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anthropometric variables and skin temperature over the biceps

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Contents (INHALTSVERZEICHNIS)

Point of View

Book/Publication Review

Original article

News in Thermology

Meetings

A review on the role of medical thermography in breast cancer imaging

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Since infrared thermal imaging has been applied in medicine in mid 50's, breast cancer was a topic of interest. This technique allowed a new indicator based in matrix obtained from an image, which maps the skin temperature distribution, calculated based in the surface skin emitted thermal radiation that reaches the camera sensors. It is believed that it represents a physiological state influenced by the peripheral blood flow, which is regulated by the autonomic nervous system. Being a non-contact, non-invasive, non- ionizing, easy to use and relative low cost when compared with other imaging methods it attracted researchers and enthusiasts in their usage.

The growth of new blood vessels, also known as angiogenesis, and release of nitric oxide, which increases blood flow, are factors related with the appearance and growth of a neoplasm [1] that might cause an increase in skin temperature. Given this, it is possible to be identified and monitored through infrared medical imaging. This in fact captivated physicians and researchers to detect breast cancer with the technique, although in the related literature there is a daze between screening and early detection, Ammer [2] pointed clearly its distinction in 2011.

According to Almaric et al. and Hoekstra & Steffek [3, 4] the alterations in skin temperature can have different causes such as:

- Anatomic: breast inequalities, aberrant veins, previous scars, skin depression (fake hotspots generator or bowl effect), and anomalies in the skin;
- Physiologic: spontaneous or provoked hormonal disorders, pregnancy, pre-menopausal stage, and fibrocystic breast disease;
- Inflammatory: acute or chronic infections, abscess, and galactophoritis;
- Dysplastic: all varieties;
- Tumour: benign tumours (adenosis, phyllodes tumours, cyst, duct stasis, fat necrosis, fibroadenoma, fibrocystic disease), and cancers (lobular carcinoma in situ, intraductal papillary, intraductal solid, invasive ductal, invasive ductal with fibrosis and invasive lobular).

It is important to notice that like any other medical imaging modality, infrared thermal imaging, is also a diagnostic and therapeutically complimentary method, which provides only one simple objective outcome that is the temperature value of the point or specific region that the examination is concerned with. For a good interpretation of the temperature findings, good anatomical, physiological and physics knowledge is required.

It is objective of this review to perform an overview in studies with the applicability of infrared thermography in breast cancer screening and early detection, different approaches to grade the thermograms, indications of the pioneer studies made in the early years and provide future lines of research in the field.

Two recent reviews [1, 4, 5] assessed the sensitivity, specificity and accuracy of infrared thermal imaging either in terms of screening and early diagnosis in identifying breast carcinoma. The values obtained had a large variation, being the all reported studies average for sensitivity of 71.5% [varying from 25% to 97.4%], for specificity of 63% [varying from 14.4% to 89%] and for accuracy of 69.8% [varying from 67% to 89%]. It is important to note that in all those studies, despite the type of study: prospective cohort, retrospective case-control, retrospective cohort and non-retrospective cohort, the equipment used had different characteristics and from different generations, different methodologies were also followed to capture and assess the thermal images, it justifies the disparity in the results. The accuracy mean value is of 69.8%, below the acceptable threshold of 80% that studies with mammogram have presented to be used as screening instrument.

Hoekstra & Steffek [4] in their second part of their review attempted to answer to questions such as: existence of specific thermal features that could define cancer, the minimum size of lesions detected by thermography, differentiation with thermography between malignancy and benignancy of the neoplasm, predominance of the nature of the neoplasm in detection with thermography and utility of using thermography as a risk assessment model for breast cancer detection. The indications were that the accuracy of the technique has demonstrated to be poor (< 80 %) in identifying carcinomas and resulted in high rate of false positive, although it was helpful to contribute in identifying cancer in specialized, high-risk patient groups, like those referral to mammography because of a suspicious lump. Malignant tumours appear to more often have a hot signature. There was evidence of strong correlation between thermographic groupings between consecutive examinations with tumour growth in the case of small tumours (< 2 cm) and therefore patient prognosis and survival. Thermography by its own is not capable of dif- ferentiating malignant from benign or healthy tissue. It can be a first early warning sign of pre-cancerous lesion and combined with other diagnostic methods proved to improve their accuracy, but can also increase the false positive rates. It can identify lesions of all sizes, however cannot provide information on tumour location for biopsy.

In the early years (60's and 70's) of introduction of infrared thermal imaging in medicine, the most attractive field of application was breast cancer detection. For that, a large multicentre study was implemented in the US to a large population of women [6, 7), the Breast Cancer Detection Demonstration Project (BCDDP). The goal was to compare the outcomes of different techniques such as mammography, ultrasound and thermo- graphy combined with clinical examination in breast cancer detection over the years The preliminary results showed that the accuracy of the studied methods was: 78 % for mammography alone, 60 % for only ultrasound, 39 % for thermograhy alone, 55% for only clinical examination and 67% for all the technique combined. These results contributed for bad reputation of the thermal imaging technique among physicians worldwide, being deprecated in their good applications and hidden from medicine general courses and IT developments in medical imaging departments. It is well established, that infrared thermal imaging of human skin re quires preparation of patients pre and during the examination, also the equipment and the examination room need specific controlled conditions, the other studied techniques need simpler apparatus, but no description is given in the examining conditions for thermography in the study reported [6, 7]. Other aspect that might have contributed to the bad results was the poor specification of the imaging equipment when compared with the actual technology.

Thermography accuracy was positively influenced by the presence of one or more positive axillary nodes. It was also more efficient in detecting larger lesions (> 3 cm). At the time an ad-hoc committee of the National Cancer Institute devised a new proposal to establish a more objective criteria for the thermograms assessment, which was accepted by the American Thermographic Society, and consisted on the number, calibre, location and configuration of blood vessels, thermal asymmetry of 2º or 3º C and breast contours, and were categorized as normal, suspicious and abnormal thermograms, it raised the accuracy of thermography from 39 % to 50 % but there was also an increase of 26% in the false positives [6]. There was an amount of patients that were positive in early screening with thermography, but negative in clinical examination and mammography that later developed malignant cancer. It was also found that any preneoplastic stage could produce a positive thermogram, which means that patients with a positive thermogram might be more predisposed to breast cancer. Pre-menopausal, menopausal and postmeno- pausal with breast cancer seem to hold the same possibility of presenting an abnormal thermogram. The venous diameter ratio (VDR), a ratio between the diameter of the largest vein near the lesion and the contralateral situated vein, also influences an abnormal thermogram, the higher the VDR in a cancerous breast, increased chances of a positive thermogram. Another factor that has shown influence in the detection with thermal imaging was the breast average vascularity, breasts with cancer and low vascularity were less likely to present an abnormal thermogram [6]. The conclusions of the project based on this were that thermography was of great use as an adjunct to mammography and physical examination, but it should not be used as sole technique for breast cancer screening [7].

Almeric et al. [3] defined as thermal signs for abnormal thermogram the following:

- An abnormally hot zone, or a hot spot with a temperature gradient of at least + 1.5º C with respect to the adjacent or opposed symmetric region;
- Hyper-vascularisation localized, with dilated and tortuous vessels;
- Hot nipple;
- A whole body hyperthermia of the breast skin, from 2.0º C.
- Any significant thermal asymmetry.

They have shown an accuracy of 83% in detecting malignant breast carcinoma, however the number of false positives was also higher. In a follow up of 5 years it was found that from patients that presented an positive thermogram 8 % had cancer in less than 1 year, 11 % in less than 2 years, 15 % in less than 3 years, 19 % in less than 4 years and 26% in less than 5 years [3].

From a total of 58,000 women that were examined [8], 1,245 were thermally classified with the TH3 stage (the thermograms were classified from stage TH1 to TH5 according with the thermovascular pattern and areas of hyperthermia) and followed up for 12 consecutive years, from this in the first assessment 784 (51%) had no abnormal clinical, mammographic or ultrasound findings, 461 (30%) were diagnosed as benign disease, mainly cystic mastopathy, and 282 (18%) were promptly confirmed histologically as cancer. Subsequently carcinoma was confirmed histologically in 38% of the initially considered normal group and 44% of the women with benign mastopathy. The risk associated with abnormal thermal imaging proved their relevance.

