other phases of the race. The external environment (sun, wind, air temperature and ambient humidity) and behaviours (cooling off with water, opening the jacket, removing t-shirt) could interfered the heat exchange process and influenced the thermoregulation process of the triathlon athletes. So, for future research it must be controlled in addition to the environmental variables, the athletes' behaviors during the race.

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References

1.Mello D. et al. Acute physiological responses during a Brazilian endurance triathlon race. Motricidade, 2020, 16 (4) 411-419.

2.Figueiredo P, Marques EA, Lepers R. Changes in contributions of swimming, cycling, and running performances on overall triathlon performance over a 26-year period. Journal of Strength and Conditioning Research, 2016, 30(9) 2406-2415.

3.Priego-Quesada JI. et al. A preliminary investigation about the observation of regional skin temperatures following cumulative training loads in triathletes during training camp. Journal of Thermal Biology 2019, 84: 431-438,

4.Kim J-H et al. Intersegmental differences in facial warmth sensitivity during rest, passive heat and exercise. International Journal of Hyperthermia, 2019; 36(1) 653-658.

5.Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJE, Costa CMA et al. Thermographic imaging in sports and exercise medicine: A Delphi study and consensus statement on the measurement of human skin temperature. Journal of Thermal Biology 2017; 69: 155-162.

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EVALUATING THE APPLICATION OF INFRA-RED THERMOGRAPHY TO THE MEASUREMENT OF SKIN TEMPERATURE DURING ROAD-RACE COMPETITION

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Introduction

Skin temperature is a critical component of the human thermoregulatory system and its measurement is common in clinical and research fields. Although contact methods are advocated for laboratory testing, limitations for use in field-based research during exercise include, wired tools restricting movement, small surface area of measurement [1] and interference of the contact method and fixation method with heat exchange [2]. Infra-red thermography (IRT) provides a non-contact, portable method, of particular interest for measurement during exercise. However, to date it has mainly been used as a between or post-exercise measure and has not been evaluated for measurement during real outdoor competition. Guidelines for the standardization of IRT analysis have been proposed [3,4,5], including stable conditions, fixed position of participants and dried skin. However, the impact of the inability to standardise, is not clear. Therefore, the aim of the study was to compare skin temperatures measured by two different cameras on moving athletes in current competitive race conditions. Secondly, to investigate which factors, required for the calculation of the correct temperatures in the images, during analysis impact results.

Methods

Infra-red video was collected every 1km roadside by two thermal cameras; by a cooled indium antimonide camera (FLIR A6750sc MWIR, FLIR Systems, West Malling, Kent) and an uncooled microbolometer camera (FLIR T1030sc) during the Women's 20km racewalk, at the 2019 World Athletics Championships, Doha. Video images were analysed using FLIR Research IR Software. Regions of interest (ROIs) covering all nude body parts were selected based on anatomical landmarks, accounting for an edge effect; this was performed for 18 athletes, every 5km. This included the upper and lower arms, torso and upper and lower legs from the anterior, lateral and posterior perspectives. Additionally, the anterior face and neck and lateral hands were collected. For weighted nude mean skin temperature all ROIs were weighted, separately for each aspect, based on the mean number of pixels contained in the ROI. As the distance from the camera varied between aspects (anterior, lateral, posterior) the pixels represent different surface areas in each. Hence the three aspects were weighted by calculating the surface area of each (by taking a known area (the height of the person) and measuring the number of pixels the height of the person was from each perspective). Cameras were compared by quality of images and the technical determinants of their ability to capture motion, based on the average speed of movement of athletes. Absolute skin temperatures were compared between cameras by Bland-Altman analysis. The skin temperatures recorded were compared for ROIs of a whole body-area and a single pixel by Bland-Altman, for both a centrally placed pixel and the hottest and coldest pixel within the body area. The impact of missing data was investigated by comparing a surface area weighted mean skin temperature, with each ROI removed and by combinations of multiple sites removed. The weighting of missing sites was distributed across all other sites. The sensitivity (the smallest absolute amount of change that can be detected by a measurement) of the software to each input parameter was identified, for each camera at the respective emissivity. Data are bias ± standard deviation, unless stated.

Findings

The mean environmental conditions across the race were 31.6±0.7°C air temperature, 76±2.8% relative humidity, <1m s^{-1} air velocity. Figure 1 shows example images collected on the cooled and uncooled cameras; the cooled providing sharp, reliable imaging, whereas blurring was a problem with the uncooled camera, mostly when athletes moved laterally through the field of view. ROIs of selected sharp images analysed on both cameras, showed a mean bias of -0.5 ± 1.0°C for the cooled camera vs. the uncooled camera (skin emissivity 0.91 vs. 0.98). Investigating thermograms collected with the cooled camera; the size of the ROI influenced the temperature recorded; with a reduction in size of the ROI increasing the difference. Compared to an ROI covering the whole calf or thigh (mean of 479 and 702 pixels respectively), an ROI of a single, centrally placed pixel produced a bias of 0.3°C, increasing up to ±1.3°C, when this was the maximum or minimum temperature pixel. A straight line vertically through the center of the area, on average recorded the most similar temperatures, but had the biggest deviation of single values (±1°C).

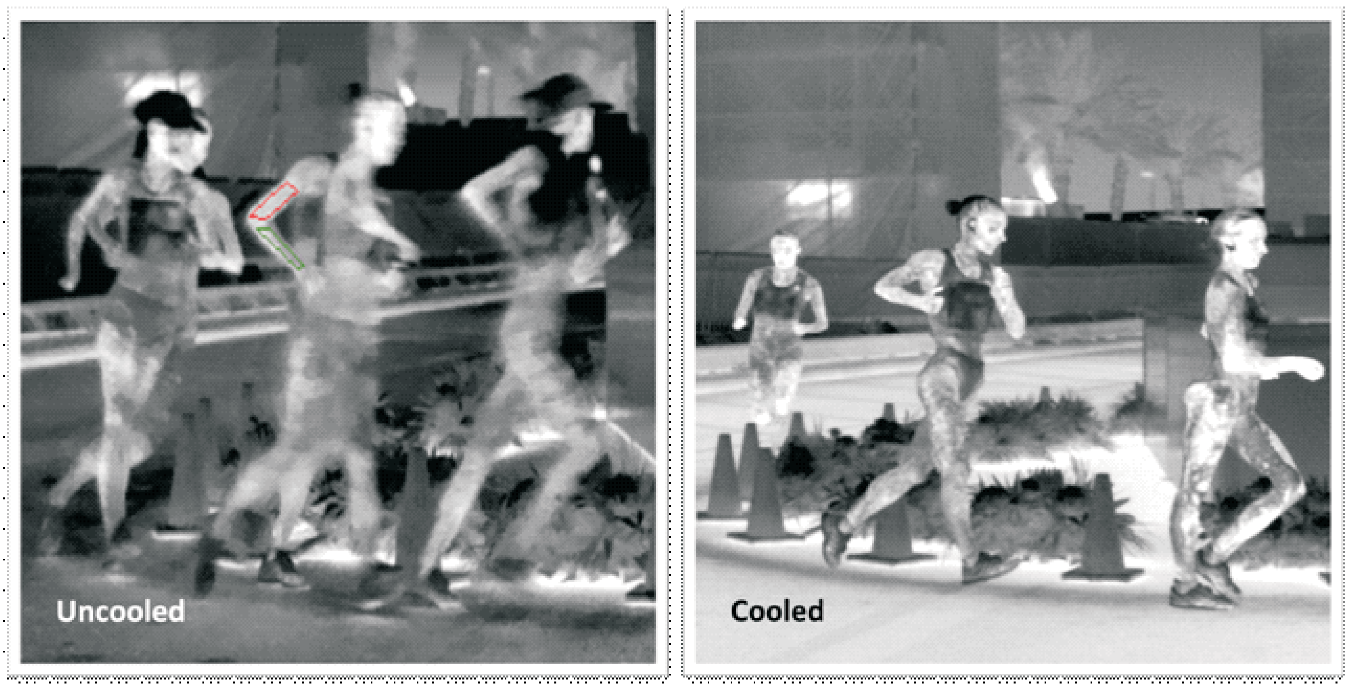
Although a 0.98 emissivity is commonly utilized, this is not the most appropriate value for skin within the wavelength range measured by the MWIR camera. In this band 0.91 emissivity is more appropriate [6, and personal communication with Raphael Danjoux, FLIR Systems]. A suggested emissivity of 0.91, for skin in the 3-5μm wavelength range, changed skin temperature readings by 0.07°C per 1°C difference between reflected and skin temperature, from the 0.98 emissivity value.

Sensitivity of the calculated skin temperature values to air and reflected tempertures increased as emissivity lowered. The sensitivity of the calculated skin temperature values to ambient relative humidity was dependent on air temperature and along with distance was small compared to the emissvity, air and reflected temperatures impacts. ROIs were removed from the mean skin temperature calculation, to assess whether missing sites are important for the mean skin temperature value, as collecting all sites cannot be guaranteed when the images cannot be standardised. Each ROI was removed individually and in combinations of sites from the mean skin temperature calculation. Individually only removing the thigh from the calculation had an effect greater than ±0.1°C, however, once three or more sites were missing this changed the mean skin temperature values by ≥0.4°C.

Conclusions

IRT can be used for measurement of skin temperature of moving athletes, valuable for thermophysiological research. Preferentially a cooled indium antimonide camera would be utilised, due to the minimal movement artefact effect. However, an uncooled microbolometer camera can provide a reasonable alternative, where the rate of motion is slow enough not to influence results. The inability to provide the same standardisation to imaging in the field, is an important consideration and its impact on results should be investigated; as we have shown the importance of the method for ROI selection, selecting the emissivity and setting the correct reflected and air temperatures.

Figure 1
Representative images taken from an uncooled microbolometer camera and a cooled indium antimonide camera, of moving athletes during the Women's 20km Racewalk, 2019 IAAF World Athletics Championships, Doha.



References

1. Harper-Smith A, Crabtree D, Bilzon J, Walsh N.The validity of wireless iButtons® and thermistors for human skin temperature measurement. Physiol Meas 2010, 31:95-114.

2. Tyler CJ. The effect of skin thermistor fixation method on weighted mean skin temperature. Physiol. Meas. 2011; 32: 1541-1547

3. Fernández-Cuevas I, Carlos J, Marins B, et al. Classification of factors influencing the use of infrared thermography in humans: A review. Infrared Phys Technol 2015; 71:28-55.

4. Ring EFJ, Ammer K The technique of infrared imaging in medicine. In: Infrared Imaging: A Casebook in Clinical Medicine. IOP Publishing Ltd, 2015, pp 1-10

5. Moreira DG, Costello JT, Brito CJ et al.Thermographic imaging in sports and exercise medicine: a Delphi study and consensus statement on the measurement of human skin temperature. J Therm Biol 2017, 69:155-162

6.Gaussorgues G. Infrared Thermography. Chapman and Hall, London 1994

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THERMORECOVERY PROJECT: EFFECT OF A 10KM RUN ON SKIN TEMPERATURE AND THERMAL PARAMETERS AFTER A COLD-STRESS TEST IN THE SUBSEQUENT 24H

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Introduction

Skin temperature 24h after exercise was previously assessed to relate its response with muscle damage and physiological stress [1-2]. However, these studies have not observed any response of the skin temperature 24 or 48h after an exercise that causes muscle damage, suggesting that there is skin vasoconstriction that does not allow to observe any results [1-2]. However, although the literature is extensive analyzing skin temperature response 24h after exercise, there is a lack of studies that monitored skin temperature in different moments of the subsequent 24h after exercise. Thus, exploring whether a temperature peak occurs before 24 hours is of interest for this type of practical application. Finally, although the cold-stress test's application helps to analyze numerous pathologies' vascularization, its use in sports science is scarce [2]. The objective of this study was to assess the effect of a 10km run on skin temperature and thermal parameters after a cold-stress test in the subsequent 24h.

Methods

Thirty physically active participants volunteered to participate in the study: 15 in the control group (5 females), 15 in the experimental group (6 females), age 36 ±7 years, height 172 ±7 cm, body mass 72.7 ±11.6 kg, and body fat percentage 20.0 ±8.2%. The experimental group ran 10 km at a competitive pace and performed two sets of 5 repetitions of 10m sprints. The Control group did not perform any exercise.

Skin temperature of the lower limbs was measured 10 min after rested in a standing position using a FLIR E60bx camera before exercise, immediately after exercise only for the experimental group, and 2 h, 5 h, 11 h, and 24 h after the run. Moreover, the cold-stress test was performed using a cryotherapy system (GameReady GRPro 2.1) for 3 min (Temperature: 0-3°C; pressure: moderate), and images were obtained 30, 60, 120, and 180s after cooling.

Environmental conditions at the different measurement moments were: Pre (19.6 ±1.9°C room temperature and 37 ±3% of relative humidity), Post (19.6 ±1.6°C and 37 ±1%), Post2h (19.8 ±1.9°C and 36 ±3%), Post5h (19.9 ±2.1°C and 36 ±4%), Post11h (20.1 ±1.0°C and 38 ±2%) and Post24h (19.4 ±2.3°C and 39 ±4%). Mean skin temperature was obtained in the following Regions of Interest

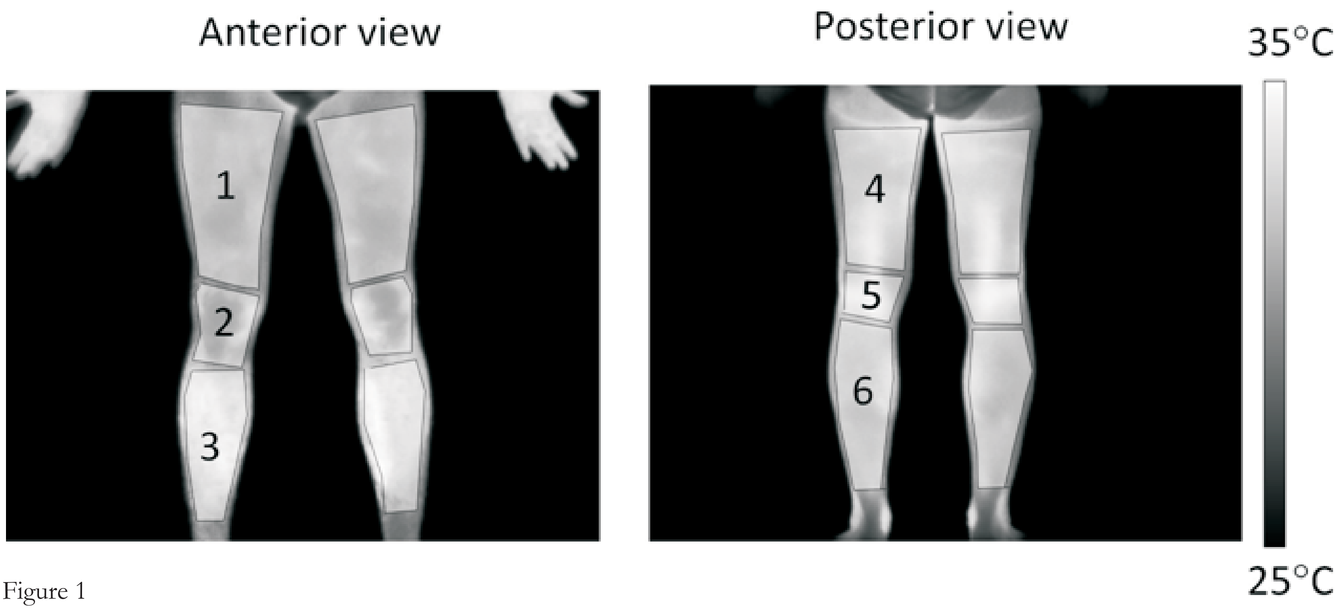


Figure 1
Regions of interest assessed: 1. Anterior thigh, 2. Knee, 3. Anterior leg, 4. Posterior thigh, 5. Posterior knee, 6. Posterior leg.

(ROI): anterior thigh, knee, anterior leg, posterior thigh, posterior knee, and posterior leg (Figure 1), using an emissivity of 0.98. For rest measurements, skin temperature variation (?T) was calculated as the difference of each moment with the measurement before exercise. For data after cooling, each ROI's logarithmic equations were calculated, and slope and constant coefficients were obtained. Differences between measurement moments and groups were assessed using repeated-measures ANOVA with Bonferroni post-hoc. Cohen effect size for pair-comparisons was also calculated and classified as small (0.2-0.5), moderate (0.5-0.8), or large (>0.8).

Results

Except in the posterior and anterior thigh, the experimental group presented higher ΔT during the subsequent 24 h after running (Figure 2), with the higher differences at 5h and 11h after running (e.g., posterior leg, Post5h 0.2 ±0.7 vs. 0.9 ±1.0ºC, IC95% of the differences between groups [0.2, 1.1ºC] and Post11h 0.2 ±0.6 vs. 1.1 ±0.7ºC, IC95%[0.5, 1.2ºC]). No differences were observed between measurement moments in any of the groups for the logarithmic coefficients obtained with the cold-stress test ($p>0.05$). Data of logarithmic coefficients are presented in Table 1.