Lloyd-Williams [9] proposed as thermal profile of breast cancer the following:

- Not all cancers were hot.
- There was a spectrum of rise in temperature from nothing to 7º C.
- Some of the very hot cancers were hotter than the body core temperature.
- The hotter the cancer the worse the prognosis.
- The hotter the tumour the worse the pathological staging.
- The hotter the tumour the worse the pathological grading.

Based on his experience ,there were 11% of cases with a rise on temperature of 3º C or more who had, despite all forms of treatment, an appalling prognosis, about 80 % were dead and 100 % presented a spread on their disease at 2.5 years and there was no survivors at 5 years [9].

In another early study [10], the manually recorded information was limited to square areas of skin ranging from 0.5 cm2 to 4 cm2 and 4 temperatures were obtained for each breast: the average areola, the average central breast, the warmest vein and the coolest avascular region. This methodology in 871 examined women presented an accuracy of 42% in identifying cancer cases and a false positive rate of 10%.

Almaric et al. [11] concluded in his 4,000 women screened that infrared thermography, combined with mammography, and seems to be the best means for early detection of mammary carcinomas, particularly in high-risk women.

Spitalier et al. [12] have shown that using breast thermography the greater the thermographic gradient, the shorter the survival of the patient. They proved that these findings contribute independently to the results of other investigations [clinical stage, histological grade, axillary staging, hormone receptors) in order to determine whether or not a patient should be considered to have a high risk of treatment failure.

Stark [13] defined and abnormal thermogram to have one or more of the following characteristics:

- A localised area of increased heat emission or hot spot: a temperature differential of 1.5 ºC or more is significant when compared to the contralateral site;
- An increased heat in one areolar area. There is a rich anastomosis of the superficial and deep venous systems at the areola and a lesion deep in the breast may manifest itself in this manner;
- A generalized increase in temperature of 1.5 ºC or more of one breast;
- A localized increased vascularity with more numerous, tortuous or dilated vessels;
- A cold avascular area surrounded by increased vascularity. This feature is associated with a small cancer around which there has been an outpouring of oedema fluid into the tissues. This oedema reduces the passage of heat from the tumour to the skin.

Stark [13] has found that in a total of 11240 women screened over 16.5 years at a 30 to 36 months interval, that the incidence in the group with no risk (negative thermogram] was of 0.4 %, with one risk factor was of 3.3 % and with two or more risk factors was of 17.1 %. Although epidemiological terms such as incidence is not very clear and stratified to understand in which period did the patients become positive or underwent into a biopsy, it is also unclear what is meant by the term "asymptomatic", whether it is absence of symptoms or absence of disease. This may be a bias in this study and avoiding mutually exclusion leads also to an overestimation of breast cancer's prevalence.

A recent study [14] defined new infrared imaging signs:

- IR1, when temperature difference ΔT] of the lesion site from the mirror image site of the contralateral breast. IR1 = 0 (negative) when ΔT≤ 2 °C; IR1 = 1 (positive) when ΔT > 2 °C.
- IR2, when temperature difference of the lesion site from the adjacent normal breast. IR2 = 0 (negative) when ΔT ≤1 °C; IR2 = 1 (positive) when ΔT > 1 °C.
- IR3, when abnormal vascular morphologic patterns at and around the tumour. IR3 = 0 when the sign is absent; IR3 = 1 when the sign is present.
- IR4, when focal edge or bulge of the surface contour with increased temperature. IR4 = 0 when the sign is absent; IR4 = 1 when the sign is present.
- IR5, when asymmetric thermographic and vascular patterns at the tumour site. IR5 = 0 when the sign is absent; IR5 = 1 when the sign is present.

The authors of this study [14] have found that IR1 imaging sign could be of relevant information to predict prognosis in patients with invasive breast cancers with stage I, II or node-negative disease. On other hand the IR5 sign was associated with overall mortality in breast cancer patients with node-negative disease.

The current gold standard for women screening following the WHO recommendations is mammography and clinical examination [15]. However none of these two methods is 100% accurate and in situations where a differential diagnosis is needed other imaging modalities are currently available such as ultrasound, CT, MRI or PET/PEM [16, 17, 18]. All of these methods have their advantages and disadvantages, for an accurate diagnosis when the possible location of the neoplasm is known a biopsy is performed. The mammography apart from exposing the patient to undesired radiation has difficulties in identifying nodules in dense breasts [18]. The ultrasound is operator dependent and unable to identify calcifications in breasts, which are also a sign of breast cancer in very early stage and some types of cancer [18]. The CT has also the disadvantage of exposing the patient to unwanted radiation along with general unavailability and cost [17, 18]. The MRI apart from being generally unavailable, costly and non-recommend for claustrophobic subjects or patients having metallic implants, it produces false positive results by detecting breast areas that do not have any cancer, leading to unnecessary biopsies, and cannot detect the micro-calcifications that indicate a suspicious area [16]. The most recent imaging techniques are PET/PEM, which are very promising but also expose the patient to unwanted radiation, are not generally available and are expensive, and the required use of radiotracer or radioisotopes can have a harmful impact on the health of the patient [16].

A recent publication [19] described the imaging features to have in consideration for its automatic analysis and the advanced computing methods for its automatic classification. Although the authors show poor clinical knowledge about breast cancer and the related work basing their assumptions in limited bibliography. In the operations of pre-processing it is not clear if the authors remove the background and filter the noise in the radiometric image or in a processing imaging keeping the original radiometric image for quantitative analysis, this is an important aspect that may influence results. The proposed image features to have in consideration are: basic statistical features, moment features, histogram features, cross co-occurrence features, mutual information, and Fourier descriptors from each breast thermogram which describes the asymmetry between the left and right breasts. Other features can be high order statistics like mean, variance, skewness, kurtosis, correlation, entropy, and joint entropy were calculated as the components of the feature vector to quantify the distribution of different intensities in each breast. All of these parameters can be of interest of study and their implication should be object of further study. The authors also referred a 2D thermograms transformation into 1D data by using radon transform, it is difficult to understand the utility of this.

For image classification the authors [19] outline the advanced artificial intelligence methods: Genetic Algorithms (GA), Neural Networks (NN), Support Vector Machines (SVM), k-means clustering (unsupervised learning) and k-nearest neighbourhood (supervised learning). The GA are very unreliable, the NN depend on the fitness function and on the database size for training the neural network, all the other methods depend on a substantial size of sample images on the database.

This is just an example of advanced analysis and classification systems that engineers often propose, but is misses the main point, a discussion needs to happen between experienced physicians, experienced thermographers and computer engineers to produce a useful tool and till now there is no valid and accepted image characterization features to be used in their analysis and classification.

Since the infrared thermal images capture equipment evolved, became more portable, reliable and its features improved, there are relevant studies missing using current technology, one of the first problem in any study is to specify a camera, there are guidelines available [20] and minimum requirements specified to their use in humans [21]. Along with the equipment there is today knowledge about preparing a thermographic examination in terms of patient pre and during examination arrangement [22, 23, 24] and in examination room and required equipment preparation [22, 25] and basic quality assured [26].

The current state of knowledge states that infrared thermal image should not be used as primary screening or early diagnostic method [2], as complementary method associated with other such as mammography and clinical examination, awareness must be raised to the generation of "false positive" cases in order to prevent the overdiagnosis. For combining thermography with other imaging methods such as breast ultrasound, MRI, CT and PET/PEM further research is required.

The current recommendations for breast cancer screening effectiveness is in discussion and according to recent studies [27] mammography seems to not be as effective as thought in the 70's, the effectiveness of screening periods are also in debate [28]. The use of infrared thermal imaging to monitor treatment response for patients with neo-adjuvant chemotherapy [14] or any other breast cancer treatment may also be a good application that needs exploitation.

In this review different approaches have been presented to evaluate breast thermograms. Some older studies reported important outcomes and emphasized the need to produce an international guideline for imaging and investigation of the female breast with infrared thermal imaging. Infrared thermography has the potential to show additional risk factors in symptomatic woman that are under 40 or 50 years old and are considered at an high-risk, which according to the most recent WHO indications should not participate in regular mammographic check-ups [15]. Their infrared records should been kept and made available for the patient and her physician for future comparisons with any subsequent relevant findings of interest. Such a responsible use of breast thermography does not interfere currently recommened diagnostic procedure, but may generate a kind of information that is not available from the current breast imaging literature.

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The view of artificial intelligence scientists'on infrared thermography

Review of Chapter 11, **"A Study and Analysis of Hybrid Intelligent Techniques for Breast Cancer Detection Using Breast Thermograms,"** by Usha Rani Gogoi, Mrinal Kanti Bhowmik, Debotosh Bhattacharjee, Anjan Kumar Ghosh and Gautam Majumdar In book: Hybrid Soft Computing Approaches - Research and Applications, Springer India, 2016, by Siddhartha Bhattacharyya, Paramartha Dutta & Susanta Chakrabort, eds.

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Summary

This chapter provides an overview of breast cancer, a summary of medical imaging methods for detecting the cancer anomalies and highlights on auto-classification of digital infrared thermal imaging using the so-called hybrid intelligent techniques. The overview on risk factors, incidence rate, mortality rate and early detection of breast cancer was comprehensive. So was the summary on methods and limitation of various medical imaging including mammogram, MRI, ultrasound, nuclear and IR thermal imaging. The last sections of the chapter highlight various important steps for acquiring, processing, feature extraction and classification of digital infrared images of breasts. Overall the chapter is well-organized and would inform readers of advances soft computing have made in automatic detection of breast cancer.

Comment

The chapter presents adequate breadth and depth coverage of the subjects. It includes figures and data to substantiate its cases and a useful compilation of references. A high spot, for example, is the Table 1 & 2 which summarize the techniques and successes of auto-detection of breast anomaly using hybrid intelligent techniques based on the researches listed in the reference. It is claimed that breast cancer thermography has a sensitivity as high as 90%, which can increase to 95% when complemented by other medical imaging modality such as mammogram. The chapter didn't define, group or provide details of the four analytic parameters for breast thermology that were used in the various artificial intelligence clinical trials and did not provide any details of the methodology. However, even the tabulation of these trials provides an investigator with valuable information.

From the data, however, it can be seen that there is no single breast cancer thermography technique that could be considered superior than others. It should be noted that the hybrid intelligent methods considered here are restricted to a synergy of statistical features and soft computing classifiers that use neural networks, fuzzy logic, clustering and global searches. Limitations of these methods might be a shortcoming of the approach. A review of the sited studies makes it is clear the application of artificial intelligence to breast thermography remains in its infancy.

The results reported in the chapter uses asymmetry of vascular patterns and/or temperature between the thermogram of left and right breast as a main criterion for classifying breast thermal signatures as normal or abnormal. This inherently compromises the application of artificial intelligence to empirically-based parameters rather than pathognomonic. It was briefly alluded to that extracted features before and after the cold stress were analysed to identify any anomaly. Well known among the breast thermogram community, a dynamic challenge, such as the cold stress test, is key to identifying signature features of pathology. The importance of dynamic challenges was not at all emphasized in this article.

Most, if not all, of research work reported in the article focuses on evaluating the effectiveness of the hybrid intelligent algorithms and techniques under investigation. Breast thermograms were mainly used as test samples to support their results. This is rightly appropriate for the engineering side of research. However, it matters that the main emphasis is not placed on the medical point of research. For example, carrying out additional tests to include clinical trials to further evaluate and validate the proposed techniques. The quantitative character of the thermographic instrumentation enables the application of artificial intelligence techniques but requires the guidance of basic oncologic science to insure its effective application.

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Hand skin temperature - are there warm and cold rewarming patterns after cold stress test?

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SUMMARY

In 116 thermographic measurements of 66 healthy male participants, 44 of whom were measured at least twice, hand skin temperature distributions before and after a cold stress test (CST) were examined to identify any typical characteristics of hand skin rewarming. On each hand, measurements from 18 regions of interest recorded every 10 s were used to calculate the surface average temperature. Temperatures at baseline (T_b), directly after cooling (T_c), and after 15 min of rewarming (T_f) were used for comparison and the averages of each finger, palm, and hand were analyzed. Using fits of normal distribution for the measured data, final hand skin temperatures were divided into two groups, A and B, with a calculated boundary at 25.4 °C. Digital analyses of all thermograms were performed to describe the process, and each group's rewarming patterns were observed. Group A was considered to demonstrate warm rewarming, since the whole hands reached a T_f approximately equal to the T_b. By contrast, Group B demonstrated cold rewarming and had whole hand T_f less than T_b. The predictive value of T_c was lower than that of T_b in Group A, whereas the opposite occurred in Group B. Altogether, the findings suggest different hand skin temperature rewarming patterns in healthy males.

KEYWORDS: Cold stress test, warm hands, cold hands, vascular response, peripheral circulation

GIBT NACH ES EINEM KALTWASSERTEST “WARME” UND “KALTE” WIEDERERWÄRMUNGSMUSTER DER HANDTEMPERATUR?

Bei 116 thermografischen Messungen an 66 gesunden Männern, von denen 44 mindestens zweimal gemessen wurden, wurden Verteilung der Hauttemperatur an den Händen vor und nach einem Kaltwassertest (CST) untersucht, um typischen Merkmale der Wiedererwärmung zu identifizieren. In 18 Messarealen an jeder Hand wurden alle 10 s Messungen durchgeführt, um die durchschnittliche Oberflächentemperatur berechnen zu können. Die Temperaturen am Beginn (T_b), direkt nach dem Abkühlen (T_c) und nach 15 min dauernder Wiedererwärmung (T_f) wurden verglichen und die Durchschnittswerte der einzelnen Finger, der Handfläche und der gesamten Hand wurden analysiert. Nach Überprüfung der Daten auf Normalverteilung, wurden die Endtemperaturen der Hand entsprechend einem berechneten Grenzwert von 25,4 ° C zwei Gruppen, A und B, aufgeteilt. Alle Thermogramme wurde computerbasiert analysiert, um den Prozess zu beschreiben, der bei der Wiedererwärmung in jeder Gruppe beobachtet wurde. Gruppe A wurde als "warme" Wiedererwärmung bezeichnet, da die Ausgangstemperaturen (T_b) und die Endtemperaturen (T_f) der Hände annähernd gleich waren. Im Gegensatz dazu, zeigte Gruppe B eine "kalte" Wiedererwärmung, die durch eine niedrigere T_f als T_b gekennzeichnet ist. In der Gruppe A war der prädiktive Wert von T_c für T_f geringer als der von T_b, während in Gruppe B T_c genauer als T_b die Endtemperatur voraussagte. Insgesamt lassen die Ergebnisse auf unterschiedliche Muster der Wiedererwärmung der Hand bei gesunden Männern schließen.

SCHLÜSSELWÖRTER: Kaltwassertest, warme Hände, kalte Hände, Gefäßreaktion, periphere Zirkulation

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Introduction

Environmental temperature is an important factor of people's well-being and ability to work. For example, working in cold conditions is challenging, since a person's ability to use his or her hands as efficient tools, given their tactile sensitivity and dexterity, depends on the temperature of the hands and fingers [1-3].

The skin temperature of hands and fingers has been studied for decades, in both health care and in medical research, largely with non-invasive methods such as infrared thermography (IRT) [4], and it is well known that thermal images reflect the underlying circulation [5-9]. Changes in circulation due to processes such as vasospasm with whitened fingers-that is, Raynaud's phenomenon (RP)-can also be studied with IRT [10-12]. Vasospasm can appear when hands are subjected to cold stress tests (CST) [13], often performed by immersing the hands in cold water [12], in order to assess and discriminate normal and dysfunctional rewarming in vascular disorders such as RP and hand-arm vibration syndrome (HAVS) [14].

Gatt et al. [15] used thermography to determine normal skin temperature patterns for the feet and hands. For the hands, they found that the thumb was the warmest finger, as well as observed a temperature gradient of a difference of more than 1.5 °C from the index to little finger.

Gasser et al. [16] found that individuals with anamnestic complaints of cold hands demonstrated a lower baseline hand skin temperature than individuals in a control group.

The former's unaltered potential to recover furthermore distinguished them from patients with RP, in contrast to results in another study, which suggested that a low baseline skin temperature can serve as a predictor of RP [17].

Hand skin temperatures of less than 29 °C have been proposed to signify cold hands and those greater than 29 °C to signify warm hands [18]. At the same time, other research has shown that hand skin thermal response in healthy individuals varies from day to day [19].

Brändström et al. [20] have classified cold recovery responses in hands as normal, moderate, and slow rewarming, based on the fingers' 30-min recovery temperature in °C and the difference between fingertip and finger-base temperatures. In another study [21], they defined normal rewarming in the hands as recovery from cold within 15 min and slow rewarming when recovery was prolonged.