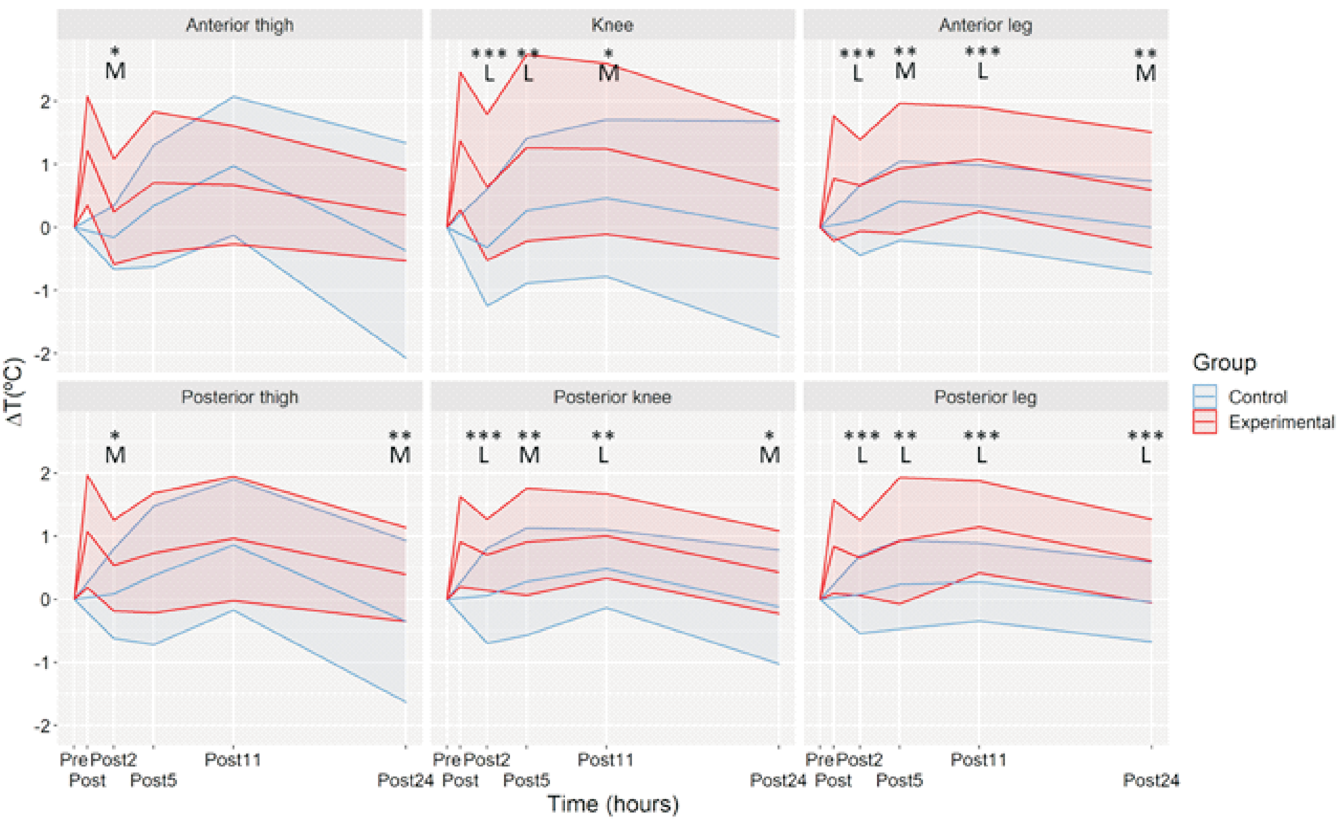
Discussion

Running 10 km at the pace of competition results in increased skin temperature during the next 24 hours, observing that between 5 and 11 hours after exercise is the best time to observe this effect. This increase in skin temperature may be due to internal heat generated by exercise and its subsequent recovery and peripheral vasodilation to dissipate said heat. However, the exercise performed did not affect the participants' thermal recovery after the cold-stress test. Therefore, it can be assumed that to alter said recovery, the stress caused by exercise to the body must be more significant. Future studies replicating this project but with an exercise that causes muscle damage are interesting to see how the observed results are modified and understand the possible application of infrared thermography to monitor muscle damage and physiological stress.

Acknowledgements

This study was funded by "Conselleria de Innovación, Universidades, Ciencia y Sociedad Digital de la Generalitat Valenciana" (Proyectos Emergentes GV/2020/050). The contribution of Catalá-Vilaplana was funded with a doctoral fellowship by "Ministerio de Ciencia, Innovación y Universidades de España" (FPU19/04462).

Figure 2
Mean ±SD of the skin temperature variation. Differences between groups are showed using symbols (* $p<0.05$; ** $p<0.01$; *** $p<0.001$) and letters (L - large effect size; M - moderate effect size).



References

1. Pérez-Guarner A, Priego-Quesada JI, Oficial-Casado F et al. Association between physiological stress and skin temperature response after a half marathon. Physiological Measurement; 2019. 40(3); 034009-034019.

2. Priego-Quesada J; Pérez-Guarner A, Gandia-Soriano A et al. Effect of a marathon on skin temperature response after a cold-stress test and its relationship with perceptive, performance, and oxidative-stress biomarkers; International Journal of Sports Physiology and Performance; 2020. 15(10); 1467-75.

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Table 1
Mean and SD of the coefficients of the logarithmic equations calculated with the skin temperature variation recovery after the cold stress test. The logarithmic equation was: Skin temperature variation (ºC) = Constant + Slope * ln (time after the cold stress test in seconds).

		Control group				Experimental group			
		Constant		Slope		Constant		Slope	
ROI	**Moment**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Anterior thigh	Pre	-11.6	3.8	1.1	0.4	-15.1	3.3	1.9	0.4
	Post					-11.0	4.9	1.3	0.7
	Post2h	-11.2	2.2	1.4	0.3	-10.6	2.8	1.2	0.3
	Post5h	-12.0	2.2	1.5	0.4	-9.7	3.0	1.2	0.3
	Post11h	-12.6	3.1	1.9	0.4	-10.3	2.4	1.4	0.4
	Post24h	-12.1	3.3	1.9	0.4	-12.3	2.3	1.4	0.4
Knee	Pre	-13.3	5.7	1.9	0.4	-14.8	1.7	1.2	0.4
	Post					-9.3	3.4	1.0	0.4
	Post2h	-10.7	3.1	1.8	0.5	-15.5	2.4	1.1	0.3
	Post5h	-10.9	2.9	1.2	0.3	-10.1	1.9	1.4	0.5
	Post11h	-12.2	4.1	1.3	0.4	-10.7	3.6	1.4	0.4
	Post24h	-10.7	3.8	1.2	0.3	-11.1	3.4	1.7	0.3
Anterior leg	Pre	-10.2	2.8	1.4	0.4	-11.0	1.9	1.6	0.5
	Post					-9.6	2.7	1.2	0.4
	Post2h	-10.2	1.8	1.4	0.2	-12.0	2.8	1.5	0.4
	Post5h	-9.7	2.0	1.5	0.4	-9.7	3.0	2.0	0.5
	Post11h	-11.4	2.6	1.5	0.5	-11.8	2.7	1.9	0.3
	Post24h	-9.5	2.7	1.4	0.5	-15.3	2.0	1.9	0.6
Posterior thigh	Pre	-15.2	2.8	1.3	0.2	-10.7	4.2	1.6	0.5
	Post					-14.5	4.5	1.7	0.7
	Post2h	-14.9	2.2	1.5	0.5	-9.6	2.2	1.8	0.4
	Post5h	-14.7	2.4	1.3	0.5	-12.1	3.6	1.8	0.3
	Post11h	-16.0	3.0	1.3	0.5	-14.5	2.1	1.8	0.4
	Post24h	-15.7	4.1	1.3	0.5	-15.5	2.2	1.8	0.4
Posterior knee	Pre	-12.3	3.7	1.1	0.5	-11.9	2.4	1.6	0.4
	Post					-11.1	3.2	1.4	0.4
	Post2h	-11.6	3.0	1.3	0.5	-14.8	1.7	1.7	0.4
	Post5h	-11.0	3.1	1.2	0.4	-15.9	2.0	1.7	0.4
	Post11h	-11.3	2.0	1.5	0.5	-10.0	2.3	1.2	0.4
	Post24h	-11.9	3.0	1.6	0.3	-11.3	2.7	1.4	0.4
Posterior leg	Pre	-14.4	3.0	1.7	0.4	-9.9	1.7	1.3	0.5
	Post					-13.7	3.2	1.7	0.5
	Post2h	-14.2	2.5	1.8	0.3	-11.4	2.6	1.3	0.7
	Post5h	-14.4	1.9	1.7	0.4	-13.5	2.4	1.6	0.8
	Post11h	-15.8	2.9	1.9	0.3	-14.2	2.5	1.2	0.3
	Post24h	-15.4	3.2	1.2	0.4	-10.8	2.5	1.6	0.5

TEMPERATURE DYNAMICS OF THE MUSICIAN'S FINGERS WHEN PLAYING THE SAXOPHONE UNDER COLD CONDITIONS

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Introduction

A special feature of modern saxophones is that they can only be played at temperatures above +15 °C. In a cold room, it is difficult to play the saxophone with your bare hands, and at temperatures below +5 °C it is almost impossible. Perhaps this is because in the cold, modern saxophones turn into refrigerators for the hands of musicians, because the saxophones are entirely made of metal and have a mass of 2 to 9 kg. Even though the saxophones continue to be modernized, the buttons of the saxophone remain as before metal. We assume that in cold conditions, the buttons of modern saxophones function as a "heat sink" for the fingers of musicians. This fact is completely ignored by the developers of the musical instrument. Studying the dynamics of the local temperature of the musicians ' fingers when playing the saxophone in a cold room will allow us to test this assumption and point out the way to modernize summer saxophones into demi-season saxophones. Therefore, the aim of this work is to study the influence of the saxophone buttons on the dynamics of the local temperature of the fingers when playing music on a saxophone in a cold room.

Method

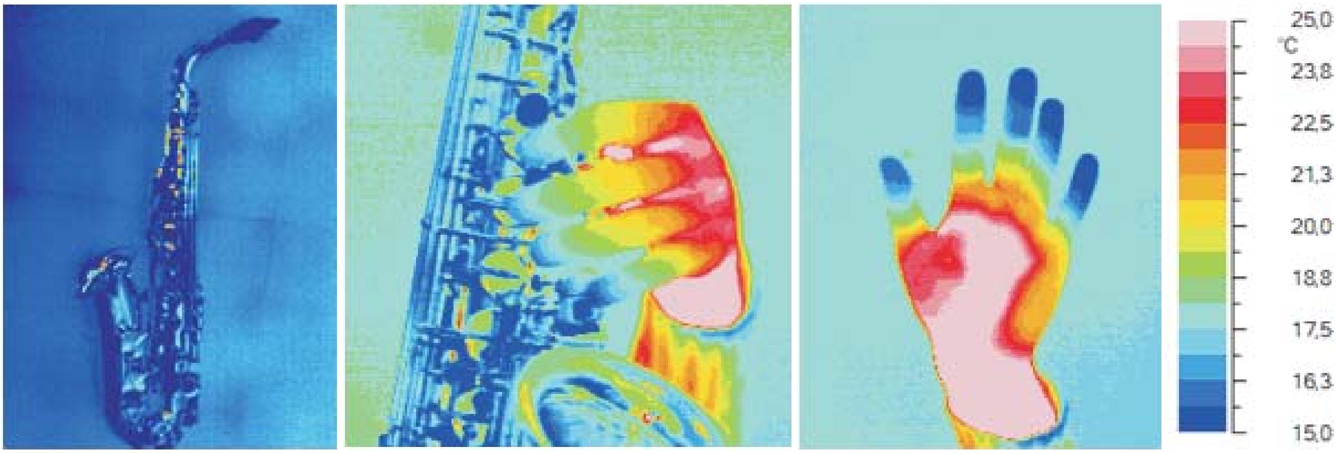
We studied the dynamics of local temperature in the fingers of adult musicians during their playing the Alto Saxophone YAS-280 (Yamaha, Indonesia) in a room with a temperature of +15 °C. Temperature dynamics were recorded using Thermo Tracer TH9100XX (NEC, USA) according to the method used in sports and physical medicine [1]. The Alto Saxophone was standard, it is made of a brass body with gold lacquer and has a mass of 2.5 kg. In the first series of observations, a saxophone with standard buttons was used. In the second series of observations, the same saxophone was used, but its buttons were covered with a layer of foam polyethylene 1 mm thick. In each series in 5 healthy adult volunteers participated. The design of the research was similar to the study of the dynamics of the temperature of the sniper's hands when shooting with a rifle in the cold [2]. Prior to the study, the study protocol was approved by the Ethics Committee of the Izhevsk State Medical Academy following the principles that are outlined in the Declaration of Helsinki of the World Medical Association. All volunteers signed a written informed consent to participate in the study.

To study the dynamics of finger temperature, thermal imaging images were obtained as follows. Initially, the musician and his saxophone were in the room at a temperature of +15 °C for 10 minutes before the performance of the musical piece. Then, after the start of the game on the saxophone, thermal images were recorded using the thermal imager every 5 minutes. The temperature in the observation room was 15 ± 1.5°C. Thermal images were recorded every 5 minutes for 15 minutes. Special attention was paid to the dynamics of the local temperature at the point of contact of the fingers with the buttons of the saxophone, where spot temperatures were obtained. After the completion of our study, a survey of the study participants was conducted. The results of the survey showed that regardless of the air temperature, saxophonists prefer to play the saxophone, the buttons of which are covered with a layer of thermal insulation material. The musicians explained their choice by maintaining the high sensitivity of the finger pads, high speed and accuracy of detecting the "right" buttons of the saxophone when performing a piece of music.

In addition, at our request, after playing 5, 10 or 15 minutes at a temperature of +15 °C on a regular saxophone and on a saxophone with heat-insulated buttons, the musicians evaluated the stiffness of the fingers of both hands on a visual analog scale (VAS) [3]. The results showed that when playing music at a temperature of +15 C on a regular saxophone, after 5 minutes of playing, the musicians noted a deterioration in finger mobility, which they estimated at 1 point. After 10- and 15-minutes musical performance, the musicians noted an increase in the stiffness of their fingers to 2 and 4 points, respectively. At the same time, when playing the saxophone, the buttons of which were previously covered with a layer of thermal insulation material, the musicians did not feel the appearance of stiffness in the fingers after 5 minutes of playing the instrument, and after 10 and 15 minutes of playing, the stiffness in the fingers was estimated by them respectively at 1 and 1.5 points. An experienced independent expert from Austria was invited to review the study design and propose additional clinical outcomes.

Results and discussion

In Series No. 1 it was found that when storing the saxophone in a cold room at a temperature of +15 C, all the elements of the saxophone are evenly cooled to the ambient temperature. In Series No. 2 the dynamics of the local temperature of all parts of the saxophone while playing it in a cold room was investigated.



A b c

Figure 1.
Thermal imaging study of the dynamics of the local temperature of the regular saxophone and the fingers of the musician. a - Alto Saxophone in 180 minutes in a room at a temperature of +15 °C without contact with the hands of the musician (Series No. 1); b - The hand of a musician in 1 minute after starting to play the Alto Saxophone in the room at a temperature of +15 °C (Series No. 2); c - The left hand of the musician after 10 minutes of continuous contact with the buttons of an ordinary saxophone when performing a piece of music at a temperature of +15 °C (Series No. 3).

It is shown that playing the saxophone does not warm him up. All parts of the saxophone remain cold, except the mouthpiece. However, when playing the saxophone in a cold room, the fingers in the musician's hand cool down (Fig. 1).

We observed that playing a modern saxophone in a cold room quickly led to cooling of the fingers of the bare working hand in all volunteers. Temperature decrease started at the fingertips, then the zone of low temperatures extended in the proximal direction and after 10 minutes the entire fingers were affected. Covering the buttons of the saxophone with foam led to a smaller decrease in the temperature of the fingers. The results obtained in series No. 3 showed that a large role in the local cooling of the musician's fingers when playing the saxophone in a cold room is played by the keyboard buttons of a musical instrument. The early appearance of foci of local cooling in the tips of the fingers touching the buttons of the saxophone, and the absence of similar foci of cooling in the first finger of the right hand, not touching the buttons of the instrument, indicates that these buttons are the main culprits for cooling the fingers of the musician when playing the saxophone in a cold room. We studied the design of the buttons and found that they lacked thermal insulation. In this regard, to prevent excessive cooling of the fingers of musicians when playing the saxophone in a cold room, it was decided to modernize the buttons of the musical instrument, covering them with a layer of thermal insulation material.