In general, literature on the topic shows different approaches to studying hand skin temperature and cold rewarming responses. Accordingly, the aim of this study was to use IRT to examine hand skin temperature distribution before and after a CST, as well as during rewarming, in order to identify any typical characteristics of hand skin temperature rewarming. An additional aim was to investigate how baseline temperature, cooled temperature, tympanic ear temperature, heart rate, blood pressure, stress, hand volume, relative humidity, and outdoor temperature influence outcomes following the CST.

Materials and Methods

Data collection was performed during April and May in both 2012 and 2013. Measurements were taken in a silent, windowless room with an ambient temperature of 23 ± 1 °C. An infrared (IR) camera (FLIR® A320, FLIR Systems, Inc., Wilsonville, OR, USA) with an image resolution of 320 × 240 pixels and thermal sensitivity of <0.05 °C at +30 °C was used. Emissivity was set to 0.95. Before use, the camera was calibrated by FLIR Systems AB in Täby, Sweden.

To obtain as homogeneous a sample as possible and avoid potential hormone-induced micro vascular or circulatory impact [22], we recruited healthy 20- to 30-year-old males as participants. Invitations were sent to all male students at Luleå University of Technology, 137 of whom registered their interest and were thus sent instructions for participating. Exclusion criteria were tobacco use, a history of thermal injuries, significant hand injuries, or symptoms of circulation disorders (e.g., whitening fingers), which left 67 participants (mean age 23 ± 3 years) for the sample. Participants were measured more than once, if possible; 22 were measured once, 39 twice, and five at least three times. Oral and written information about the testing procedure was provided to all participants, who prepared by not drinking alcohol for 24 h prior to testing, by not engaging in physical exercise on the test day, and by fasting and not drinking either coffee or tea for 2 h before testing. One participant did not follow the instruction to not engage in physical exercise for the second measurement and was thus excluded from the study.

Prior to the test, participants rested for at least 30 min in a nearby room with the same temperature as the testing room. Participants' age, height, weight, and hand volume were recorded, along with their initial blood pressure, heart rate, tympanic ear temperature, handedness, and estimated stress level on a 10-point VAS scale (1 = No stress at all, 10 = Worst stress imaginable). The outdoor temperature was also recorded.e

In total, measurements for 232 hands wre taken. On each hand, 18 regions of interest were used to calculate the average surface temperature and recorded every 10 s, as in previous research [19] and as shown in Figure 4 a. Temperatures at baseline (T_b), directly after cooling (T_c) and after 15 min of rewarming (T_f) were used for comparison. T_b was recorded as the average of 12 temperature measurements taken during 2 min prior to the CST, T_c as the first measurement directly after the CST, and T_f as an average during the last 2 min of measurement in the same way as for T_b; T_b, T_c, and T_f were similarly analyzed for each finger, palm, and hand. An average of the ROIs in each of these regions was calculated. Digital analyses of all thermograms were performed in order to describe the process.

The camera was turned on at least 30 min before measurements were taken. The water temperature was continuously monitored with a digital thermometer and controlled with a mercury thermometer before each CST, which was preceded with baseline measurements. For each CST, the participant's bare hands were immersed to styloid level in water at a temperature of 10 ± 0.5 °C for 30 s and then carefully dried. During measurements, participants were seated behind a screen placed in front of the camera; their hands were inserted into two holes in the screen and held at heart level, with palms and splayed fingers directed toward the camera positioned 65-67 cm from the hands. The screen had a lower temperature than any hand temperature following the CST, which afforded a well-defined background and protected the camera from reading any disturbing temperature radiation from the participant's body. Participants were instructed to keep their hands as motionless as possible during measurements; an edge detection algorithm reduced movement artifacts and recognized the hand and fingers. In all, the CST procedure was similar to that used in a previous study [19].

Data analysis

Data analysis was conducted with Microsoft Excel®, the Statistical Package for the Social Sciences version 21.0 (IBM, Armonk, NY, USA), and MATLAB® 2014b (Math Works, Inc., Natick, MA, USA). As an initial analysis of the data, background statistics and probability distributions of variables were examined. The probability distribution of the final temperature, T_f, was particularly analyzed, since it was regarded as an outcome following the CST. A value of $p < .001$ was considered to be statistically significant.

To determine how different variables influenced T_f, non-parametric regression based on ordinary least squares was used. As such, the relationships were not assumed to have a predetermined functional form, but were constructed according to information derived from the data. To describe the predictive value of the relationships, the adjusted coefficient of determination ($\bar{R}^2$), p-value, and standard uncertainty (u) of the coefficients were calculated.

Images were exported to MATLAB®. For thermograms, a rainbow palette was used together with a temperature scale. Digital analysis was performed mostly by the first and third authors. To describe how skin temperature was distributed, digital images were viewed several times by the first and third authors and controlled by the second and fifth authors.

Ethics

The study followed the principles of the Declaration of Helsinki [23], and participants gave their informed, written consent. The Regional Ethical Review Board in Umeå approved the study (nos.2010-119-31M and 2011-223-32M).

Results

Figure 1 shows the probability distribution of the final hand skin temperature, T_f, for the 232 measurements; the complete dataset can be described as a superposition of two distributions. Using fits of normal distribution to the measured data, T_f values were divided into two groups, A and B, with a calculated boundary at 25.4 °C. Group A, with $T_f > 25.4$ °C, was classified as warm rewarming, whereas Group B, with $T_f < 25.4$ °C, was classified as cold rewarming.

As Figures 2 and 3 show, the two variables that significantly ($p < .001$) influenced T_f were T_b and T_c. By contrast, tympanic ear temperature, heart rate, blood pressure, stress, hand volume, relative humidity and outdoor temperature had no statistically significant influence on T_f. Analyses of the influence on T_f in Groups A and B were made separately.

Baseline temperature

Figure 2 shows the relationship between T_f and T_b, which in Group A was

$$T_f = 0.68\ T_b + 8.9\ °C \quad (1)$$

with $p << 0.001$ and an adjusted coefficient of determination $\bar{R}^2 = 0.33$. Measurements show that the final temperature (T_f) was approximately equal to the baseline temperature (T_b) as clear from

Equation 1, which shows $T_f = T_b$ at 27.8 °C and is thus in the measurement interval. In Group B, the relationship between T_f and T_b was

$$T_f = 0.66\ T_b + 3.6\ °C \quad (2)$$

with $p << 0.001$ and an adjusted coefficient of determination $\bar{R}^2 = 0.66$. Such a result means that the T_f in Group B was approximately 5 °C lower than that in Group A. The measurements furthermore show that $T_f < T_b$, as also clear from Equation 2. As an example, T_b of 28 °C yielded a T_f of 22 °C.

Figure 2 shows that for $T_b < 27$ °C, measurements fell into Group B (i.e., cold rewarming), whereas for $T_b > 30$ °C, most measurements fell into Group A (i.e., warm re- warming). In the interval 27 °C < T_b < 30 °C, temperatures could

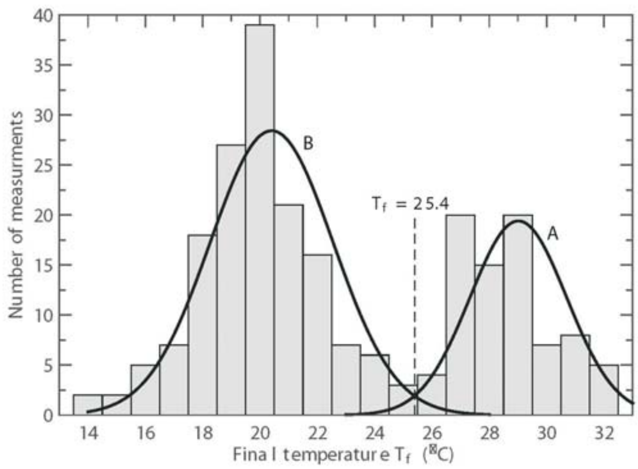

Figure 1
Final temperatures, T_f, of hands (n = 232); curves (A) and (B) represent fits of normal distributions to the measured data. The distribution can be divided into two groups, A and B, with a boundary at 25.4 °C.

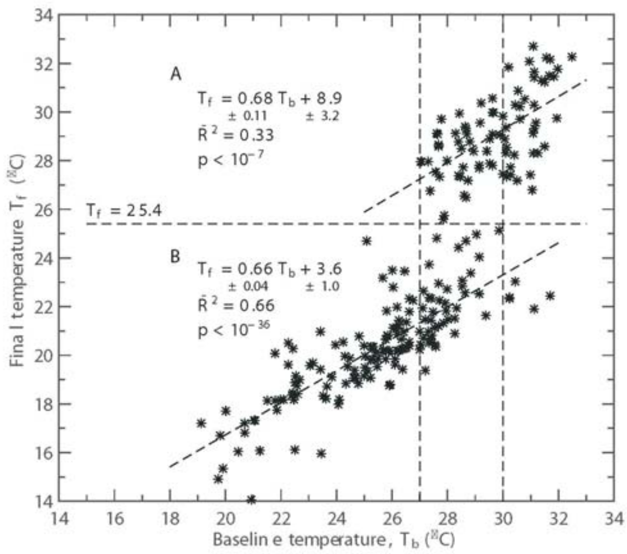

Figure 2
Final temperature (T_f) as a function of the baseline temperature (T_b) of hands (n = 232). Fitted lines appear together with equations, standard uncertainties, adjusted coefficients of determination, $\bar{R}^2$, and p-values.
The dashed horizontal line at $T_f = 25.4$ °C shows the calculated boundary between Groups A and B, whereas the vertical lines show the temperature interval 27 °C < T_b < 30 °C, within which the measurements fell into either Group A or B.

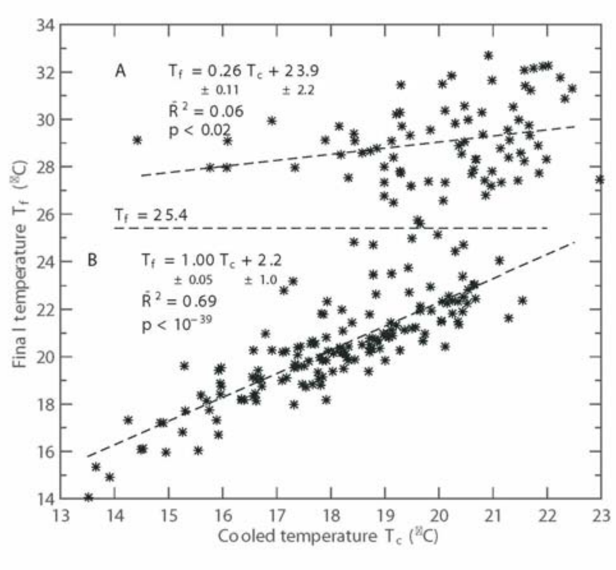

Figure 3
The final temperature (T_f) as a function of cooled temperature (T_c) of hands (n = 232). Fitted lines appear together with equations, standard uncertainties, adjusted coefficients of determination, $\bar{R}^2$, and p-values. The dashed horizontal line shows T_f = 25.4 °C, which is the calculated boundary between Groups A and B.

have fallen into either Group A or B. In that interval, the baseline temperature was thus a poor predictor for cold or warm rewarming.

Cooled temperature

Figure 3 shows the relation between T_f and T_c. In Group A, the relationship showed values of $p < 0.02$ and $\bar{R}^2 = 0.06$, meaning that the predictive value of T_c for T_f was less than that of T_b in Group A. By contrast, the relation between T_f and T_c had p < <0.001 and $\bar{R}^2 = 0.69$ in Group B, meaning that the predictive value of T_c was greater than that of T_b in Group B.

Group A: Warm rewarming pattern

A warm rewarming pattern was observed in 79 hands. Typical of this pattern was that hands were warm in the palms at baseline (30.4 ± 1.4 °C) and in all fingers (T_b = 29.4 ± 1.5 °C) as Figure 4a and Table 1 show. Directly after the CST, palm temperature decreased to 22.4 ± 1.3 °C and finger temperature to 19.2 ± 1. 7 °C (Table 1). In all five fingers, a temperature gradient emerged with cooler distal phalanges, and warmth areas occurred over the interphalangeal joints (Figure 4b). During rewarming, warm streaks on the sides of the fingers surfaced and extended distally toward the fingertips. Once fingertip rewarming began, general rewarming continued toward the proximal phalange (Figure

Table 1.
Mean hand skin temperatures at baseline (T_b), after the cold stress test (T_c), and after 15 min (T_f) for the whole hand, palm, fingers (II-V), and thumbs in Groups A and B.

Group A n = 79	T_b (°C)	T_c (°C)	T_f (°C)
Palms	30.4 ± 1.4	22.4 ± 1.3	29.2 ± 1.3
Fingers	29.4 ± 1.5	19.2 ± 1.7	28.9 ± 1.8
Thumbs	30.6 ± 1.5	20.2 ± 4.0	30.7 ± 1.6
Hands	29.7 ± 1.4	20.1 ± 1.7	29.1 ± 1.6

Group B n = 153	T_b (°C)	T_c (°C)	T_f (°C)
Palms	28.0 ± 1.8	21.3 ± 1.5	25.1 ± 1.9
Fingers	24.6 ± 2.9	17.0 ± 1.8	18.8 ± 2.2
Thumbs	25.9 ± 2.9	17.8 ± 3.5	20.8 ± 3.7
Hands	25.5 ± 2.6	18.1 ± 1.7	20.4 ± 2.2

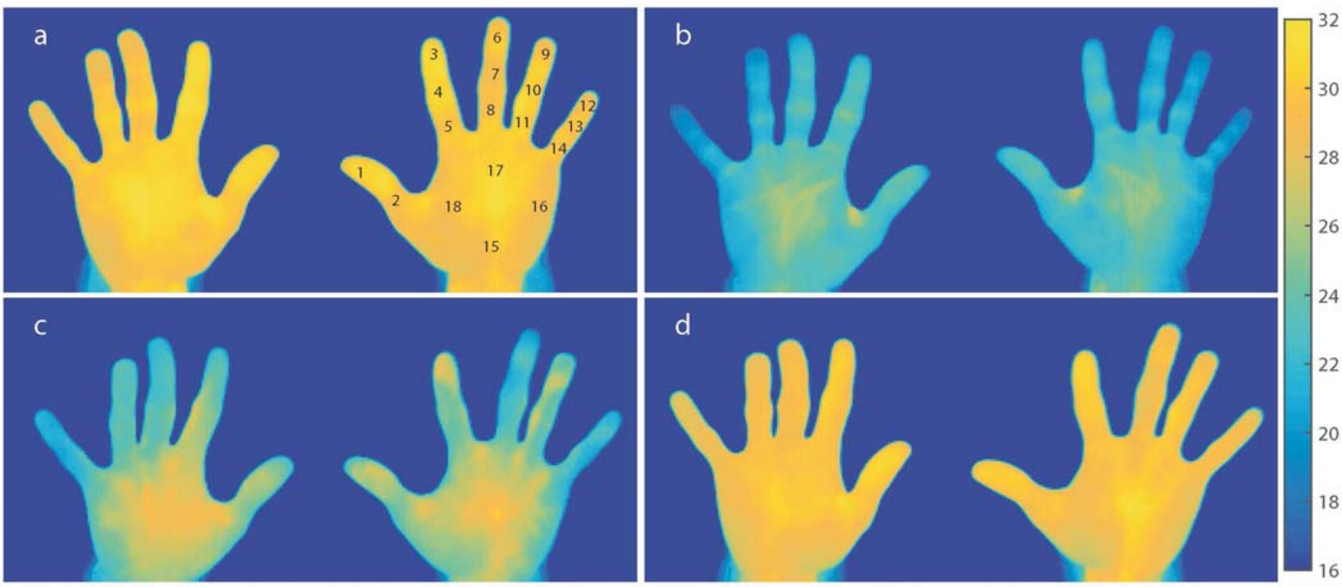

Figure 4.
Typical thermograms of participants in Group A (i.e., warm rewarming pattern) taken at baseline (a), directly after the cold stress test (b), after approximately 7 min of rewarming (c), and after 15 min of rewarming (d). The hand was divided into 18 predefined ROIs, as shown for the right hand in Figure (a). The ROIs are located on corresponding positions on the left hand. On the fingers the ROIs are roughly 200 pixels.