For the modernization of the musical instrument, the same ordinary saxophone was used, which was used by us earlier. As a heat-insulating material, a film made of porous polyurethane foam with a thickness of 1 mm was chosen. Circles were cut out of this film, the dimensions of which exactly correspond to the size of the surface of the buttons

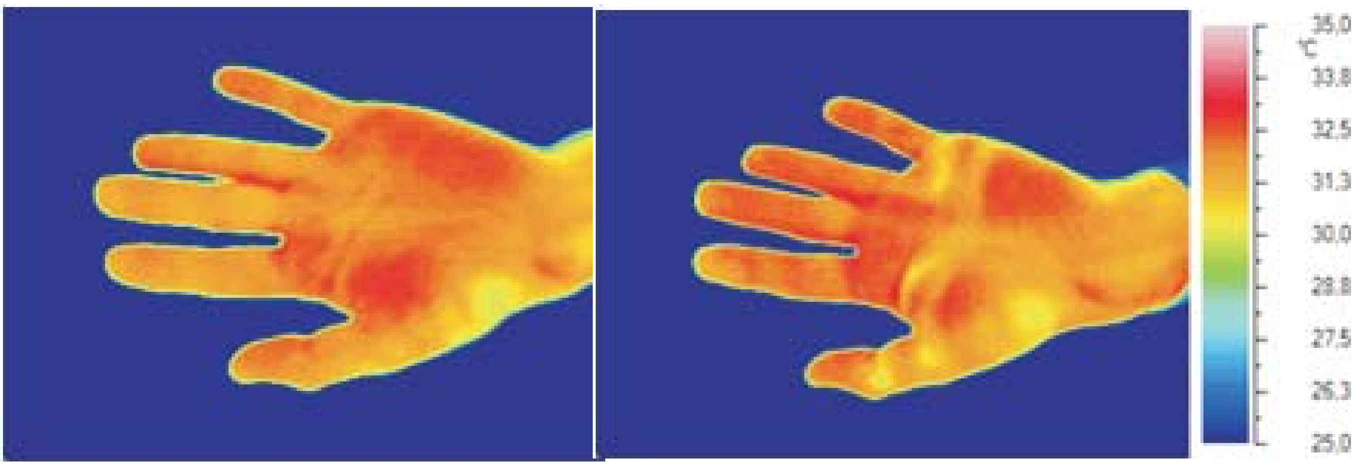


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Figure 2
Thermal images of a musician's left hand while playing a saxophone with heat-insulated buttons (Series No. 4). a - before playing the saxophone with heat-insulated buttons; b - after 15 minutes of playing the saxophone with heat-insulated buttons.

of the saxophone keyboard. Then these circles of thermal insulation material were pasted on the working surface of the buttons. After that, a saxophone with buttons covered with a heat-insulating material was used by us to study the dynamics of local temperature in the fingers of musicians when playing the saxophone in a cold room.

In series No. 4, we studied the dynamics of the local temperature of the fingers and palms of both hands in musicians playing a modernized saxophone in a room at a temperature of +15 C. The results showed that a cold saxophone with heat-insulating buttons practically does not absorb heat from the hands of the musician. Therefore, the fingers of the musician's hands remain warm (Fig. 2).

Therefore, the thermal imager can be used to record the dynamics of the local temperature of the fingers of musicians while playing musical instruments to improve the quality of performance of musical works and for the correct and high-quality modernization of musical instruments.

References

1. Moreira DG, Costello JT, Brito CJ, Adamczyk JG, Ammer K, Bach AJ, et al. Thermographic imaging in sports and exercise medicine: a Delphi study and consensus statement on the measurement of human skin temperature. Journal of thermal biology. 2017; 69:155-62.

2. Urakov A.L., Ammer K., Dementiev V.B., Urakova N.A., Gadelshina A.A. The contribution of infrared imaging to designing a "winter rifle" - An observation study. Thermology International. 2019;29(1):40 - 46.

3. Hayes M.H.S., Patterson D.G. Experimental development of the graphic rating method. Psychol. Bull. 1921; 18: 98-99).

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Changes of body surface temperature associated with high-speed treadmill exercise in Beagle dogs by use of infrared thermography

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Introduction

The influence of treadmill exercise on body surface temperature distribution in dogs has been studied with infrared thermography (IRT), where areas of the neck, shoulder, back and thigh significantly increased in temperature after treadmill exercise [1]. However, that study included different breeds, which introduced variability of surface temperature due to different thickness and quality of hair coat. Also, the study did not employ specific regions of interest. The aim of our research was to assess the influence of high-speed treadmill exercise on body surface temperature using IRT in selected body regions of healthy Beagle dogs, considering gait and recovery time. The hypothesis of the study was that all body regions increase in temperature in response to high-speed exercise on the treadmill. The study was based exclusively on the Beagle breed, commonly used in canine thermography studies [2, 3] which presents short, uniform and straight hair, and provides less insulation than hair that lays flat against the surface of the body [4].

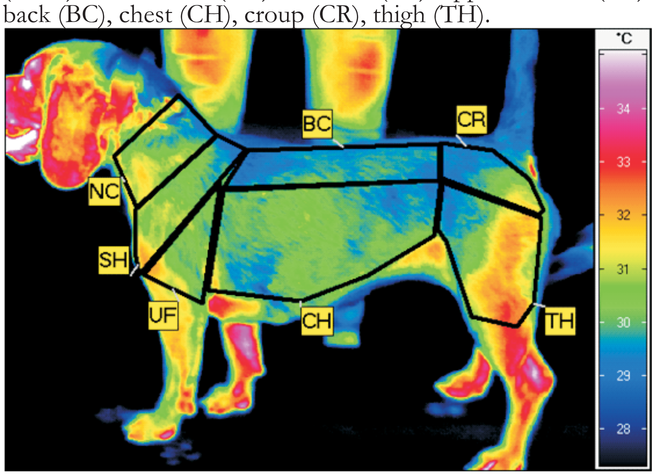
Material and Methods

Nine clinically healthy Beagle dogs (4 females and 5 males; aged 4-17 years; mean body weight 14±1.5 kg) with no history of lameness or musculoskeletal pathology were subjected to training on an electronic treadmill. All dogs underwent a full physical examination to rule out possible clinical abnormalities. The dogs were owned by Wroclaw University of Environmental and Life Science and were housed in individual pens (140 × 200 cm) lined with wood shavings with daily exercise provided. The study was conducted at the research room of Department of Internal Medicine and Clinic of Diseases of Horses, Dogs and Cats, where dogs were familiarized with the treadmill exercise for 3 months before the study was performed. Mean ambient temperature in the examination facility, was maintained at 20 ± 2 °C with humidity 60% (without major fluctuations). Thermographic images of both sides of body taken individually were performed before exercise (BE), after walk (AW), after trot (AT), after canter (AC), after second walk (JAE), 5 min after exercise (5AE), 15 min after exercise (15AE), 30 min after exercise (30AE), 45 min after exercise (45AE) and 2 hours after exercises (120AE) using a Vario Cam HR infrared camera (uncooled microbolometer focal plane array; resolution, 640x480 pixels; spectral range, 7.5-14 mm; InfraTec, Dresden, Germany). The images taken from different sides had the same background. Average body surface temperature was measured in seven regions of interest (ROIs) including: neck (NC), shoulder (SH), upper forearm (UF), back (BC), chest (CH), croup (CR), thigh (TH) Figure 1. Measurements of the left side of the body were included for further calculations, as there were no statistically significant differences in average surface temperature between both sides of the body. The research did not require the consent of the Local Ethical Commission for Animal Experiments at the Institute of Immunology and Experimental Therapy of the Polish Academy of Sciences in Wroclaw, Poland (Act of 15 January 2015 on protection of animals used for scientific or educational purposes).

Results

ANOVA indicated a significant effect of exercise on all ROIs ($P<0.001$). Higher temperature values were found in

Figure 1
Example of thermographic image of the left side of the dog taken just after training on the treadmill with 7 regions of interest (ROIs) shown: neck (NC), shoulder (SH), upper forearm (UF), back (BC), chest (CH), croup (CR), thigh (TH).



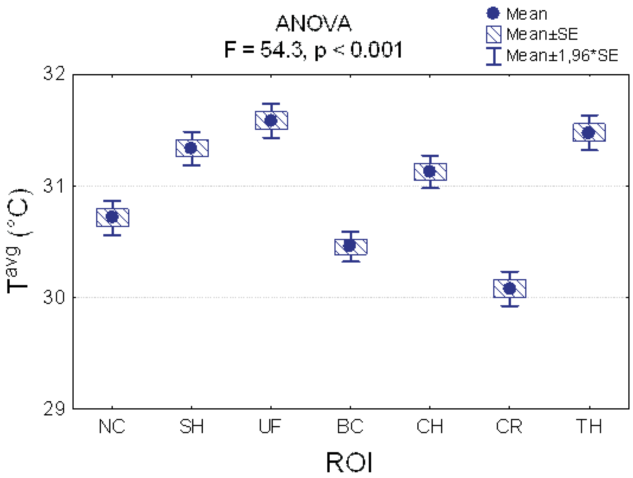


Figure 2
Comparison of mean body surface temperature (Tavg) of seven regions of interest (ROIs): neck (NC), shoulder (SH), upper forearm (UF), back (BC), chest (CH), croup (CR), thigh (TH) measured before treadmill exercises, immediately after each exercise and during recovery time in 9 dogs.

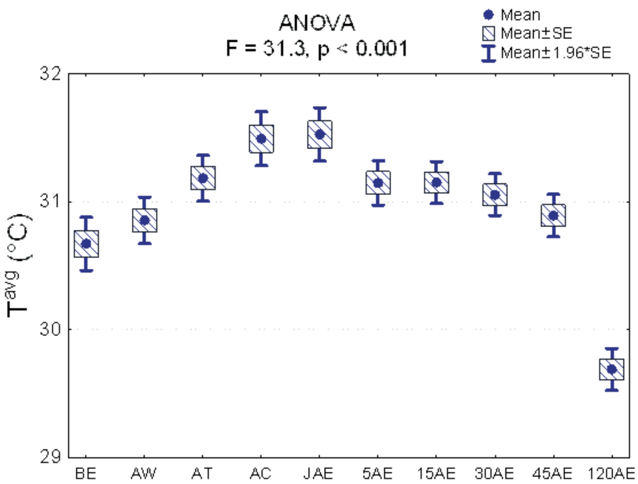


Figure 3
The mean body temperature (Tavg) of all regions of interest measured before exercise (BE), after walk (AW), after trot (AT), after canter (AC), after second walk (JAE), 5 min after exercise (5AE), 15 min after exercise (15AE), 30 min after exercise (30AE), 45 min after exercise (45AE) and 2 hours after exercise (120AE) in 9 dogs.

the upper forearm and thigh and colder in the croup, back and neck (Figure 2). A statistically significant increase from the temperature at BE occurred in all ROIs at AT ($p = 0.004$) and lasted up to 15AE, returning to the initial level at 30AE. The highest values of surface temperature in all ROIs were at AC and JAE (31.5°C), and the lowest were at 120AE (Figure 3).

Conclusions

The study indicated that body surface temperatures were influenced by high-speed physical exercise on treadmill due to muscle activity and changes in blood flow in Beagle dogs. The surface temperature in all ROIs was not influenced by exercise - generated heat greater than 30 minutes after training on the treadmill. Reduction of body surface temperature by 1°C at 120AE could be associated with cool-down mechanism - panting. IRT can be a viable, non-in vasive modality that provides imaging of temperature variation of specific body regions in response to high-speed treadmill exercise of healthy Beagle dogs. More research is now required to explore body surface temperature changes of different pure - breeds in response to high- speed treadmill exercises.

References

1.Rizzo M, Arfuso F, Alberghina D, Giudice E, Gianesella M, Piccione G. Monitoring changes in body surface temperature associated with treadmill exercise in dogs by use of infrared methodology. Journal of Thermal Biology 2017; 69: 64-68

2.Loughin CA, Marino DJ. Evaluation of thermographic imaging of the limbs of healthy dogs. American Journal of Veterinary Research 2007; 68: 1064-9.

3.Zanghi B. Eye and ear temperature using infrared thermography are related to rectal temperature in dogs at rest or with exercise. Front. Vet. Sci. 2016; 19.

4.Kwon CJ. Brundage C.M. Quantifying body surface temperature differences in canine coat types using infrared thermography. Journal of Thermal Biology 2019; 82:18-22.

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APPLICATION OF INFRARED THERMOGRAPHY IN THE ASSESMENT OF PERFORMANCE OF LIPIZZAN HORSES

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Introduction

Knowledge about the physiological responses of Lipizzan horses (Lipizzans) to a workload and physiological norms for assessing their fitness level during training or performance are insufficient. Therefore, the aim of this study was to measure the changes of physiological parameters including heart rate (HR), respiratory rate (RR) rectal temperature (RT) and body surface temperature (BST) in Lipizzans before and after an exercise. Presented results will contribute to definition of standards and protocols for monitoring fitness level, training progress, health status and well-being of Lipizzans.

Materials and Methods

The study was conducted at the Pedagogical and Research Equestrian Centre (Biotechnical Faculty, University of Ljubljana) with 6 purebred Lipizzan horses (3 geldings, 2 mares, 1 stallion) with an average age of 9 ± 0.8 years and an average body mass of 455 ± 36 kg. The horses, regularly used in student riding classes, were considered clinically healthy and were dewormed regularly. They were housed in individual boxes bedded with sawdust. They were fed hay and shredded oats twice daily, to which a vitamin-mineral mixture was added, and had free access to automatic waterers. The study consisted of two exercise tests conducted in the spring and fall of the same year in an outdoor riding arena. Each horse was lunged for 30 minutes at walk, trot, and canter (10 minutes at each gait). Immediately before and after exercise, physiological values (BSTs of different body regions (loin, back, neck, buttocks, chest), RRs, RTs and HRs) were measured. Ambient temperature and humidity were also recorded during the test. STs were measured using a FLIR infrared thermal imager (Figure 1), HRs telemetrically using a set of equipment Polar Equine and RTs using a digital thermometer. RRs were measured directly by counting the movements of the chest. Ambient temperature and humidity were measured with a Testo 635 digital metre. The average air temperatures and humidities were 19.8±0.7°C and 58.9±4.1% in spring and 11.6±0.7°C and 83.6±4.7% in autumn. Data were analysed using the commercial software SPSS 20.0 IBM (Chicago, USA). Values are expressed as mean ± standard deviation. Differences are considered significant at P≤ 0.05.

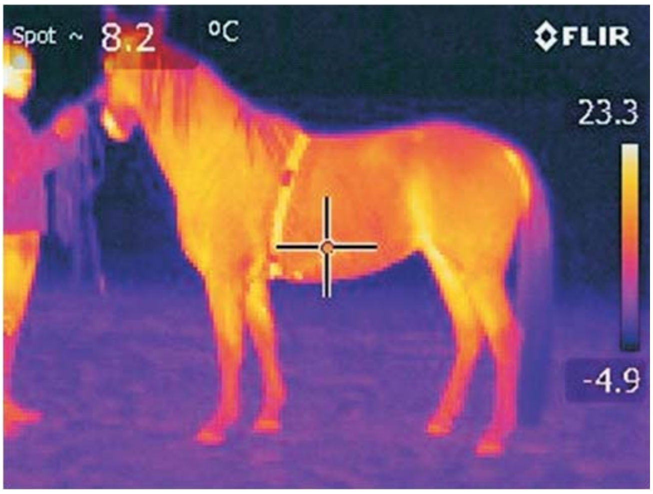

Figure 1
Thermographic image of the left side of a horse (measured at an ambient temperature of 8.2 °C).

Results and Discussion

Basal values of HRs, RRs, and BSTs in the studied Lipizzan horses in spring and autumn are presented in Table 1 and are within the reported values for horses [1, 2, 3]. In both sessions, a significant increase for HRs and RRs was registered after the exercise as the result of increased metabolic demand, oxygen consumption and heat production during exercise [2,4]. The BSTs of different body regions before and after both exercise tests are shown in Figure 2 and were similar to those reported by other authors [4,5]. A significant increase in BSTs of all regions followed the exercise test compared with basal values in both seasons, but the temperature increase was higher in autumn than in spring for all regions (P< 0.001), with the lowest for the back

Table 1:
Heart rates, respiratory rates and body temperatures in Lipizzans before and after exercise test in spring and summer

Season	Phase of the test	Heart rate (beats/min)	Respiratory rate (breaths/min)	Skin temperature (°C)
Spring	Before Exercise	40.83±2.6	19.3±3.1	37.5±0.1
	After Exercise	131.8±5.8	54.0±7.6	38.6±0.2
Autumn	Before Exercise	49.3±5.9	12.3±1.6	37.5±0.1
	After Exercise	126.2±11.9	30.3±5.0	38.3±0.2

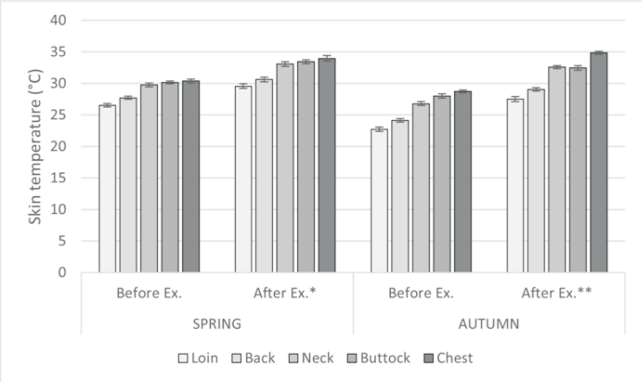

Figure 2
Skin temperatures of different body regions in Lipizzans before and after exercise tests in spring and autumn; *P<0.001 in spring for all regions after exercise compared to values before exercise; **P<0.001 in autumn for all regions after exercise compared to values before exercise.