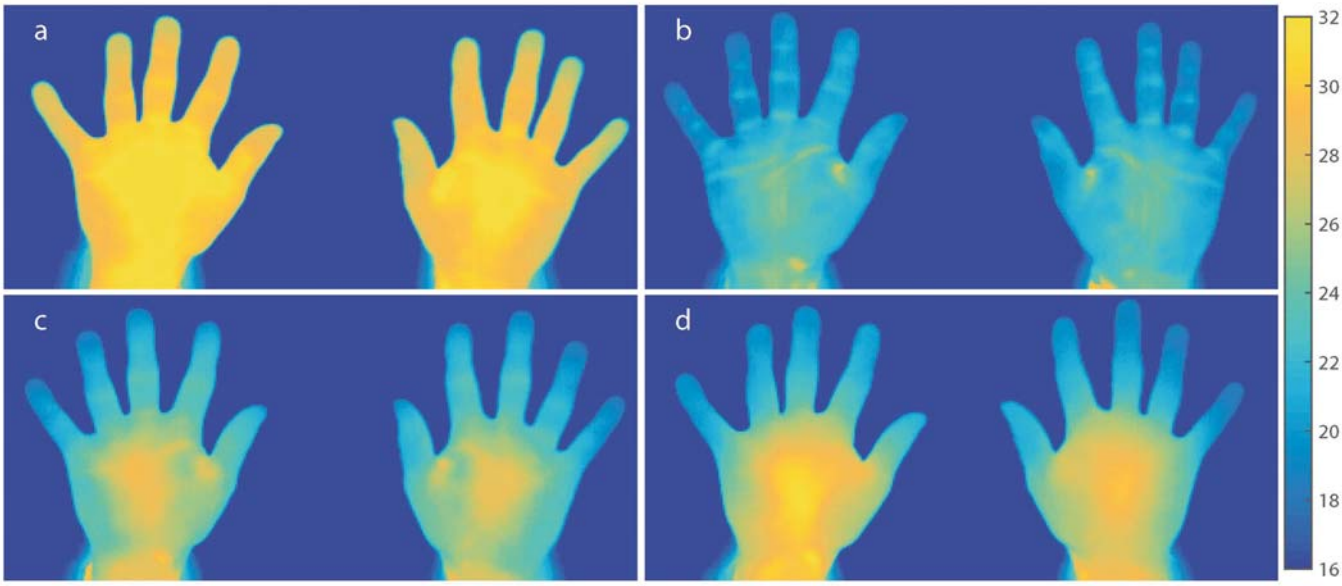

Figure 5.
Typical thermograms from Group B (i.e., cold rewarming pattern) taken at baseline (a), directly after the cold stress test (b), after approximately 7 min of rewarming (c), and after 15 min of rewarming (d).

4c). After 15 min of rewarming, the temperature pattern resembled that observed at baseline: 29.2 ± 1. 3 °C in the palms and 28.9 ± 1.8 °C in the fingers (Figure 4d, Table 1).

Group B: Cold rewarming pattern

A cold rewarming pattern was observed in 153 hands. Typically, cold rewarming involved a baseline palm temperature of 28.0 ± 1.8 °C and finger temperature of 24.6 ± 2.9 °C (Table 1). As such, the fingers had a far lower temperature than the palm, and variability in finger and thumb temperatures was greater than in the hands demonstrating the warm rewarming pattern. Furthermore, a temperature gradient emerged at baseline, with distal phalanges that were colder than those in middle and proximal phalanges (Figure 5a). Directly after the CST, palm temperature decreased to 21.3 ± 1.5 °C and finger temperature to 16.9 ± 1.8 °C (Table 1). In all five fingers, a temperature gradient occurred with cooler distal phalanges. Additionally, warmth areas surfaced over the interphalangeal joints, as Figure 5b shows. During slow rewarming, the warmth area in the palms increased, but no warm streaks on the sides of the fingers occurred (Figure 5c). After 15 min of rewarming, the temperature pattern differed from that observed at baseline, with a palm temperature of 25.0 ± 1.9 °C and finger temperature of 18.8 ± 2.2 °C (Figure 5d, Table 1). For the fingers, the difference of T_b - T_f was approximately 6 °C.

Intrapersonal variability (i.e., different rewarming patterns on different measurement days) occurred in six of the 42 participants who were measured more than once. Four of those participants also had one hand in Group A and the other in Group B for the same measurement. The order in which fingers rewarmed showed both inter- and intra-individual differences. Furthermore, a left-right asymmetry (T_{diff}) was detected in measurements in which the right hands' average temperature in 82% of the measurements

Table 2.
Temperature difference betweenthe hands (left and right); mean values are given for the whole hand, thumbs, fingers, and palms at baseline, cooled, and final measurements
(116 measurements × two hands).

n = 116	Mean absolute T_{diff} value (°C)		
	Baseline	Cooled	Final
Palms	0.6 ± 0.4	0.5 ± 0.5	0.8 ± 0.8
Fingers	0.8 ± 0.5	0.6 ± 0.4	1.1 ± 1.1
Thumbs	0.8 ± 1.2	1.6 ± 3.5	1.3 ± 1.8
Total hand	0.7 ± 0.5	0.5 ± 0.3	0.9 ± 0.9

was warmer at baseline, 69% at the cooled temperature, and 71% at the final measurement (Table 2). Six of the 66 participants were left-handed. No correlations were detected between left-right asymmetry and handedness.

Discussion

An aim of this study was to investigate whether any typical characteristics of hand skin rewarming exist. The data revealed a spectrum of cold challenge responses, but allowed us to identify two rewarming patterns: warm rewarming (i.e., Group A) and cold rewarming (i.e., Group B). In Group A, the final temperature pattern was similar to that observed at baseline, whereas in Group B, the final temperature was far from reaching the baseline temperature. Based on the distribution of temperatures, T_f = 25.4 °C was chosen as the boundary between the rewarming patterns.

The baseline temperature was of limited use in predicting warm or cold rewarming. T_b < 27 °C resulted in cold rewarming, whereas T_b > 30 °C indicated warm rewarming; however, in the interval 27 °C < T_b < 30 °C, baseline temperature demonstrated a poor function as a predictor for the outcome after a CST for either cold or warm rewarming. Furthermore, T_c demonstrated an even worse predictive value for the final temperature in the warm group (Group A). However, for Group B, T_c was a better function as a predictor than Tb. Although T_b was not fully predictive of the outcome of a CST, there was a clear correlation between T_b and rewarming behavior.

The division of T_b into three regions-namely, T_b < 27 °C, 27 C < T_b < 30 °C, and T_b > 30 °C-is comparable to the three types of peripheral thermoregulation patterns in individuals presented by Gahlen and Kluken [24] in the early 1950s. In those patterns, temperatures in the range of 27-34 °C are homoiotherm, those in the range of 18-27 °C are poikilotherm, and a mix was ampitherm [24].

In the present study, most young, healthy male participants demonstrated a cold rewarming pattern (Group B), which contradicts the findings of Dupuis [25] and Pollock et al. [26]. Our findings furthermore indicate that a cold rewarming pattern is common in this subset, which takes support from Smits et al. [27], who reported slow rewarming patterns in both healthy participants and patients, yet opposes the findings of Merla et al. [28], who regarded a poorer rewarming pattern as pathological and claimed that normal fingers have increased distal temperature after a CST. Corresponding results were not observed in our study.

We also detected a difference between left- and right-hand skin temperatures; most participants had a warmer rewarming pattern in their right hands. At baseline and after 15 min, the temperature difference was greater than 0.5 °C, which Uematsu et al. [29] defined as the limit for temperature symmetry between the left and right sides, which they considered to be normal. By contrast, our results indicate that temperature differences up to 1 °C are normal. We moreover found greater differences between sides in some healthy individuals.

It should also be noted that intrapersonal variability occurred in the rewarming pattern. This means that the same individual could demonstrate warm rewarming (Group A) on one occasion and cold rewarming (Group B) on another.

A weakness of our study was the method of recruiting participants. Invitations sent to male students might have introduced a bias to prospective participants interested in participating only because they think that they have cold hands. That bias was avoided by applying exclusion criteria, yet ensured by the participants themselves.

We could not find typical rewarming sequences of the fingers. It has previously been described that rewarming starts in the fingertips [30]. The warm rewarming (Group A) has similarities to that of active rewarming beginning in the fingertips. However, a more important finding is that warm rewarming typically followed the digital arterials along the sides of the fingers before entering the fingertips.