(2.9±1.6°C in spring and 4.9±2.0°C in autumn, P< 0.001) and the highest for the chest (3.5±1.4°C in spring and 6.1±1.4°C in autumn, P< 0.001). Although the mean basal STs of all body regions were lower in autumn than in spring, differences were found between regions in both seasons, with the lowest STs in the loin and the highest in the chest (P< 0.001). The results of our study suggest different contributions of these regions to thermoregulatory functions, and the influence of environmental conditions on these processes authors [4,5].

Conclusions

The results of our study demonstrate the physiological responses of the Lipizzans to a graded exercise load and can be accepted as a contribution to the knowledge of thermoregulation and responses of some cardiovascular and respiratory parameters of horses in different seasons, as well as to the recognition of the complex physiological processes that occur during exercise. The study also demonstrates the usefulness of infrared thermography and provides a basis for further research in the field of equine exercise testing and sports medicine.

References

1.Munsters, C.C.; Van Waarden, A.; Van Weeren, R.; Sloet Van Oldruitenborgh-Oosterbaan, M. M. Exercise testing in Warm blood sport horses under field conditions 2014; Vet. J. 202; 11-9.

2.Padalino, B.; Zaccagnino, P.; Celi, P. The effect of different types of physical exercise on the behavioural and physiological parameters of standardbred horses housed in single stalls 2014; Vet. Med. Int. 4; 875051.

3. Cebulj-Kadunc, N.; FrangeŽ, R.; Žgajnar, J.; Kruljc, P. Cardiac, respiratory and thermoregulation parameters following graded exercises in Lipizzaner horses 2019; Vet. arhiv 89; 11-23.

4. Soroko, M; Spitalniak-Bajerska, K; Zaborski, D; Pozniak, B; Dudek, K; Janczarek, I. Exercise-induced changes in skin temperature and blood parameters in horses 2019; Arch. Anim. Breed., 62, 205-13.

5. Redaelli, V.; Bergero, D.; Zucca, E.; Ferrucci, F.; Nanni Costa, L.; Crosta, L.; Luzi, F. Use of thermography techniques in equines: principles and applications 2014; J. Equine Vet. Sci. 34; 345-50.

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THE EFFECT OF TRAINING ON INFRARED THERMOGRAPHIC IMAGES OF THE FORELIMB AND HINDLIMB JOINTS OF HEALTHY RACEHORSES

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Introduction

In the field of exercise physiology, recent studies have suggested the use of infrared thermography (IRT) in monitoring the influence of training on body surface temperature in performance horses [Arfuso et al. 2016; Soroko et al 2017]. The surface temperature distribution of the forelimbs and hindlimbs has been described in detail in horses at rest, with proximal areas warmer compared to the distal limbs [Palmer 1983]. IRT has been used to assess forelimb and hindlimb surface temperature change after treadmill exercise as a measure of muscle activity [Simon et al. 2006, Yarnell et al. 2014]. No previous studies have measured the changes of surface temperature overlying the joints in racehorses subjected to regular racing training. The aim of this study was to evaluate the influence of training on body surface temperature over the joints in racehorses, measured by IRT. The hypothesis of the study was that regular training increases surface temperature over the joints, and that the increase in temperature of the skin overlying the proximal joints is greater than the increase at the distal forelimbs.

Material and Methods

All horses recruited to the study were subjected to standard procedures without any harm or discomfort and therefore the study did not require the consent of the Local Ethical Commission for Animal Experiments at the Institute of Immunology and Experimental Therapy of the Polish Academy of Sciences in Wroclaw, Poland (Act of 15 January 2015 on protection of animals used for scientific or educational purposes).The study involved monitoring 14 Thoroughbred racehorses aged 2 years in 6 imaging sessions over a period of 3 months. Temperature measurements of the forelimb and hindlimb joints were made before and just after training including: shoulder, hip, elbow, stifle, carpal, tarsal, metacarpophalangeal and metatarsophalangeal joint (Fig 1). Thermographic images were captured using a VarioCam hr Resolution infrared camera (uncooled microbolometer focal plane array, resolution 640 x 480 pixels, spectral range 7.5-14 mm, InfraTec, Dresden, Germany). The ambient temperature and humidity inside and outside the stable were measured using a handheld HM 34 Humidity and Temperature Meter (Vaisala HUMICAP®, Finland).This preliminary analysis of ambient temperature differences indicated that sessions: first and second, and sessions three, four and five did not significantly differentiate results obtained, therefore were merged (sixth session was significantly different from any other). Sessions were divided into three groups of mean outside ambient temperature: low (sixth session, 14.1 °C) vs medium (first and second sessions, mean 15.8 °C) vs high temperature (third, fourth and fifth sessions, mean 19.7 °C).

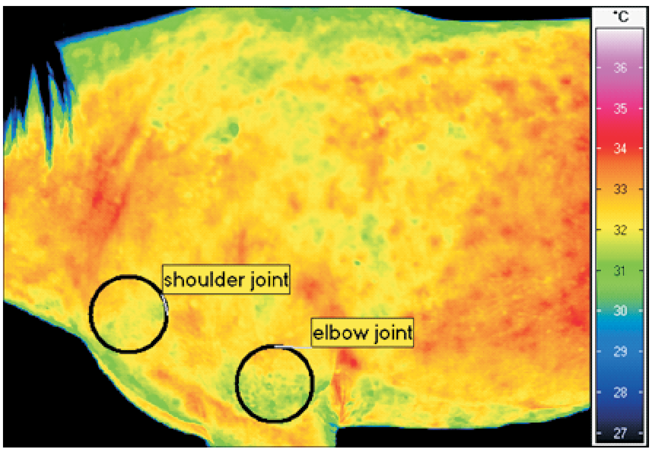

Figure 1
An example thermographic image of the left side of the proximal forelimb area before training with the shoulder joint and elbow joint region of interests (ROIs) indicated.

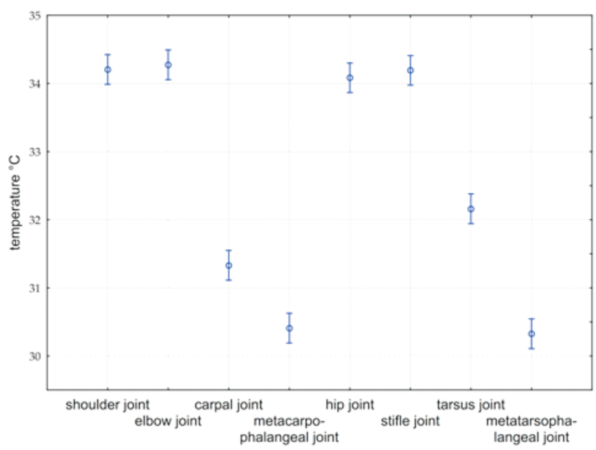

Figure 2
Average temperature over each joint site. Data shown are Mean ± SD from all horses, including both before and after training measurements.

Results

Joint temperature at the forelimbs (shoulder, elbow, carpal and metacarpophalangeal joint) and hindlimbs (hip, stifle, tarsal and metatarsophalangeal joint) increased significantly after training. Environmental temperature had a statistically significant influence on surface temperature over the joints. The lowest surface temperatures were recorded over the metacarpophalangeal and metatarsophalangeal joint and the highest temperatures in the shoulder, elbow, hip and stifle, joint (Fig. 2). The metacarpophalangeal and metatarsophalangeal joints warmed the least during training but were influenced the most by differences in environmental temperature.

Conclusions

Regular exercise caused an increment of surface temperature over the joints in healthy horses. The study indicated that surface temperature over the joints in the upper part of the body (shoulder, elbow, hip, stifle)was higher than the surface temperature over the joints in the distal part of the limbs (carpal and tarsus joint, fetlock joint of the forelimb and hindlimb). The surface temperature differences before and after training may be an important indicator of the of the thermoregulatory response to exercise in racing horses Understanding surface temperature changes in response to regular training is necessary for future studies in diagnosing injuries of joints in young racehorses. In order to monitor and prevent possible injuries further studies should indicate how long the temperature over the joints stays increased after exercise.

Acknowledgements

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References

Arfuso F, Giannetto C, Giudice E, Fazio F, Piccione G. Dynamic modulation of platelet aggregation, albumin and nonesterified fatty acids during physical exercise in Thoroughbred horses. Res Vet Sci. 2016;104: 86-91.

Palmer SE. Effect of ambient temperature upon the surface temperature of equine limb. Am J Vet Res. 1983;44: 1098-1101.

Simon EL, Gaughan EM, Epp T, Spire M. Influence of exercise on thermographically determined surface temperatures of thoracic and pelvic limbs in horses. J Am Vet Med Assoc. 2006;229: 1940-1944.

Soroko M, Howell K, Dudek K, Henklewski R, Zieli?ska P. The influence of breed, age, gender, training level and ambient temperature on forelimb and back temperature in racehorses. Anim Sci J. 2017;88: 347-355.

Yarnell K, Fleming J, Stratton TD, Brassington R. Monitoring changes in skin temperature associated with exercise in horses on a water treadmill by use of infrared thermography. J Therm Biol. 2014;45: 110-116.

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COMPARISION OF HIGH INTENSITY LASER THERAPY (HILT) EFFECT ON SURFACE TEMPERATURE AND VEIN DIAMETER IN PIGMENTED AND NON-PIGMENTED SKIN IN HEALTHY RACEHORSES

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Introduction

Laser therapy uses light the within red and infrared spectra. Therapeutic laser devices with a power higher than 0.5 W are classified as class IV lasers and are used in High Intensity Laser Therapy-HILT. This relatively novel treatment has been introduced in equine veterinary medicine recently. Only a few studies have evaluated the impact of HILT in the treatment of orthopaedic disorders in horses. One of the preconditions for improving HILT procedures in veterinary medicine is the determination of photothermal effects, which are a result of the transformation of absorbed light energy to heat [1]. Studies on humans have confirmed that dark, strongly melanized (pigmented) skin absorbs much more laser light energy than fair (non-pigmented) skin [2,3] Therefore, HILT parameters must be carefully considered when the therapy is performed in treatment areas with dark skin [4,5].In our previous study we evaluate the thermal effect (with infrared thermography) of HILT on clinically healthy tarsal joints, but the study did not control for skin pigmentation in the treatment area [6].

Aim

To assess differences in the influence of HILT on surface temperature and vein diameter in the lateral fetlock joint region in a group of healthy racehorses with pigmented and non-pigmented skin in the treatment area.

Methods

Twenty 3-4 years old Thoroughbreds were divided into two equal groups: group A - pigmented and group B - non-pigmented skin groups. Each horse received a single HILT treatment with the same parameters of the therapy: energy density 25 J/cm2, power output 4 W, frequency 2000 Hz and total energy dose 650 J. Just before and immediately after HILT, thermographic examination was performed to measure surface temperature changes, and ultrasonographic examination assessed changes of the lateral digital palmar vein diameter. The coat in treatment area was shaved. Just after shaving each horse was subjected to thermographic examination, followed by ultrasonographic examination. Minimal amount of coupling gel was applied

Table 1
Surface temperature, vein diameter and differences in values of surface temperature and vein diameter (median and IQR) before and after HILT application for horses from pigmented skin group (A) and non-pigmented skin group (B).

Parameters	Group A Pigmented skin	Group B Unpigmented skin	P-value
T_{avg} before HILT (°C)	25.8 (23.0-29.5)	30.1 (22.1-31.8)	0.257
Min - Max	21.3 – 30.8	17.8 – 32.2	
D_{avg} before HILT (mm)	3.1 (2.8-3.7)	3.8 (2.9-4.3)	0.226
Min - Max	2.4 – 4.1	2.6 – 5.7	
T_{avg} after HILT (°C)	28.2 (26.1-31.6)	27.8 (22.9-30.7)	0.496
Min - Max	24.3 – 33.9	20.9 – 31.9	
D_{avg} after HILT (mm)	4.0 (3.5-4.9)	4.3 (3.2-5.5)	0.596
Min - Max	2.7 – 5.0	2.5 – 5.8	
ΔT_{avg} (°C)	3.0 (2.1-3.6)	-0.2 (-2.5-0.7)	**0.001**
Min - Max	0.5 – 5.5	-3.5 – 3.1	
ΔD_{avg} (mm)	0.9 (0.4-1.1)	0.4 (0.1-0.9)	0.140
Min - Max	0.2 – 1.8	-0.1 – 1.5	

Statistically significant result of the independent non-parametric Mann-Whitney U test in **bold**.
Abbreviations: HILT, High Intensity Laser Therapy; SD, standard T_{avg}, average surface temperature; D_{avg}, average vein diameter; DT_{avg}, differences of values in average surface temperature after HILT; DD_{avg}, differences of values in average vein diameter after HILT

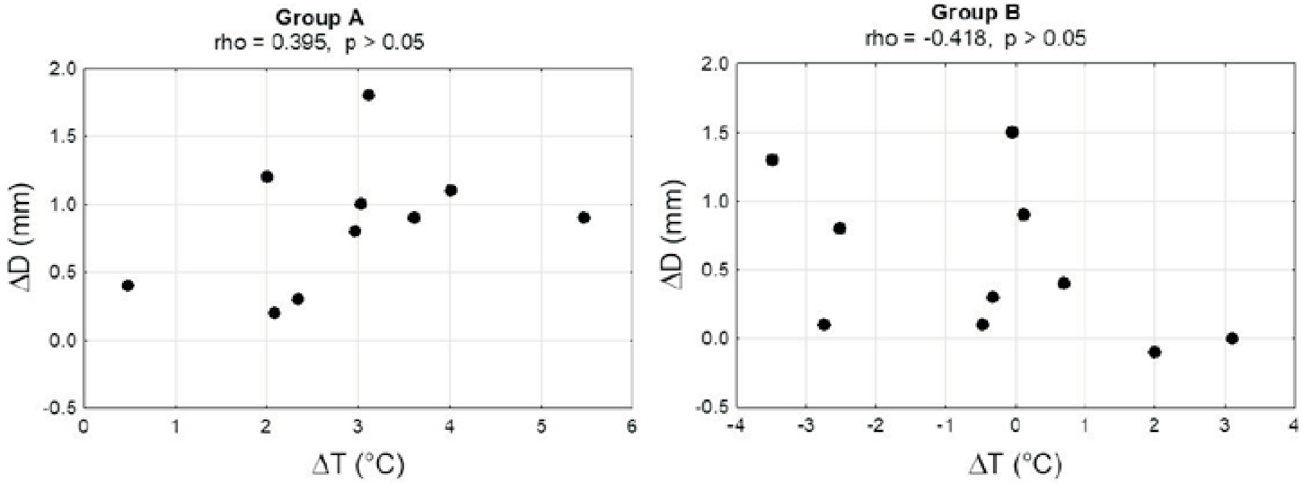

Figure 1
Correlation between the differences in values of surface temperature and vein diameter after HILT application in group A and group B, and results of Spearman's rank correlation coefficient. Tavg, differences in values of surface temperature before and after HILT; Davg, differences in values of vein diameter before and after HILT

to minimize body surface temperature changes. After ultrasonographic examination the treatment area was dried from coupling gel with paper towel and HILT was performed. Immediately after HILT treatment the thermographic and then ultrasound examination was repeated to assess the changes in body surface temperature and vein diameter. Thermographic examination was performed using a Vario Cam hr resolution infrared camera (InfraTec, Dresden, Germany). The study was approved by the Local Ethical Committee for Experiments on Animals, Wroclaw, Poland (no 003/2020).

Results

The comparison between both groups of surface temperature and vein diameter changes before and after HILT showed that the changes in surface temperature were statistically significant ($Z=3.175$, $p<0.001$; Table 1), but the changes in vein-diameter were not ($Z=1.476$, $p=0.140$; Table 1). After HILT there was no correlation between differences in values of surface temperature and differences in values of vein diameter in both groups ($rho=0.359$, $p>0.005$ for group A and $rho=-0.418$, $p>0.005$ group B; Figure 1).

Discussion

To the best of our knowledge, this is the first clinical study that documents a difference in the effects of HILT performed on pigmented and non-pigmented skin in the treatment area in clinically healthy racehorses. Limitations of the study included the lack of laser-sham group receiving no HILT treatment. Further research is therefore necessary to describe the physiological and clinical effects of HILT performed on pigmented and non-pigmented skin.

References

1.Thomsen S: Pathological analysis of photothermal and photomechanical effects of laser-tissue interactions. Photocchem Photobiol. 1991, 53, 825-835

2.Anderson RR. Laser-tissue interactions in dermatology. In: Arndt, K.A., Dover, J.S., Olbricht, S.M. eds. Lasers in Cutaneous and Aesthetic Surgery. Philadelphia, PA: Lippincott-Raven. 1997, p28.

3.Goldman L, Blaney DJ, Kindel DJ, Franke EK. Effect of the laser beam on the skin. J Invest Dermatol. 1963, 40, 121-122.

4.Bhatt N, Alster TS. Laser surgery in dark skin. Dermatologic surgery. 2008, 34, 184-195.

5.Tanzi EL, Alster TS. Cutaneous laser surgery in darker skin phototypes. Cutis. 2004, 73, 21-30.