Regarding a hand temperature as warm might depend on the focus of the investigation. For example, when the perception of a vibration stimulus was studied, hand temperatures between 28-33 °C were regarded as warm [31, 32]. By contrast, we considered T_f ≥ 25.4 °C to represent a warm rewarming pattern. The boundary between warm and cold is an effect of the CST: bare hands for 30 s in 10 °C and 15 min of rewarming. Other cooling procedures would probably alter the boundary temperature. The cooling procedure can be altering by the temperature of the cooling water, time of cooling, and the use of protective gloves. Of those factors, using protective gloves has been shown to be of minor importance for the rewarming process [33].

Although many thermographic studies of the hands involve imaging of the dorsal aspect [30, 34, 35], we focused on the palm instead. Humans use their hands as tools for everything in daily life, and bare hands in contact with cold surfaces face the risk of cold injuries, especially for the skin of the palm [36, 37]. Therefore, the palmar aspect of the hand measured in our study was considered to be more relevant.

In all, our findings indicate that the processes controlling hand skin temperature seem to be physiologically complex, which aligns with conclusions made by Charkoudian [38] that reflex control of skin's blood circulation and its thermoregulatory control are complex and not fully understood.

Our findings also reveal different hand skin rewarming patterns in healthy young males. When investigating hand skin temperatures and assessing rewarming capability, variety in individual peripheral thermoregulation should be taken into account.

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Contributions

K. Leijon-Sundqvist designed the study; conducted data collection; was responsible for the data analysis strategy and data analysis; had the main responsibility for writing the article.

Y. Tegner designed the study; participated in the analysis strategy and data analysis; collaborated in writing the manuscript.

U. Juntti participated in design of the study; participated in data collection; collaborated in writing.

K. Karp collaborated in designing of the study; collaborated in writing.

N. Lehto designed and supervised the study; had responsibility for the analytic strategy and data analysis processing; collaborated in the writing of the article.

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The relationship between anthropometric variables and skin temperature over the biceps

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SUMMARY

BACKGROUND: Agreement existsbetween researchers on the effect of subcutaneous fat tissue on skin temperature, however, conflicting results about the association of anthropometric variables and skin temperature are found in the literature.

OBJECTIVE: To investigate the association between several anthropometric variables and the skin temperature over the biceps and to compare skin temperature over the biceps between groups based in the upper arm fat percentage.

METHODS: A cross-sectional study was conducted on 18 healthy young adults. Anthropometric variables were assessed and their association with skin temperature over the biceps was analysed. The effect of upper arm fat percentage on skin temperature was also analysed stratifying the sample according to the median value of the upper arm fat percentage.

RESULTS: Correlation coefficients between anthropometric variables and skin temperature (body fat %: rho = -0.662, p=0.003; upper arm fat percentage: rho = -0.661, p=0.003; tricipital skinfold: rho = -0.652, p=0.003; sum of 8 skinfolds: rho = -0.633, p=0.005) were calculated and significant differences in temperature values (p=0.031) were found between groups based in the arm fat percentage of the subjects.

CONCLUSION: Moderate correlations between selected anthropometric variables and skin temperature over the biceps were found and the amount of fat percentage in the arm affected the skin temperature values over the biceps.

KEYWORDS: anthropometry, skin temperature, biceps, skinfold

ZUSAMMENHANG ZWISCHEN ANTHROPOMETRISCHEN VARIABLEN UND DER HAUTTEMPERATUR ÜBER DEM ARMBIZEPS

HINTERGRUND: Bei Forschern besteht Übereinstimung über den Einfluss des Unterhautfettgewebes auf die Hauttemperatur, allerdings finden sich in der Literatur widersprüchliche Ergebnisse über den Zusammenhang der Hauttemperatur mit anthropometrischen Variablen.

ZIEL DER STUDIE war es den Zusammenhang zwischen mehreren anthropometrischen Variablen und der Hauttemperatur über dem Armbizeps zu untersuchen und Hauttemperatur über dem Bizeps bei Personen mit unterschiedlichen Fettanteil am Oberarm zu vergleichen.

METHODE: Eine Querschnittsuntersuchung wurde an 18 gesunden jungen Erwachsenen durchgeführt. Anthropometrische Variablen wurden bewertet und ihre Assoziation mit Hauttemperatur über den Bizeps wurde analysiert. Der Einfluss des Fettanteils am Oberarm auf Hauttemperatur beurteilt, nachdem die die Probanden entsprechend dem Medianwert des Fettanteils am Oberarm in zwei Gruppen stratifiziert worden waren.

ERGEBNISSE: Korrelationskoeffizienten zwischen anthropometrischen Variablen und der Hauttemperatur (Körperfett %: Rho =-0.662, p = 0,003; Oberarm Fettanteil: Rho =-0.661, p = 0,003; Trizipitale Hautfalte: Rho =-0.652, p = 0,003; Summe aller acht Hautfalten: Rho =-0.633, p = 0,005) wurden berechnet. Signifikante Unterschiede in den Temperaturwerten (p = 0.031) fanden sich zwischen den Personen mit unterschiedlichen Fettanteil am Oberarm.

SCHLUSSFOLGERUNG: Es fanden sich nur mäßige Korrelationen zwischen ausgewählten anthropometrischen Variablen und Hauttemperatur über den Bizeps. Hingegen war der Fettanteil am Oberarm im erheblichen Ausmaß mit der Hauttemperatur über dem Bizeps vergesellschafte

SCHLÜSSELWÖRTER: Anthropometrik, Hauttemperatur, Hautfaltendicke, Armbizeps

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Introduction

Thermal imaging is a safe image modality - due to its non-invasive, non-ionizing and emission free properties - that allows skin temperature (Tsk) mapping, giving insight on the vasomotor function related to skin thermoregulatory processes [1, 2]. A recent review [3] has exhaustively discussed the factors that can influence the analysis and interpretation of thermograms. Anthropometric factors are among the list and in this group, those related to the weight and body composition of the subject are the most discussed in the literature.

Several studies have addressed the relationship between Tsk and skinfold values [4-11], subcutaneous fat percentage or subcutaneous fat mass [4, 12], body fat percentage [6, 8-15], lean body mass percentage or skeletal muscle mass percentage [6, 13], visceral fat mass [12], body surface area [13] and body mass index (BMI) [12, 13, 15] in different body locations. An inverse and significant relationship between body fat and Tsk has been suggested in certain body areas - chest, abdomen, upper back and lower back - but not on upper limbs [12] and the demand for more studies to increase the knowledge on this subject has been identified [3].

Concerning Tsk measurements on upper limbs and their relation with anthropometric variables, Neves et al. [4] reported a moderate negative correlation between arm muscle and total arm cross sectional areas and the difference between core temperature and Tsk over the biceps, and no significant correlation between subcutaneous fat percentage and Tsk, but the correlation between skinfold thickness and Tsk was not assessed. In another study [5], the same group reported a moderate negative correlation between the biceps skinfold and Tsk measured over the biceps. Chudecka and Lubkowska [6] assessed the influence of physiological and morphological parameters on Tsk changes of the arms and forearms, and through regression analysis found no significant effect of anthropometric data on Tsk changes in the series of tests. The authors also pointed out that the anterior surface of the arms and forearms seems to be more suitable for assessing the dynamics of temperature changes due the decreased fat distribution at the anterior surface. Indeed, Neves et al. [4] found significant differences between biceps and triceps skinfold values. Two more studies [12, 13] have reported no significant correlation between Tsk at the arms and forearms and BMI, body fat percentage, skeletal muscle mass percentage, body surface area, visceral fat mass and subcutaneous fat mass.

Given the conflicting results in the literature, the aim of this study was to investigate the association between several anthropometric variables and the Tsk over the biceps and to compare Tsk over the biceps between groups based on the upper arm fat percentage.

Materials and Methods

Participants

GPower 3.1 [16]was used to determine the sample size needed to detect a significant difference from r=0 assuming a correlation of 0.62, an α=0.05 and a statistical power of 0.8. According to the software, the required sample size was 18 subjects. The value 0.62 was assumed based on data reported previously [17] as the lowest significant correlation value between skin temperature over the biceps (TskB) and anthropometric variables. This cross-sectional study followed the recommendations of the Helsinki Declaration and was approved by the local University ethical committee. All experimental procedures were explained to the participants before obtaining their informed written consent to participate. Eighteen young adults (nine females) aged 18-32 years agreed to participate. None of the volunteers had pathologies on the upper limbs and nor were taking any form of medication. The volunteers were requested not to smoke, drink beverages containing alcohol and caffeine or to have eaten a heavy meal two hours prior to assessment. In addition, the volunteers were requested not to have carried out heavy exercise or to have used cosmetics or oil ointments on the assessment day.