6.Godlewska M; Soroko M; Zieli?ska P. Assessment of Vein Diameter and Body Surface Temperature after High-Intensity Laser Therapy (HILT) on the Tarsal Joint in Healthy Horses. J. Equine Vet. Sci. 2020; 93; 103-198.

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THE USE OF INFRARED THERMOGRAPHY TO EVALUATE THE EFFECT OF HIGH INTENSITY LASER THERAPY ON THE SURFACE TEMPERATURE OF THE HINDLIMB'S FLEXOR TENDON AREA IN CLINICALLY HEALTHY RACEHORSES

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Introduction

Infrared thermography (IRT) has been widely used in equine veterinary medicine in diagnosis and monitoring repair process of tendon injuries [1], bones injuries like bucked shins, podotrochleosis or laminitis [2,3] joint diseases [4], muscle and other soft tissue disorders [5,6]. IRT has been also used in detection of neurological disorders [7]. Increasingly IRT has been involved in evaluation of the effectiveness of physiotherapy devices on regeneration process of injured tissues for example during the treatment of the pulsed electromagnetic field therapy [8] focused extracorporeal shock wave therapy [9], cryostimulation [10] and exercise in water treadmill [11]. In our previous study IRT was used to evaluate the effect of High Intensity Laser Therapy (HILT) on clinically healthy tarsal joint [12]. However, none of the previous studies indicted influence of HILT on surface temperature changes of clinically healthy soft tissue. The aim of the study was thermographic assessment of flexor tendon temperature changes before and after HILT in clinically healthy racehorses.

Methods

The study was conducted on 18 clinically healthy Thoroughbreds all aged 3 years, trained for racing performance. Thermographic images of distal hindlimbs from the plantar aspect were taken before and just after HILT application. For temperature measurements a Vario-Cam HR®, InfraTec thermographic camera with a resolution 640x480 was used. The measurement was taken from the middle part of the third metatarsal bone, where superficial digital flexor tendon and deep digital flexor tendon are placed. Before and just after HILT the measuring region in the shape of rectangle in the middle part of the left third metatarsal bone was determined for each thermographic image to calculate average surface temperature (Figure 1). The study was approved by the Local Ethical Committee for Experiments on Animals.

Results

There were statistically significant differences in temperatures of flexor tendons before and after HILT ($p < 0.001$). The surface temperature of examined area was higher (by an average 3,5 °C) after HILT comparing to temperature measured before HILT (Figure 2).

Discussion

IRT enabled assessment of the surface temperature in response to HILT application. Previous studies evaluated effects of HILT on pathologically changed tissues which

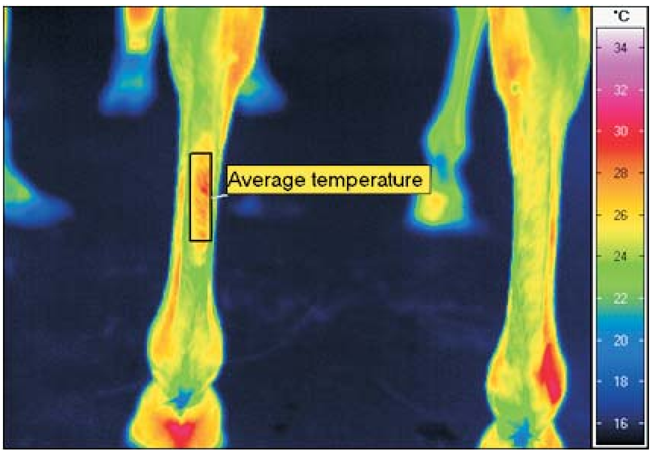

Figure 1
Distal hindlimbs from plantar aspect. The average surface temperature of a rectangular area placed over the middle part of the metatarsal bone after High Intensity Laser Therapy.

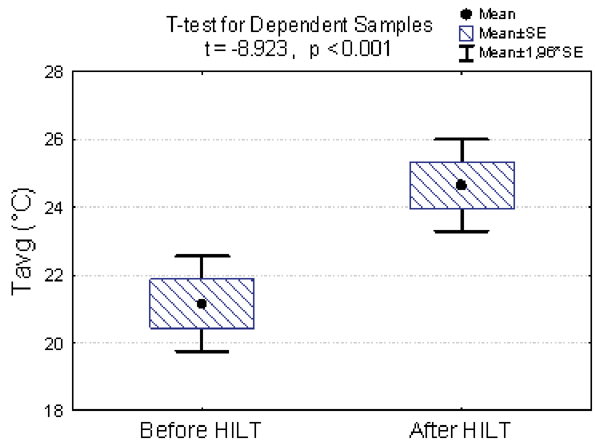

Figure 2
Mean temperature of the metatarsal surface before and after HILT and the result of the significance test
(Student's t-test for related variables).

could impair the assessment of real impact of HILT on tissue metabolism and tissue reaction, in contrast this study enable to assess the actual impact of HILT on non-pathologically changed tissues. Results of the study can be helpful to determine the most effective parameters of the HILT for regeneration process of the tissue or to monitoring short-term and long-term effects of HILT. Future studies are needed to indicate a correlation of thermography in diagnosis and monitoring of the injured tissues with other diagnostic methods like ultrasonography, radiology, scintigraphy and magnetic resonance.

References:

1.Soroko M, Henklewski R, Filipowski H, Jodkowska E. The effectiveness of thermographic analysis in equine orthopedics. J. Equine Vet. Sci. 2013; 33; 760-762.

2.Eddy AL, van Hoogmoed LM, Snyder JR. The Role of Thermography in the Management of Equine Lameness. Vet. J. 2001; 162; 172-181.

3.Yanmaz LE, Okumus Z. Thermographic Assessment of Extremity Temperature Alterations of Cases with Bucked Shin Complex, Splints, Carpal Osteoarthritis and Sesamoiditis in Sport Horses. Erciyes Üniv. Vet. Fak. Derg. 2018; 15; 41-45.

4.Cetinkaya MA, Demirutku A. Thermography in the assessment of equine lameness. Turk. J. Vet. Anim. Sci. 2012; 36; 43-48.

5.Ciutacu O, Tanase A, Miclaus, I. Research about evaluation of locomotory system of sport equine through digital infrared thermography. Buletin USAMVCN. 2007; 64; 386-390.

6.Levet T, Martens A, Devisschear L, Duchateur L, Bogaert L, Vlamink L. Distal limb cast sores in horses: risk factors and early detection using thermography. Equine Vet. J. 2009; 41; 18-23.

7.Bello CAO, Vianna ARCB, Nogueira K, Santos AC, Lima EMM. Acupuncture in the restoration of vasomotor tonus of equine athletes with back pain. J. Dairy Vet. Anim. Res. 2018; 7; 140-144.

8.Rindler N, Biermann NM, Westermann S, Buchner HHF. The effect of pulsed electromagnetic field therapy on surface temperature of horses' backs. Wien. Tierarztl. Monat. 2014; 101; 137-141.

9.Ringer SK, Lischer CJ, Ueltschi G. Assessment of scintigraphic and thermographic changes after focused extracorporeal shock wave therapy on the origin of the suspensory ligament and the fourth metatarsal bone in horses without lameness. Am. J. Vet. Res. 2005; 66; 1836-1842.

10.Bogard F, Bouchet B, Murer S, Filliard JR, Beaumont F, Polidori G. Critical evaluation of whole body cryostimulation protocol in racehorses. J. Equine Vet. Sci. 2020; 88.

11.Yarnell K, Fleming J, Stratton TD, Brassington R. Monitoring changes in skin temperature associated with exercise in horses on a water treadmill by use of infrared thermography. J. Therm. Biol. 2014; 45; 110-116.

12.Godlewska M, Soroko M, Zielinska P. Assessment of Vein Diameter and Body Surface Temperature after High-Intensity Laser Therapy (HILT) on the Tarsal Joint in Healthy Horses. J. Equine Vet. Sci. 2020; 93; 103198.

Figure 1
Distal hindlimbs from plantar aspect. The average surface temperature of a rectangular area placed over the middle part of the metatarsal bone after High Intensity Laser Therapy.

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CONVENTIONAL AND NOVEL APPROACH FOR THE ASSESSMENT OF FLANK TEMPERATURE OF POLISH NATIVE BREED MARES DURING PREGNANCY

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Introduction

Thermographic imaging has been reported as a potentially useful tool in pregnancy detection in equids [1-3]. Especially in late gestation, intrauterine processes require mares to expend a large amount of metabolic energy leading to an increase in body temperature of mare's tissues surrounded the placenta and fetus [1,4]. The regional blood flow, proliferation of tissues, metabolic and/or hormonal interactions, and protein synthesis activity have been suggested as important factors increasing the temperature of mares' body surface [1] since local alterations in metabolic processes [5,6] and blood flow [7] have been described as strongly conditioning the surface body temperature (SBT). SBT is affected both by these internal and external conditions, such as the thermal properties [8] and gradients [9]. The thermal properties of mares' body may be estimated with the use of the skin and hair coat lengths [8], whereas the thermal gradients with measurement and comparison the body and environment temperatures [9]. The conventional approach included measurement of maximal, average temperature, and/or minimal temperature in the selected region [1,3,6,8], whereas the novel approach counted the pixels in the annotated area marked as the area with the highest temperatures in the range of 3 oC which was named the area with the highest temperature. Therefore, this study aimed to assess the flank SBT of mares using conventional mean and maximal temperature and novel, an area with the highest temperature, approach. The presented computational model included the influence of external conditions and the comparison of pregnant and non-pregnant mares over consecutive months of pregnancy. We hypothesized an application of area with the highest temperature approach of the flank SBT allows to early distinguish between pregnant and nonpregnant mares. This preliminary study is the first step to noninvasive monitoring of pregnancy in wildlife polish native ponies and wild equids kept in captivity in the zoo.

Methods

The research was carried out at stud Dobrzyniewo, which is a Polish state stud farm running conservation breeding of Konik Polski horses, according to a protocol approved by the II Local Ethical Committee on Animal Testing in Warsaw (WAW2/007/2020; 15.01.2020). From the herd of 90 Konik Polski horses, 26 nonlactating mares after natural matings in February and March were selected and included in the pregnant mares group (n=26). Another 14 non-l actating mares, which were not mated this reproductive season, were qualified for the non-pregnant group (n=14). Data collection began in February, in the first month of pregnancy, and was conducted once a month until January when the last foaling of the examined mares took place. The pregnancy was confirmed ultrasonographically (MyLabOne; ESAOTE, Italy with a linear 5 MHz transducer).

Thermographic images, hair coat samples, and environment temperature were monthly examinations throughout nine months of pregnancy. Images were taken on the right and left side of the mare's body without moving a horse, using a non-contact thermographic camera (FLIR Therma CAM E60, FLIR Systems Brasil, Brazil; emissivity (e) 0.99; fixed temperature range between 10.0 and 40.0°C). The camera was placed at a distance of approximately 2.0 m from the imaged area and positioned halfway up the vertical line through the tuber coxae. Flank area was limited by the vertical line behind the tuber coxae and by the edge of the last rib. Images were taken in a closed space, protected from wind and sun radiation. The ambient temperature and humidity were measured each research day. The hair coat samples were taken from the mid-neck approximately 5 cm below the base of the mane following previously described protocol [10]. The hair coat samples including the roots were collected into the individual tubes. The conventional flank SBT (mean and maximal temperature) was calculated on the Rainbow HC palette thermal images using SENSE Batch software (SENSE Software, Poland).

The novel flank SBT approach (area with the highest temperature) was annotated in yellow on the Gray palette thermal images using FLIR Tools Professional software (FLIR Systems Brasil, Brazil) and calculated by annotated pixels counting. Pixels were segmented by thresholding the three colour channels (red, green, blue). Pixels were counted and included into the area with the highest temperature when the values of their channels were red<0.8 and green<0.8 and blue>0.5. The pixels counting experiment was implemented in Python 3.6.9. Linear regressions were calculated to compare the measurements across months of pregnancy. The regression equation and r square were presented. When differences between the slopes were not significant ($p > .05$), one slop for all the data was calculated, and then the intercepts were compared. Where necessary, linear regression was supported by Spearman's rang correlation coefficient or nonparametric tests. All statistical analyses were performed using GraphPad Prism6 software (GraphPad Software Inc., United States), where the significance level was established as $p < .05$.

Results

No differences in all features of SBT ($p < .05$) between left and right sides of the lateral surface of mares' abdomen were noted. The hair coat length and environment temperature were closely inversely proportionately related. The average and mean flank SBT differed significantly ($p < .0001$) between the months of research within pregnant and non-pregnant groups. The pregnant and nonpregnant groups were distinguished base on differences in conventional and novel features of SBT. Conventional flank SBT allowed to distinguish groups from the 9th month of pregnancy. Evidence of association between the conventional flank SBT and features of external conditions was observed. In the linear regression equation, the slopes were not different, but the intercepts were different, thus one slope for each data pairs was established. The area with the highest flank SBT differed significantly ($p < .0001$) between the months of research within the only pregnant group. Based on the novel flank SBT, distinguish groups is possible from the 7th month of pregnancy. No evidence of an association between the novel flank SBT and features of external conditions was predominantly observed.

Conclusions

The area with the highest flank SBT seems to potentially useful as a novel approach to mares' pregnancy evaluation, however, further research is needed in Polish native breed mares kept in the wild.

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References

1. Bowers S, Gandy S, Anderson B, Ryan P, Willard S. Assessment of pregnancy in the late-gestation mare using digital infrared thermography. Theriogenology 2009, 72(3); 372-7.

2. Cilulko J, Janiszewski P, Bogdaszewski M, Szczygielska E. Infrared thermal imaging in studies of wild animals. Eur. J. Wildl. Res. 2013, 59(1); 17-23.

3. Roberto JVB, De Souza BB. Use of infrared thermography in veterinary medicine and animal production. J. Anim. Behav. Biometeorol. 2020, 2(3); 73-84.

4. Beythien E, Wulf M, Ille N, Aurich J, Aurich C. Effects of sex, pregnancy and season on insulin secretion and carbohydrate metabolism in horses. Anim. Reprod. Sci. 2017, 184; 86-93.

5. Hodgson DR, McCutcheon LJ, Byrd SK, Brown WS, Bayly WM, Brengelmann GL, Gollnick PD. Dissipation of metabolic heat in the horse during exercise. J. Appl. Physiol. 1993, 74(3); 1161-70.

6. Witkowska-Pilaszewicz O, Masko M, Domino M, Winnicka A. Infrared thermography correlates with lactate concentration in blood during race training in horses. Animals 2020, 10(11); 2072.

7. Winsor, T. Vascular aspects of thermography. J. Card. Surg. 1971, 12; 379-188. PMID: 5137343

8. Domino M, Romaszewski M, Jasinski T, Masko M. Comparison of the surface thermal patterns of horses and donkeys in infrared thermography images. Animals 2020, 10(12); 2201.

9. Satchell G, McGrath M, Dixon J, Pfau T, Weller R. Effects of time of day, ambient temperature and relative humidity on the repeatability of infrared thermographic imaging in horses. Equine Vet. J. 2015, 47; 13-4.

10. Osthaus B, Proops L, Long S, Bell N, Hayday K, Burden F. Hair coat properties of donkeys, mules and horses in a temperate climate. Equine. Vet. J. 2018, 50; 339-42.

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EFFECTIVENESS OF HYDROTHERAPY APPLIED ON VARIOUS BODY PARTS IN SUPPORTING SKIN COOLING OF HORSES TRAINED IN DIFFERENT AMBIENT TEMPERATURES DURING SUMMER PERIOD

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Introduction

The process of thermoregulation allows to maintain homeostasis as it protects the body against overheating or hypothermia. Mechanisms of temperature regulation include both physiological and behavioural changes and help the organism to cope with thermal stressors. However, certain situations such as intensive training or extreme ambient temperatures may require alternative support of heat exchange. Among several methods of increasing heat dissipation, cold hydrotherapy is of particular interest. The aim of the study was to compare the effect of various hydro- therapy variants on body surface temperature changes after training in different ambient temperatures, using infrared thermography. We tested the hypothesis that the scope of required support for heat dissipation after an effort depends on ambient temperature.

Methods

We examined each of the 16 adult school horses eight times during eight separate days: four variants of supporting the thermoregulation process were carried out on warmer days and the same four variants of cooling down the horse were tested on cooler days. The experiment was conducted in the summer period (June - September 2017) and all of the horses were shorthair but not shaved. Four sessions were conducted at ambient temperature 26.1?C and four sessions at ambient temperature 15.9?C. All training sessions were performed inside an indoor riding school. After each training one of the four 30 - minutes lasting treatments was taken: only hand - walking without a saddle inside an indoor riding school (a control trial) or hand - walking combined with cooling lower parts of the body/cooling upper parts of the body/cooling the whole body (three research trials; hydrotherapy variants). In research trials, horses were cooled with 18ºC water for a 30-second. Cooling was applied directly after the workout, 10 and then 20 minutes after its end. We analysed the mean temperature values for the left and right side of the front (head, neck, shoulder blade, front leg), the central (rib cage) and rear part (hindquarters, hind leg) of the horse body. Measurements were carried at rest, directly after the training and then 10, 20 and 30 minutes later (but before cooling down the body in research trials) with a thermal imaging camera (Thermal Imagers Ti9 FLUKE). It was located 250 cm from the horse body. The horse was standing still in a dark, closed room with a constant temperature, which made it possible to avoid the impact of weather conditions on the results of the study. During the measurements, the horses had no wraps, blankets or any other protection kept on them which would distort the obtained results. The images were subsequently uploaded to the computer and analysed in SmartView 4.1 software. The statistical analysis was based on repeated measures analysis of variance and multiple T-Tukey tests.

Results

The weather conditions had no effect on the post-workout temperature of the head, rib cage and legs but for the neck, shoulder blade and hindquarters higher values were recorded after the exercise in warmer air temperature. Applying hydrotherapy at ambient temperature 15.9°C resulted in faster surface temperature drop compared to 26.°C. The most significant differences concerned cooling lower parts of the body or cooling the whole body. However, in cooling the whole-body treatment, delayed surface temperature decline was observed. During a lower ambient temperature experiment stage, we noted significant drop of surface temperature in each body part whereas in the first stage (26.1°C) changes were observed to a lesser degree and did not include head and rib cage. In most of the measurements, applying a control trial was associated with the highest surface temperature, especially in colder weather. Concerning four variants of supported recovery in the same type of external conditions, the analysis revealed their different impact on skin temperature. Cooling the whole body or its lower parts turned out the most effective hydrotherapy variant for horses trained in higher air temperature. In turn, the most significant effect of heat dissipation after exercise at 15.9°C was found for cooling the whole body or its upper parts. In this case, cooling the lower parts of the body had a moderate effect.

Discussion

Ambient temperature had a particular impact on the post-workout surface temperature of body parts with a greater percentage of muscles generating heat, but this effect was short - term. After exercise, in warmer days, the process of heat dissipation was not entirely effective, and the surface temperature drop after training in lower ambient temperature was greater. Thus, air temperature should be considered when choosing an optimal supporting treatment. Because hand - walking in a shaded area may not be sufficient recovery, certain variants of hydrotherapy ought to be considered. In higher air temperatures cooling the whole body or its lower parts may be applied since these methods are just as effective. Even if cooling the whole body is the most effective thermoregulation supporting treatment in lower air temperatures, this variant should not be followed a workout in colder days as it can lead to excessive cooling of the body surface. We rather recommend a moderate variant - cooling lower body parts, when necessary, instead.

Table 1
External conditions in two stages of the experiment (means ± SD)
Means in rows marked with different letters significantly differ at P≤ 0.05.

External conditions	Warmer days	Cooler days
Air temperature (°C)	26.1 ± 2.7a	15.9 ± 2.4b
Air relative humidity (%)	57.3 ± 8.0a	55.0 ± 8.4 a
Speed of air movement (m/s)	0.5 ± 0.0a	0.51 ± 0.0 a

Table 2
Post-workout surface temperature of the front part of the body of examined horses (means ± SD)
Means in columns marked with different letters significantly differ at P≤0.05.

	Warmer days	Cooler days
Head (°C)	34.7 ± 0.4a	33.5 ± 0.3a
Neck (°C)	39.4 ± 0.4a	34.5 ± 0.5b
Shoulder blade (°C)	38.0 ± 0.3a	33.14 ± 0.2a
Front leg (°C)	34.9 ± 0.8	32.78 ± 0.7a

Table 3
Post-workout surface temperature of central and rear part of the body of examined horses (means ± SD)
Means in columns marked with different letters significantly differ at P≤0.05.

	Warmer days	Cooler days
Rib cage (°C)	34.8 ± 0.9a	34.4 ± 0.6a
Hindquarters (°C)	36.6 ± 0.7a	34.5 ± 0.7b
Hind leg (°C)	33.3 ± 0.6a	33.2 ± 0.8a

Table 4 – The first recovery surface temperature (°C) of the front part of the body of examined horses (means ± SD)
Means in columns marked with different letters (x, y: concerning various types of ambient conditions during the same variant of supported recovery; a, b - concerning different variants of supported recovery in the same type of external conditions) significantly differ at P≤0.05.

Variant of supported recovery	Head	Neck	Shoulder blade	Front leg
Warmer days				
Control	33.5 ± 1.1xa	37.0 ± 1.1xa	36.7 ± 1.7xa	32.5 ± 1.1xa
Cooling lower parts of the body	33.7 ± 1.9xa	36.4 ± 1.3xa	34.7 ± 1.3xb	31.2 ± 1.8xa
Cooling upper parts of the body	33.3 ± 1.2xa	35.9 ± 1.3xa	36.4 ± 1.2xa	32.4 ± 1.1xa
Cooling the whole body	33.8 ± 0.9xa	33.9 ± 1.0xb	34.6 ± 1.5xb	31.2 ± 1.6xa
Cooler days				
Control	33.4 ± 1.2xa	34.3 ± 1.1ya	34.5 ± 1.2ya	32.9 ± 1.0xa
Cooling lower parts of the body	33.3 ± 1.6xa	34.7 ± 1.5ya	34.9 ± 1.5xa	31.1 ± 1.9xab
Cooling upper parts of the body	32.9 ± 0.9xa	32.2 ± 1.0yb	33.4 ± 1.1ya	31.5 ± 1.0xab
Cooling the whole body	33.0 ± 0.7xa	33.3 ± 0.9xab	33.7 ± 0.9xa	30.5 ± 1.4xb

Table 5
The first restitution surface temperature (°C) of the rear part of the body of examined horses (means ± SD)
Means in columns marked with different letters (x, y: concerning various types of ambient conditions during the same variant of supported recovery; a, b, c - concerning different variants of supported recovery in the same type of external conditions) significantly differ at P≤0.05.

Type of supported recovery	Rib cage	Hindquarters	Hind leg
Warmer days			
Control	34.3 ± 1.2xa	36.5 ± 1.4xa	33.0 ± 1.3xa
Cooling lower parts of the body	35.5 ± 1.0xa	35.1 ± 1.7xb	32.0 ± 1.9xa
Cooling upper parts of the body	34.0 ± 1.2xa	35.5 ± 1.3xb	32.6 ± 1.5xa
Cooling the whole body	34.1 ± 1.2xa	33.7 ± 1.4xc	32.0 ± 1.4xa
Cooler days			
Control	34.3 ± 1.4xa	35.3 ± 1.4ya	33.3 ± 1.2xa
Cooling lower parts of the body	33.5 ± 1.7ya	33.6 ± 1.8yb	31.9 ± 1.7xb
Cooling upper parts of the body	33.3 ± 1.7xa	32.8 ± 1.7yb	32.0 ± 1.7xb
Cooling the whole body	33.4 ± 1.0xa	34.0 ± 1.1xab	31.1 ± 1.1xb

Table 6
The second recovery surface temperature (°C) of the front part of the body of examined horses (means ± SD)
Means in columns marked with different letters (x, y: concerning various types of ambient conditions during the same variant of supported recovery; a, b - concerning different variants of supported recovery in the same type of external conditions) significantly differ at P≤0.05.

Type of supported recovery	Head	Neck	Shoulder blade	Front leg
Warmer days				
Control	33.3 ± 1.1xa	34.0 ± 1.3xa	34.3 ± 1.5xa	32.2 ± 1.6xa
Cooling lower parts of the body	33.5 ± 1.6xa	34.3 ± 1.6xa	35.0 ± 1.6xa	30.6 ± 1.3xb
Cooling upper parts of the body	32.9 ± 1.2xa	32.2 ± 1.1xb	33.4 ± 1.0xa	31.5 ± 1.4xab
Cooling the whole body	33.0 ± 1.1xa	33.3 ± 1.3xa	33.7 ± 1.6xa	30.5 ± 1.1xb
Cooler days				
Control	33.4 ± 1.6xa	34.1 ± 1.6xa	34.3 ± 1.0xa	32.6 ± 2.2xa
Cooling lower parts of the body	33.0 ± 1.4xab	33.0 ± 1.6yab	33.3 ± 1.3yb	29.9 ± 1.3xb
Cooling upper parts of the body	32.1 ± 0.8xb	32.4 ± 1.3xb	33.2 ± 1.2xb	31.2 ± 1.3xb
Cooling the whole body	33.3 ± 1.3xa	32.7 ± 1.2 xb	33.5 ± 1.4xa	29.1 ± 1.2yb

Table 7
The second recovery surface temperature (°C) of the rear part of the body of examined horses (means ± SD)
Means in columns marked with different letters (x, y: concerning various types of ambient conditions during the same variant of supported recovery; a, b - concerning different variants of supported recovery in the same type of external conditions) significantly differ at P≤0.05.

Variant of supported recovery	Rib cage	Hindquarters	Hind leg
Warmer days			
Control	34.1 ± 1.4xa	33.7 ± 1.3xa	32.6 ± 1.6xa
Cooling lower parts of the body	34.2 ± 1.5xa	33.7 ± 1.6xa	31.1 ± 2.0xb
Cooling upper parts of the body	33.3 ± 1.0xa	32.8 ± 0.9xa	33.0 ± 1.1xab
Cooling the whole body	33.4 ± 1.4xa	34.0 ± 1.4xa	31.1 ± 1.7xb
Cooler days			
Control	34.2 ± 1.9xa	33.9 ± 1.9xa	33.1 ± 2.0xa
Cooling lower parts of the body	33.4 ± 1.8xab	33.0 ± 1.9xab	30.6 ± 1.7xb
Cooling upper parts of the body	32.7 ± 1.8xb	33.2 ± 1.7xab	31.4 ± 1.6xb
Cooling the whole body	32.9 ± 1.4xb	32.7 ± 1.4yb	29.9 ± 1.9xb

Table 8
The third recovery surface temperature (°C) of the front part of the body of examined horses (means ± SD)
Means in columns marked with different letters (x, y: concerning various types of ambient conditions during the same variant of supported recovery; a, b - concerning different variants of supported recovery in the same type of external conditions) significantly differ at P≤0.05.

Recovery supporting variant	Head	Neck	Shoulder blade	Front leg
Warmer days				
Control	33.1 ± 1.1xa	34.0 ± 1.2xa	34.3 ± 1.1xa	32.1 ± 1.6xa
Cooling lower parts of the body	33.5 ± 1.4xa	33.9 ± 1.7xa	34.3 ± 1.0xa	30.1 ± 2.2xb
Cooling upper parts of the body	33.0 ± 1.2xa	33.4 ± 1.3xa	34.0 ± 1.1xa	32.0 ± 1.7xa
Cooling the whole body	33.6 ± 1.1xa	33.0 ± 1.5xa	34.1 ± 1.4xa	30.7 ± 1.9xb
Cooler days				
Control	33.1 ± 1.3xa	33.8 ± 1.5xa	34.1 ± 1.6xa	32.2 ± 1.6xa
Cooling lower parts of the body	33.3 ± 1.3xa	33.6 ± 1.4xa	33.3 ± 1.2yab	30.0 ± 1.7xb
Cooling upper parts of the body	32.4 ± 1.2xa	32.1 ± 2.0yb	33.1 ± 1.2xab	31.1 ± 1.8xab
Cooling down entire body	32.5 ± 0.9xa	32.1 ± 1.4xb	33.0 ± 1.2yb	28.6 ± 1.9yb

Table 9
The third recovery surface temperature (°C) of the hind part of the body of examined horses (means ± SD)
Means in columns marked with different letters (x, y: concerning various types of ambient conditions during the same variant of supported recovery; a, b - concerning different variants of supported recovery in the same type of external conditions) significantly differ at P≤0.05.

Type of supported recovery	Rib cage	Hindquarters	Hind leg
Warmer days			
Control	34.1 ± 1.2xa	33.8 ± 1.2xa	32.6 ± 1.6xa
Cooling lower parts of the body	33.9 ± 1.8xa	33.4 ± 1.8xa	30.7 ± 2.4xb
Cooling upper parts of the body	33.6 ± 1.2xa	32.9 ± 1.2xa	32.3 ± 1.2xa
Cooling the whole body	33.7 ± 1.9xa	33.2 ± 1.7xa	31.2 ± 1.9xb
Cooler days			
Control	34.0 ± 1.8xa	33.7 ± 1.8xa	32.7 ± 1.5xa
Cooling lower parts of the body	33.2 ± 1.4xa	32.9 ± 1.7xab	30.6 ± 1.7xb
Cooling upper parts of the body	32.4 ± 1.9xb	32.1 ± 1.9xb	31.1 ± 1.8xb
Cooling the whole body	32.3 ± 1.3yb	32.0 ± 1.4xb	29.3 ± 1.8xb

References

Bueley D, Voisine P, Tutton J, Watters R. U.S. Patent Application; 2004; 10/282, p. 616.

Charkoudian N. Skin blood flow in adult human thermo- regulation: how it works, when it does not, and why. Mayo Clinic Proceedings 2003; 78(5) 603-12.

Eccles R. Acute cooling of the body surface and the common cold. Rhinology 2002; 40: 109-14.

Hassi J, Rytkönen M, Kotaniemi J, Rintamäki H. Impacts of cold climate on human heat balance, performance and health in circumpolar areas. Int. J. Circumpolar Health 2005; 64: 459-467.

Hodgson DR, Davis RE, McConaghy FF. Thermoregulation in the horse in response to exercise. Br. Vet. J. 1994; 150: 219-235.

Höppe PR. Heat balance modelling. Experientia 1993; 49: 741-746.

Jodkowska E, Dudek K, Przewozny M. The maximum temperatures (Tmax) distribution on the body surface of sport horses. J. Life Sci. 2011; 5: 291-297.

McKeever KH; Eaton TL; Geiser S, Kearns CF, Lehnhard RA. Age related decreases in thermoregulation and cardiovascular function in horses. Equine Vet. J. 2010; 42: 220-227.

Olczak K, Klocek C. Wplyw wybranych zjawisk atmosferycznych na zachowanie koni. Medycyna Weterynaryjna 2013; 69(10) 602-605.

Skandhan KP, Rajahariprasad A. The process of spermatogenesis liberates significant heat and the scrotum has a role in body thermoregulation. Med. Hypotheses 2007; 68: 303-307.

Snoeks MG, Moons CPH, Ödberg FO, Aviron M, Geers R. Behavior of horses on pasture in relation to weather and shelter - A field study in a temperate climate. Journal of Veterinary Behavior 2015; 10: 561-568.

Soroko M, Morel MCGD. Equine thermography in practice; 2016; p. 5-140.

Turner TA. Diagnostic thermography. Vet. Clin. North Am. Equine Pract. 2011; 17: 95-114.

Van Hoogmoed LM, Snyder JR. Use of infrared thermography to detect injections and palmar digital neurectomy in horses. Vet. J. 2002; 164: 129-41.

Waclawik J, Branny M. Zasady oceny obciazenia termicznego metoda modelowania wymiany ciepla miedzy pracownikiem a otoczeniem. WUG: Bezpieczenstwo Pracy i Ochrona Srodowiska w Górnictwie 2006; 1: 3-13.

Young AJ, Sawka MN, Epstein Y, Decristofano B, Pandolf KB. Cooling different body surfaces during upper and lower body exercise. J. Appl. Physiol. 1987; 63: 1218-1223.

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THERMOGRAPHIC MEASUREMENTS IN THE TOPIC OF THESES OF STUDENTS OF HEALTH CARE STUDY PROGRAMMES

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Introduction

The aim of the paper is to present the topics of students' theses, which use methods of thermographic measurements. We have had the InfraTec VarioCAM® HD thermal imaging camera with a resolution of 640 x 480 pixels since January 2018 and its main use is in teaching students of medical and non-medical health care study programmes. Students of general medicine and non-medical medical programs get acquainted with the using of thermal imaging camera in medicine within the teaching of biophysics during the first year of study. Students of non-medical health programs then prepare their bachelor's or master's thesis at the end of their studies. In the topics of student thesis, the use of a thermal imaging camera also appears in practice.

Methods

From the beginning, we have cooperated very closely with the Department of Rehabilitation, further cooperation has been established with the Department of Epidemiology and Public Health.

The final theses of physiotherapy students are standardly focused on physiotherapy in various areas, bachelor's theses usually deal with a specific case study. However, it turned out that thermal imaging evaluation of therapy is a suitable tool to confirm the effectiveness and objectification of the effects of therapy. The first of the works that used a thermal imaging camera was **"Monitoring effectiveness of manual soft tissue techniques in therapy of scar in abdominal cavity"**. The aim of the thesis was verification if the manual soft tissue techniques will change blood supply and pain in active scar localized in abdominal skin. The practical part of the thesis contains research, where the experimental group consisted of 20 women with active scar after cesarean section. Thermal imaging was used as a surrogate measure for blood flow and the pain level was measured with a visual analogue scale. pain. The experimental group was monitored the short-Ostrava 3, Czech Republicterm effect of therapy immediately after application of manual soft technique, and 13 of them were evaluated the long-term effect of therapy after 1 and 6 weeks. Research shows that pain and blood flow are not the same at all points of the scar. The results showed a statistically significant difference ($p = 0,0004$) in the change in the scar temperature range after 6 weeks of therapy and a statistically significant ($p = 0, 0015$) reduction in scar pain after 1 and 6 weeks of therapy. According to the findings, the manual soft tissue techniques positively influences scar quality.

Also, two other thesis **"The Influence of vacuum therapy in the form of cupping on trigger point therap**y**"** and **"Thermographic evaluation of effects of selected means of physical therapy and post-isometric relaxation in trigger point therap**y**"** were focused on thermographic evaluation of techniques used in physiotherapy. The aim of the second thesis was to compare myorelaxant effect of dia-d ynamic currents, combination therapy, and post-isometric relaxation in trigger point therapy. Changes of temperature were observed at specific spots above trigger points and these points were treated by one of the three therapeutic measures. The temperature differences before and after the therapy were similar in two selected muscles with greatest change after combination therapy, followed by treatment with diadynamic currents, and after post-isometric relaxation. Statistically significant difference in temperatures above trigger points was found only with application of combination therapy and by use of post-isometric relaxation.

The diploma thesis **"Objectivisation of changes in body blood circulation during increased physical activity within working activity"** is then the first of those where thermo- graphic evaluation taken as primary outcome. The measurement took place outside the school laboratory, directly at the probands' workplace. The research was done in a company that produces plastic parts and components. The skin above selected muscles were evaluated by thermographic camera on both sides in corresponding parts of the body and the temperature difference caused by one-sided loading was monitored. A total of 20 probands participated in the research and were allocated into 2 groups - those who exercised regularly and those who did not. There were 11 probands in the exercising group, the non-exercising group consisted of 9 subjects. The exercising probands were asked to perform an exercising routine aimed at muscle strengthening, improving the muscle coordination, relieving the increased muscle tension and stretching of the shortened muscles in the most strained body parts for seven weeks. The measurements were taken in a total of three sets, with the second measurement being performed after one month and the third set after seven weeks. Each set of measurements was divided into 3 measurements. The first measurement was taken before the start of the work shift, the second followed in the middle of the work shift and the third measurement was performed at the end of the workday. The results show a significant decrease in temperature difference in all measured segments of corresponding parts of the body after seven weeks of exercise.

In the field of hygiene and public health, the thermal imaging camera was used for the diploma thesis in the study program for specialist in public health protection for the assessment of thermal effects of radiofrequency radiation from commonly available sources - mobile phones. These effects were measured by thermal imaging. Specifically, the area near the ear was scanned on 15 probands during a 30minute call with a different type of mobile phone. In addition, a phantom was created to compare the heating of human skin caused by exposure to radiation from a mobile phone, which was exposed to many times higher microwave power than the mobile phone. The evaluation of the measurements showed an increase in the surface temperature of the skin, mostly during the first 6 minutes of exposure, however, the resulting temperature difference was still within the recommended values.

Conclusion

Based on current experience, we offer new topics for next academic years related to the use of a thermographic camera, such as a topic devoted to the effect of hyperbaroxia or a topic focused on influencing the measurement results by non-standard conditions. We still plan to continue cooperation with the Department of Rehabilitation and the Department of Hygiene and Epidemiology and to implement other topics within the student work.

References

Kotajna, Z.; Monitoring effectiveness of manual soft tissue techniques in therapy of scar in abdominal cavity. Diploma thesis. Supervisor: Kubonova, E., Consultant: Sochorova, H.; 2018.

Kubac, J.; The Influence of vacuum therapy in the form of cupping on trigger point. Bachelor thesis. Supervisor: Kristinikova, J., Consultant: Sochorova, H.; 2019.

Novotna, A.; Thermographic evaluation of effects of selected means of physical therapy and post-isometric relaxation in trigger point therapy. Diploma thesis. Supervisor: Kristinikova, J., Consultant: Sochorova, H.; 2020.

Barnet, P.; Objectivization of changes in body blood circulation during increased physical activity within working activity. Diploma thesis. Supervisor: Kristinikova, J., Consultant: Sochorova, H.; 2020.

Hnizdilova, V.; The use of Thermography in evaluating the effect of one-hour sitting at a computer on the muscular system. Bachelor thesis. Supervisor: Wrona, J., Consultant: Sochorova, H.; 2021.

Mlynkova, M.; Thermal effects of radiofrequency radiation. Diploma thesis. Supervisor: Sochorova, H.; 2021.

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DYNAMICS OF THE LOCAL TEMPERATURE OF BLOOD, PUS, MUCUS AND CATALASE SOLUTION WHEN THEY INTERACT WITH A SOLUTION OF HYDROGEN PEROXIDE IN VITRO

A.L.Urakov[1], A.P.Stolyarenko[1], M.V.Kopitov[1], L.I.Bashirov[1]

[1] Izhevsk State Medical Academy, Russia,

Introduction

The solution of hydrogen peroxide is widely used in medical institutions and in domestic conditions as a hygienic, antiseptic, and disinfectant for various purulent diseases. The chemical formula of hydrogen peroxide is similar to the formula of water (H_2O), differing by an additional oxygen atom - H2O2. This extra oxygen is relatively loosely bound, making H_2O_2 a highly reactive chemical that tends to oxidize any other molecules around it. It is so reactive that it can be used as rocket fuel in high concentrations. In this regard, for safety, even an aqueous solution of hydrogen peroxide with a concentration of 35% requires special processing and transportation procedures. Therefore, a solution of 3% hydrogen peroxide is usually used as a household disinfectant.

A hydrogen peroxide solution is a kind of oxygen salt solution with a time-varying pH level and molecular oxygen content. The pH value depends, most of all, on the degree of dissociation. In dilute solutions, hydrogen peroxide spontaneously breaks down into H_2O and O_2. In turn, it is the disproportionation reaction (in other words, the splitting reaction) that determines the amount of molecular oxygen. This reaction is catalysed by transition metal ions (catalysts) and some proteins, in particular, the enzyme catalase. The breaking of the hydroperoxide O-O bond in the H_2O_2 molecule may have a heterolytic and/or homolytic mechanism. In this case, different complexes of iron porphyrins have a different effect on the mechanism of splitting hydrogen peroxide, which can occur as heterolysis or haemolysis. In this case, the mechanism of cleavage is determined by the electronic nature of iron porphyrin complexes. In addition, the catalyst for the cleavage of hydrogen peroxide is $Fe(NO_3)_3$. In living systems, in addition to transition metal cations, the enzyme catalase has a huge influence on the process of splitting hydrogen peroxide into water and oxygen gas. Catalase is a common enzyme found in nearly all living organisms exposed to oxygen (such as bacteria, plants, and animals) which catalyzes the decomposition of hydrogen peroxide to water and oxygen. In some bacteria catalase may account for as much as 1% of their total dry weight.

In mammals, catalase is found predominantly in the liver. High concentrations are also present in erythrocytes, where it serves to neutralize the hydrogen peroxide formed during the autoxidation of oxyhaemoglobin to methaemoglobin. Human erythrocyte catalase is used to protect haemoglobin by removing hydrogen peroxide generated from erythrocytes. Human catalase is a haem-containing enzyme whose primary function is to break down hydrogen peroxide into two molecules of water and one molecule of oxygen. The hydrogen peroxide cleavage reaction is an exothermic reaction.

When applied topically, hydrogen peroxide can oxidize various biological substances and materials. In this case, during their oxidation, heat can be released, which can increase the local temperature in the interaction region. Therefore, local hyperthermia can be an indicator of the intensity of oxidation and a criterion for the adequacy of the administered dose of hydrogen peroxide. However, the dynamics of the local temperature of the treated tissues at the site of interaction of the hydrogen peroxide solution with biological material products such as blood, pus, mucus, meconium, or faecal matter remain unexplored. Monitoring the local temperature with a thermal imager may be a safe and non-invasive method for assessing the quality of the local action of a hydrogen peroxide solution in real time in areas of medicine such as purulent surgery, otorhinolaryngology, dentistry, cosmetology, paediatrics, obstetrics and gynaecology, as well as in the food industry.

Methods

We studied the dynamics of local temperature in a portion of venous blood, as well as pus and mucous obtained from the upper respiratory tract of patients suffering from acute respiratory infections, when interacting locally with a portion of a 3% hydrogen peroxide solution in a Petri dish. In this case, biological fluids in a volume of 0.2 ml were placed on the bottom of a Petri dish and formed a round puddle with a diameter of about 10 mm, then a solution of hydrogen peroxide was introduced into the centre of each puddle in the volume of 3 drops. Drops dripped from the spout of the factory bottle from a height of 10 mm. The studies were conducted in a room with a temperature of +24 ± 1.5 °C. The temperature dynamics were recorded using a Thermo Tracer TH9100XX (NEC, USA). The temperature was recorded for 90 seconds after the beginning of the local interaction of the studied media.

Results

We investigated the ability of a hydrogen peroxide solution to change the local temperature of an isolated portion of blood, pus, and mucus under local interaction at room temperature. The results showed that hydrogen peroxide caused the formation of a white foam when interacting with all these biological fluids. The foam appeared immediately after the introduction of drops, and the intensity of its formation was comparable in all biological objects. At the same time, the temperature of the portion of pus and mucus practically did not change for 90 seconds, and the temperature of the portion of blood increased rapidly from the very beginning. Moreover, after 18-22 s, it increased to the maximum value, and then decreased and reached the initial value after 70-75 s. The maximum value of local hyperthermia was observed on average 20 ± 0.7 s after the start of the local interaction. The zone of maximum local temperature was in the geometric centre of the blood portion, into which a solution of hydrogen peroxide was injected. (Fig. 1).

It turned out that in the center of the interaction zone, the maximum values of the local temperature exceeded the initial values by an average of 9 ± 0.5 °C.

Thus, the same portions of pus, mucus and blood are equally foamed, and a white foam is formed in them in the same way when interacting locally with a solution of 3% hydrogen peroxide. However, these biological fluids emit heat differently when interacting with hydrogen peroxide. Pus and mucus obtained from the respiratory tract emit little heat when interacting with a solution of hydrogen peroxide, and the venous blood immediately begins to emit heat and the temperature of the foam increases by 9 °C. At room temperature, the blood foam remains warm for more than 1 minute.

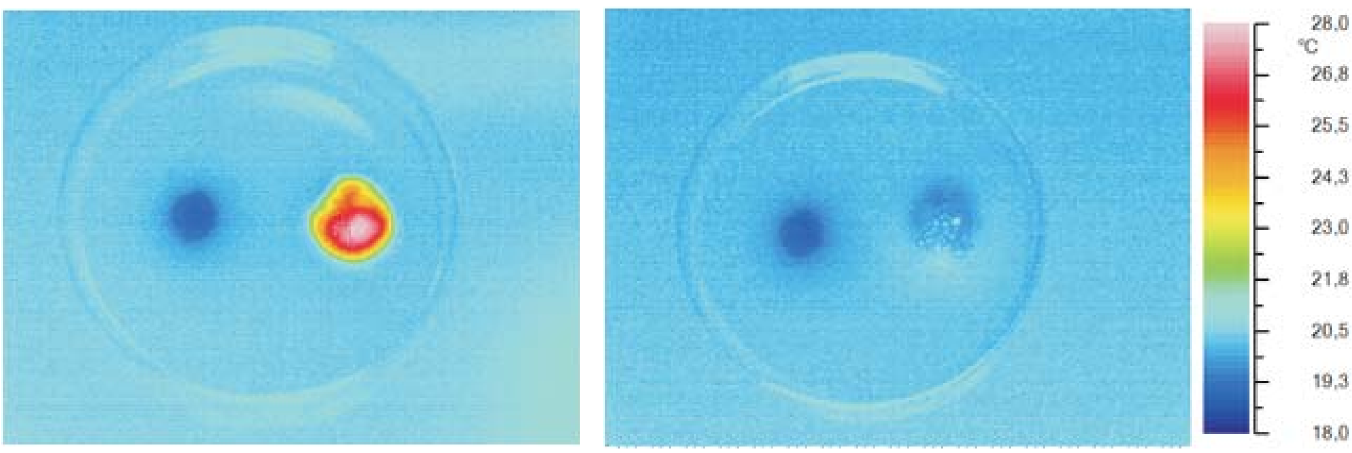
In our opinion, the appearance of foam in the interaction of a solution of hydrogen peroxide with pus, mucous and blood, indicates the splitting of hydrogen peroxide into water and oxygen gas. This occurs under the influence of catalase, which is present in these biological fluids in quite large quantities. Heat can be released in this case since the splitting of hydrogen peroxide is an exothermic reaction. However, a lot of heat is released only when hydrogen peroxide interacts with venous blood.

After that, another series of experiments was carried out, in which a solution of hydrogen peroxide was re-injected 3 drops into a portion of pus, mucus and blood 3 minutes after the first injection. When hydrogen peroxide solution was re-injected into these biological fluids, new foam became visible, but the surface temperature of foam was the same as the ambient temperature. The results showed that repeated administration of a solution of hydrogen peroxide repeatedly causes the appearance of a white foam in all these biological fluids, but only the first reaction emits a lot of heat. Strong heating of the foam occurs only when a solution of hydrogen peroxide is injected into the blood. Heating occurs even though at this point the blood loses the status of "venous" blood and has the status of "arterial" blood, that is, oxygenated blood.

Therefore, when hydrogen peroxide interacts with biological fluids, heat can be released, which can be detected using a thermal imager. It turned out that heat is released most of all when hydrogen peroxide interacts with blood. and the release of heat is practically independent of the oxygenation of the blood. Apparently, heat is released not only due to the catalase cleavage of hydrogen peroxide, but also due to the interaction of molecular oxygen with haemoglobin, as with an organic pigment. In particular, heat can be released during the oxidative discolouration of haemoglobin and its coloured metabolites [1].

Conclusion

Infrared visualization allows us to evaluate the dynamics of the local temperature in the extracted areas of interacting media in real time without physical contact, without interfering with the course of physical and chemical processes.



a b

Figure 1.
Two portions of venous blood 20 seconds (a) and 75 s (b) after the introduction of 3 drops of 0.9% sodium chloride solution (left) and 3% hydrogen peroxide solution (right) on the bottom of a Petri dish at room temperature.

Therefore, the thermal imager can be suitable for controlling chemical equipment (in particular, dishes), technologists for the modernization of chemical, physical and physical-chemical processes in scientific laboratories, as well as in production workshops to improve the accuracy of modelling and synthesis of processes and the quality of final products. In addition, our results show that the thermal imaging study of the dynamics of the local temperature of the medium interacting with chemical reagents allows a qualitative control of thermal energy release.

References

1. Urakov A., Urakova N., Nikolenko V., Belkharoeva R., Achkasov E., Kochurova E., Gavryushova L., Sinelnikov M. Current and emerging methods for treatment of hemoglobin related cutaneous discoloration: a literature review. Heliyon. 2021; 7(1): e059542.

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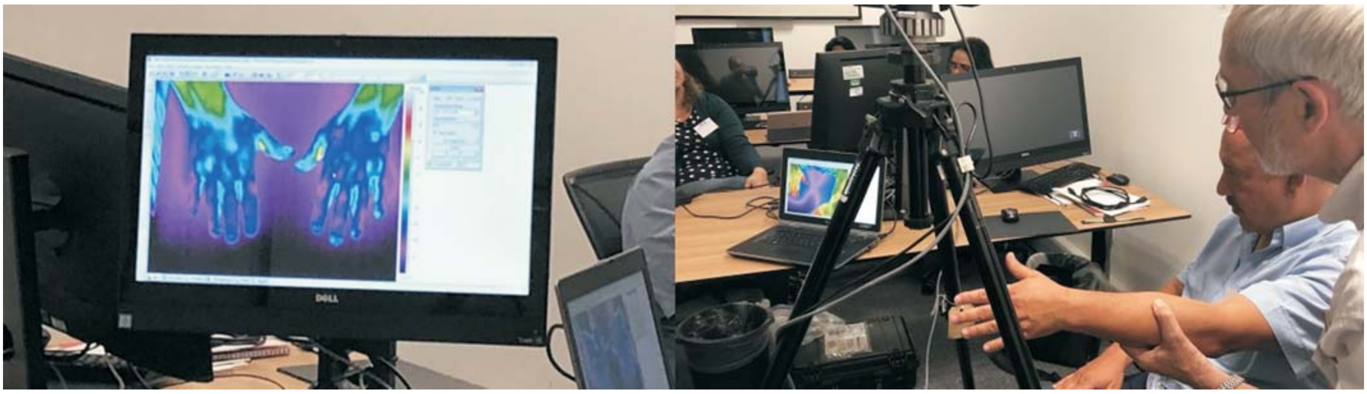

The Short Course in Medical Thermography

will take place online on 1st September 2021, immediately prior to the XV Congress of the EAT.

- Main themes of the 2021 syllabus will include:
- Physical principles of heat transfer (Ricardo Vardasca)
- Principles of thermal physiology and skin blood perfusion (James Mercer)
- Standardization of thermal imaging, recording and analysis (Kurt Ammer)
- Quality assurance for thermal imaging systems (Kevin Howell)
- Producing a thermographic report (Kurt Ammer)
- Provocation tests (James Mercer and Manuell Sillero)
- Image analysis (Kurt Ammer and Ricardo Vardasca)
- Image capture and analysis example (Aderito Seixas and Ricardo Vardasca)
- Educational resources (Aderito Seixas)

Online Programme

Thursday 2nd September 2021

All times CEST (Central European Summer Time)

Chair: Dr. Kevin Howell, President, EAT
Royal Free Hospital, London, UK.

12:45-13:00 Conference Opening.

13:00-13:30 KEYNOTE: COMFORT, THERMAL STRESS, AND CLOTHING
Prof George Havenith, Professor of Environmental Physiology and Ergonomics, Loughborough University, UK.
13:30-13:40 Discussion.

13:40-13:55 PROGRESS IN IMPROVING BODY TEMPERATURE MEASUREMENT ON A GLOBAL BASIS.
G. Machin, X. Lu, D. del Campo, M. Martin, I.Pušnik, W. Li.
13:55-14:00 Discussion.

14:00-14:15 THE USE OF THE CAMERA FLIR T530sc TO IDENTIFY PATIENTS WITH FEVER IN A TERTIARY HOSPITAL IN BRASÍLIA - BRAZIL.
T.H.T. Carvalho, T. Miliou, H.S. Luz, I.A.G. Oliveira.
14:15-14:20 Discussion.

14:20-14:35 SYSTEMATIC REVIEWS AND META-ANALYSIS ABOUT INFRARED THERMOGRAPHY IN MUSCULOSKELETAL RESEARCH - TRENDS AND CRITICAL APPRAISAL.
A. Seixas.
14:35-14:40 Discussion.

14:40-14:55 SELECTING DOMINANT PERFORATING BLOOD VESSELS FOR AUTOLOGOUS BREAST RECONSTRUCTION: A COMPARATIVE STUDY USING DYNAMIC INFRARED THERMOGRAPHY, LASER FLUORESCENCE ANGIOGRAPHY OF INDOCYANINE GREEN, ULTRASOUND DOPPLER AND CT ANGIOGRAPHY.
J.B. Mercer, M. Chaudhry, S. Weum, L. de Weerd.
14:55-15:00 Discussion.

15:00-15:15 THERMORECOVERY PROJECT: EFFECT OF A 10KM RUN ON SKIN TEMPERATURE AND THERMAL PARAMETERS AFTER A COLD-STRESS TEST IN THE SUBSEQUENT 24H.
J.I. Priego-Quesada, I. Catalá-Vilaplana, J.L. Bermejo-Ruiz, A. Gandia-Soriano, M.T. Pellicer-Chenoll, A. Encarnación-Martínez, R. Cibrián Ortiz de Anda, R. Salvador-Palmer.
15:15-15:20 Discussion.

Friday 3rd September 2021

Chair: Dr. Maria Soroko, Chair of XV Congress Organising Committee
Wroclaw University of Environmental and Life Sciences, Wroclaw, Poland.

10:00-10:05 **Welcome to Day 2.**

10:05-10:20 BLOOD SUPPLY VISUALIZATION BY INFRARED THERMOGRAPHY AND INDOCYANINE GREEN FLUORESCENCE IMAGING IN OPEN
E. Staffa, V. Bernard, J. Pokorna, T. Juza, V. Can, M. Farkasova, S. Richter, V. Mornstein, Z. Kala
10:20-10:25 Discussion.

10:25-10:40 THERMAL IMAGING IN RHEUMATOID ARTHRITIS KNEES JOINTS AND ist CORRELATION WITH POWER DOPPLER ULTRASOUND.
V. Vasdev, R. Singh.
10:40-10:45 Discussion.

0:45-11:00 PLANTAR FOOT ASSESSMENT USING LIQUID CRYSTAL THERMOGRAPHY.
P. Plassmann, B. Kluwe.
11:00-11:05 Discussion.

11:05-11:20 THE USE OF INFRARED THERMOGRAPHY TO EVALUATE THE EFFECT OF HIGH INTENSITY LASER THERAPY ON THE SURFACE TEMPERATURE OF THE HINDLIMB'S FLEXOR TENDON AREA IN CLINICALLY HEALTHY RACEHORSES
M. Godlewska, M. Soroko, P. Zielinska, K. Dudek.
11:20-11:25 Discussion.

11:25-11:40 APPLICATION OF INFRARED THERMOGRAPHY IN THE ASSESMENT OF
N. Cebulj-Kadunc, R. Frangež, P. Kruljc.
11:40-11:45 Discussion.

11:45-12:00 CHANGES OF BODY SURFACE TEMPERATURE ASSOCIATED WITH HIGH-SPEED TREADMILL EXERCISE IN BEAGLE DOGS BY USE OF INFRARED THERMOGRAPHY.
M.Soroko, W. Górniak, K.J. Howell P. Zielinska, K. Dudek, M. Eberhardt, P. Kalak, M. Korczynski.
12:00-12:05 Discussion

12:05-12:20 Award ceremony: The Francis Ring and Kurt Ammer prizes.

12:20 Close of conference.

Online video presentations

View "on-demand" at our website from 2nd September.

EVALUATING THE APPLICATION OF INFRA-RED THERMOGRAPHY TO MEASUREMENT OF SKIN TEMPERATURE DURING ROAD-RACE COMPETITION.
P.E. Aylwin, S. Racinais, P-E. Adami, J-M. Alonso, S. Bermon, N. Bouscaren, S. Buitrago, M. Cardinale, C. Esh, F. Garrandes, J. Gomez-Ezeiza, S. Hodder M. Ihsan, M. Labidi G.Lange, A. Lloyd, S. Moussay, K. Mtibaa, L. Taylor, N. Townsend, M. Wilson, G. Havenith.

IRT IMAGE EVALUATION VARIABILITY - EFFECT OF SUBJECTIVE PLACEMENT OF THE REGION OF INTEREST.
V. Bernard, E. Staffa.

PAINFUL SHOULDER SYNDROME IN THERMAL AND SONOGRAPHIC IMAGING.
J. Gabrhel, Z. Popracová, Z. Tauchmannová.

BODY TEMPERATURE MEASURED BY A FOREHEAD THERMOMETER IN AFEBRILE SUBJECTS ATTENDING A HOSPITAL CLINIC DURING THE COVID-19 PANDEMIC.
K. J. Howell, R.E. Smith.

EFFECTIVENESS OF HYDROTHERAPY APPLIED ON VARIOUS BODY PARTS IN SUPPORTING SKIN COOLING OF HORSES TRAINED IN DIFFERENT AMBIENT TEMPERATURES DURING SUMMER PERIOD.
A. Wisniewska, W. Janicka, E. Tkaczyk, R. Kusy.

IMAGE ANALYSIS AND MACHINE LEARNING CLASSIFICATION FOR SKIN CANCER THERMAL IMAGES USING OPEN SOURCE TOOLS.
C. Magalhaes, J. Mendes, R. Vardasca.

INFLUENCE OF TWO DIFFERENT MILITARY COMBAT JACKETS ON FACE TEMPERATURE.
D. Mello, E. Borba Neves, B. H. Canabarro, J. V. Poiatti, G. Rebouças, J. Mendes, V. Azeredo, A. Lino-Samaniego; M. Sillero-Quintana.

UNCERTAINTY OF THERMAL IMAGERS FOR BODY CORE TEMPERATURE SCREENING.
V.Mlacnik, I.Pušnik.

APPLICATION OF DYNAMIC THERMOGRAPHY AFTER A FATIGUING STRENGTH EXERCISE.
M. Muñoz-Alcami, M. Gimeno-Raga, J. I. Priego-Quesada, A. Durán-Lozano, R.J González-Peña, M. Gil-Calvo.

INFRARED THERMOGRAPHY TO CONFIRM THE CORRECT PLACEMENT OF THE NEEDLE IN THE PERFORMANCE OF LUMBAR SYMPATHETIC BLOCKS FOR COMPLEX REGIONAL PAIN SYNDROME.
M. Cañada, M. Bovaira, C. García-Vitoria, R. Salvador Palmer, R. Cibrián Ortiz de Anda, D. Moratal, J. I. Priego-Quesada.

DYNAMICS OF THE LOCAL TEMPERATURE OF BLOOD, PUS, MUCUS AND CATALASE SOLUTION WHEN THEY INTERACT WITH HYDROGEN PEROXIDE IN VITRO.
A.L. Urakov, A.P. Stolyarenko, M.V. Kopitov, L.I. Bashirov.

TEMPERATURE DYNAMICS OF THE MUSICIAN'S FINGERS WHEN PLAYING THE SAXOPHONE IN COLD CONDITIONS. A.L.Urakov, A.P.Stolyarenko.

MACHINE LEARNING TECHNIQUES ON PANDEMIC FEVER SCREENING.
R. Vardasca.

COMPARISION OF HIGH INTENSITY LASER THERAPY (HILT) EFFECT ON SURFACE TEMPERATURE AND VEIN DIAMETER IN PIGMENTED AND NON-PIGMENTED SKIN IN HEALTHY RACEHORSES.
P. Zielinska, M. Soroko, M. Godlewska, W. Hildebrand, K. Dudek, K.J. Howell.

Posters

View at our website from 2nd September.

EXPLORATIONS IN SKIN TEMPERATURE AND OBJECTIVE SKIN COLOUR MEASUREMENTS IN RAYNAUD'S PHENOMENON: A PILOT STUDY.
J. Allen, B. Griffiths.

CONVENTIONAL AND NOVEL APPROACH FOR THE ASSESSMENT OF FLANK TEMPERATURE OF POLISH NATIVE BREED MARES DURING PREGNANCY.
M. Masko, T. Jasinski , L. Zdrojkowski, M. Domino.

ATHLETES' FACE TEMPERATURE RESPONSE DURING AN ENDURANCE TRIATHLON RACE.
W. Romão, D. Mello, E. Borba Neves, G. Rosa, R. Vale.

THERMOGRAPHIC MEASUREMENTS IN THE TOPIC OF THESES OF STUDENTS OF HEALTH CARE STUDY PROGRAMS. H. Sochorova.

THE EFFECT OF TRAINING ON INFRARED THERMOGRAPHIC IMAGES OF THE FORELIMB AND HINDLIMB JOINTS OF HEALTHY RACEHORSES.
M. Soroko, K. Howell, M. Godlewska, W. Górniak.

DYNAMICS OF THERMOGRAPHIC AND NEUROLOGICAL DATA IN ASSESSING THE EFFECTIVENESS OF REHABILITATION OF CHILDREN 5-8 YEARS OLD WITH SPASTIC FORMS OF CEREBRAL PALSY.
M.G. Volovik, G.E. Sheiko, A.N. Kuznetsov.

THERMAL IMAGING SIGNS OF SPASTIC FORMS OF CEREBRAL PALSY IN CHILDREN 4-7 YEARS: PRELIMINARY RESULTS.
M.G. Volovik, G.E. Sheiko, A.N. Kuznetsov.

The XV Congress of the EAT is supported by:

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2021

28th-30th September 2021

XIV International Conference THERMOGRAPHY AND THERMOMETRY IN INFRARED
in Kazimierz Dolny nad Wisla, Poland -**online**

Due to the possible worsening of the epidemiological conditions, the Organising Committee decided to organise the TTP 2021 Conference online. Technical details of the internet connection will be sent to participants prior to the conference.

The organisers kindly ask for registration

Further information

http://thermo.p.lodz.p/ttp

1st-3rd October 2021

AAT 2021 Annual Scientific Session

Virtual and Live Streaming Presentations

About The Event

The 2021 Annual Scientific Session will be a Virtual Meeting consisting of both recorded presentations and live sessions. Those who register for the full meeting with next year's membership will be given 60 days post-meeting access to the recorded presentations.

Separate registration is required for the Pre-Meeting Physician's Thermography Interpretation Course. It will be held between 8:30am and 5:00pm (Eastern Time) on Friday, October 1st, 2021. This meeting will be a live virtual session

Further information at the AAT-website
https://annualmeeting.aathermology.org/

Programme

Day 1 - Friday, October 1s^{t}, 2021

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

8:30 am - 4:00 pm
By Robert Schwartz, MD AAT COB, Greenville, SC

Day 2 - Saturday, October 2^{nd,} 2021

General Sessions

7:30 am
Virtual Log In Open

Registration would be started by 8:00 am.

7:45 am - 9:30 am
From Artificial Intelligence to Fundamental Physics for Medical Thermology

7:45 am - 8:00 am
Welcoming Remarks

By Robert Schwartz, MD AAT COB, Greenville, SC

8:00 am - 8:20 am
The AAT Medical Thermography Artificial Intelligence Intiative

By Robert Schwartz, MD AAT COB, Greenville, SC

8:20 am - 9:00 am
Clinical Applications of PACS in Thermal Imaging

By Marcos Brioschi, MD, PhD Sao Paulo, Brazil

9:00 am - 9:30 am
Fundamentals of Infrared Imaging Systems

By Javier Gonzalez PhD AAT Member, Orlando Florida

9:30 am - 11:30 pm
Neuro-Musculoskeletal Thermology

9:30 am - 10:00 am
SSR Medical Thermography and Neuromodulation

By Behnum Habibi, MD AAT Board, Philadelphia, PA

10:00 am - 10:30 am
Medical Thermography Applications In a MSK Pain Practice

By Matthew Terzella, MD AAT Board, Greenville, SC

10:30 am - 10:45 am
Clinical Applications of Thermography in Complex Regional Pain Syndrome

By Jason Hamamoto, MD Resident, Dept of PMR, Temple University

10:45 am - 11:00 am
Clinical Applications of Thermography in Complex Regional Pain Syndrome (Continued)

By Jay Darji, DO Resident, Dept. of PMR, Temple University

11:00 am - 11:30 am
Use of Medical Thermography In Craniocervical Junction Disorders

By Robert Schwartz, MD AAT COB, Greenville, SC

11:30 am - 12:00 am
Virtual Exhibit Hall

12:00 pm - 1:00 pm
Lunch

1.00 pm - 3.00 pm
Clinicians Corner: Breast Thermography

1:00 pm - 1:20 pm
Defining Specific Applications of Breast Thermography
By Robert Kane, DC AAT Member, San Francisco, CA

1:00 pm - 3:00 pm

1:20 pm - 1:40 pm
Updates in Breast Guidelines, Thermal Signs Assessment, and A Case Report
By Robert Schwartz, MD AAT COB, Greenville, SC

1:40 pm - 2:10 pm
Thermography, Ultrasonography And Elastography In Breast Cancer
By Severino Tadeu de Menezes Lima, MD ABTHERM Member, Serra Telhada, Brazil

2:20 pm - 2:40 pm
Breast Thermography and the Practice of Gynecology
By Rita de Cassia Dantas Monteiro, MD ABTHERM Member, Ponta Verde, Brazil

2:40 pm - 3:00 pm
Addressing Challenges of Outsourced Thermography Services
By Nina Rea Atlanta, GA

3:00 pm - 3:30pm
Virtual Exhibit Hall

3:30 pm - 5:00 pm
Veterinary Session: Thermology Presentations

3:30 pm - 3:55 pm
Infrared Thermal Imaging For The Diagnosis/Assessment Of Back Pain In Horses

By Tracy Turner, DVM Past President, AAT, Elk River, MN

3:55 pm - 4:20 pm
Infrared Thermography As A Means Of Screening And Preventing Injury In Elite Equine Athletes

By Ken Marcella, DVM AAT Member, Canton, GA

4:20 pm - 4:40 pm
Combining Thermal Imaging and Musculoskeletal Ultrasound to Identify Sports Medicine Injuries in Working and Performance Dogs

By Kim Henneman, DVM Park City, Utah

4:40 pm - 5:00 pm
Use of Thermal Imaging in Equine Integrative Sports Medicine

By Sara s Le Jeune, DVM UCDavis, CA

5:00 pm
Saturday Session Ends

5:30 pm - 6:00 pm
Virtual Meet and Mingle Reception

Day 3 - Sunday, October 3rd, 2021

General Sessions and Annual Business Meeting

8:00 am - 10:30 am
Oral Systemic Session

8:00 am - 8:20 am
Thermographic Imaging of Gastroenterology Patients

By Richard Brownstein, MD AAT Member, Clarksdale, MS

8:20 am - 8:40 am
Medical Thermology in Family Practice

By Eric Ehle, DO AAT Member, Amarillo, TX

8:40 am - 9:00 am
Thermal Imaging to Monitor Laser Therapy Treatment Effects
By John Godbold, Jr., DVM AAT Member, Jackson, TN, Ronald Riegel, DVM Marysville, OH

9:00 am - 9:40 am
Virtual Exhibit Hall

9:40 am - 10:00 am
Software as a Medical Device (SaMD)
By Robert Schwartz, MD AAT COB, Greenville, SC

10:00 am - 10:20 am
Machine Learning Applied to the Korean Temperature Data Base for Oral Systemic Conditions

By Ho Yeol Zhang, MD, PhD NHIS Ilsan Hospital, Seoul, Korea

10:20 am - 10:30 am
Why The AAT Is Needed In The SaMD Space

By Barry Hix MBA, MPH Birmingham, AL

10:30 am - 10:45 am
Missed Breast Pathology: A Problem With The Test Or The Report?

By Rebecca Peden, B.C.N.D., D.A.Hom., L.E.H.P. AAT Member, Lawrenceville, GA

10:45 am - 11:00 am
Equine Thermography Versus Symptoms, PE, & Other Studies

By Irma Wensink, Paraveterinair AAT Member, Epe, The Netherlands

11:00 am
General Session Ends

11:00 am - 1:00 pm
Board of Directors Meeting (Board Members Only)