Anthropometric Measurements

Body height was measured with a stadiometer Seca 217 (Seca, Hamburg, Germany), body mass was measured with a bioelectrical impedance balance Tanita BC-545 (Tanita Corporation of America, Illinois, USA) and BMI was calculated from both measurements. Skinfolds were measured at 8 sites (triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, front thigh and medial calf) with a skinfold caliper and the upper arm circumference was obtained using an anthropometric tape. All variables were measured according to the recommendations of the International Society for the Advancement of Kinanthropometry (ISAK) [18, 19]. The anthropometric measurements were performed by an experienced examiner with adequate training, certified in the ISAK method and with adequate technical error of measurement, according to the values shown in the literature of 5% for skinfolds [18]. The sum of skinfolds and the percentage of body fat were used as indicators of total fat. The sum of skinfolds was obtained using all the skinfolds above mentioned and the percentage of body fat was estimated through the Yuhasz equations [20], using triceps, subscapular, supraspinal, abdominal, front thigh and medial calf skinfolds.

The estimates for fat and muscle areas where calculated from the equations of Frisancho [21]. The upper arm area (UAA), upper arm muscle area (UAMA) and upper arm fat area (UAFA) derived from measures of upper arm circumference (UAC) and triceps skinfold (T). The upper arm fat percentage (UAFP) derived from UAFA and UAA.

$$1.)\ \mathrm{UAA}(\mathrm{mm}^2) = \frac{\pi}{4} \times d^2, \quad \text{where } d = \frac{UAC}{\pi}$$

$$2.)\ \mathrm{UAMA}(\mathrm{mm}^2) = \frac{\left(UAC - \pi T\right)^2}{4\pi}$$

$$3.)\ \mathrm{UAFA}(\mathrm{mm}^2) = \mathrm{UAA} - \mathrm{UAMA}$$

$$4.)\ \mathrm{UAFP}\ (\%) = \frac{UAFA}{UAA} \times 100$$

Skin Temperature Measurements

The Tsk measurement protocol followed the recommendations of previously published literature [22-24]. Thermograms were obtained with a FLIR E60 camera with resolution of 320 x 240 pixels, thermal sensitivity <0.05ºC and ± 2ºC of accuracy (FLIR Systems, Wilsonville, USA). The emissivity was set to 0.98 and the temperature scale to 27º-37ºC. Environmental conditions were controlled, all subjects were asked to undress and remain still in the examination room for 15 minutes (temperature: 20.9 ± 1.4ºC; relative humidity < 50%; no airflow). The camera was positioned 1 meter away, perpendicular to the anterior surface of the subject's right arm for image capture. One region of interest was defined over the right biceps, above the cubital fossa and below the

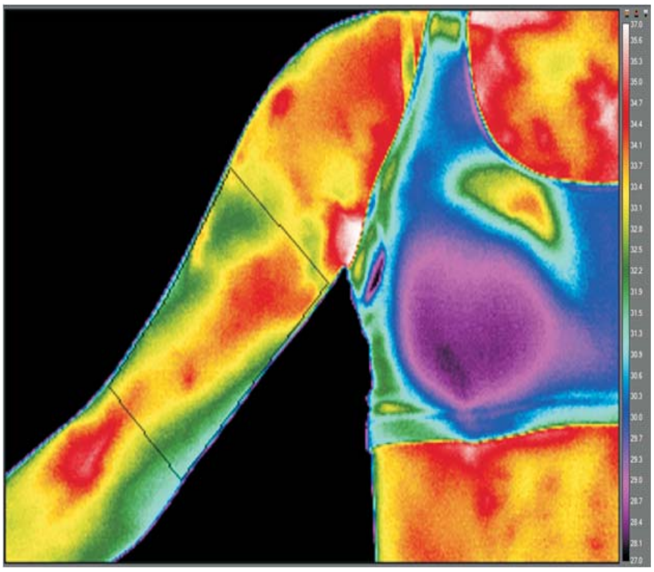

Figure 1
Example thermogram showing the region of interest over the biceps used in this study

axilla (Figure 1), and TskB was obtained, as the mean temperature value of the region of interest, using the software FLIR ResearchIR Max.

Statistical Analysis

Calculations were performed using Statistical Package for Social Sciences version 23 (SPSS Statistics, IBM). Descriptive statistics (mean and standard deviation were used to summarize the characteristics of temperature and anthropometric data. Shapiro Wilk's normality test, assessment of skewness and kurtosis and visual inspection of the variable histogram were used to assess the normality of each variable and, since not all variables had normal distribution, non-parametric tests were selected for the analysis. Spearman's rho was used to assess the association between Tsk and anthropometric data. Confidence intervals for the correlation were obtained through a bootstrapping approach. After descriptive data analysis the volunteers were divided in two groups based on the median value of the UAFP and the Mann-Whitney U Test was used to compare variables between the groups. To estimate the confidence intervals across groups the Hodges-Lehmann estimate was used. The significance level was set at $p \leq 0.05$.

Table 1
Descriptive statistics – mean and standard deviation (SD) – of variables analysed in the study

Variable	n	Mean ± SD
Age (years)	18	23.4±3.1
BMI (Kg/m^2)	18	22.3±2.6
Sum of 8 skinfolds (mm)	18	115.3±48.0
Bicipital skinfold (mm)	18	7.4±4.2
Tricipital skinfold (mm)	18	12.9±6.5
Body fat (%)	18	15.6±7.4
Arm fat (%)	18	14.86±9.04
Arm lean mass (Kg)	18	3.0±1.0
UAC (cm)	18	28.4±3.4
UAA (cm^2)	18	65.00±15.6
UAMA (cm^2)	18	48.5±16.6
UAFA (cm^2)	18	16.5±7.6
UAFP (%)	18	26.7±11.9
TskB (ºC)	18	33.5±0.7

Results

All the volunteers fulfilled the requirements to be enrolled. Table 1 summarises the variables assessed in the study.

A correlation analysis was performed between TskB and BMI, the sum of 8 skinfolds, bicipital skinfold, tricipital skinfold, body fat percentage, arm fat percentage, arm lean mass, UAC, UAA, UAMA, UAFA and UAFP. The results for the Spearman's rho, p value and 95% confidence intervals (CI) are shown in table 2.

From the table we can notice a negative moderate correlation between TskB and the sum of 8 skinfolds (rho = -0.633; p=0.005; CI=[-0.90, -0.22]), the tricipital skinfold (rho = -0.652; p=0.003; CI=[-0.87, -0.26]), the percentage

Table 2
Spearman's correlation coefficients between Tsk over the biceps (ºC) and the anthropometric variables analysed in the study and the respective p value and 95% CI

Variable	Spearman's rho	*p* value	95% CI	rho^2
BMI (Kg/m2)	0.196	0.435	[-0.36, 0.72]	0.038
Sum of 8 skinfolds (mm)	-0.633**	0.005	[-0.90, -0.22]	0.401
Bicipital skinfold (mm)	-0.340	0.167	[-0.78, 0.17]	0.116
Tricipital skinfold (mm)	-0.652**	0.003	[-0.87, -0.26]	0.425
Body fat (%)	-0.662**	0.003	[-0.89, -0.28]	0.438
Arm fat (%)	-0.223	0.373	[-0.71, 0.30]	0.050
Arm lean mass (Kg)	0.376	0.124	[-0.17, 0.78]	0.141
UAC (cm)	0.313	0.206	[-0.23, 0.78]	0.098
UAA (cm^2)	0.316	0.202	[-0.23, 0.78]	0.099
UAMA (cm^2)	0.535*	0.022	[-0.01, 0.89]	0.286
UAFA (cm^2)	-0.506*	0.032	[-0.81, -0.06]	0.256
UAFP (%)	-0.661**	0.003	[-0.88, -0.25]	0.437

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed)

of body fat (rho = -0.662; p=0.003; CI=[-0.89, -0.28]), the UAFA (rho = -0.506; p=0.032; CI=[-0.81, -0.06]) and the UAFP (rho = -0.661; p=0.003; CI=[-0.88, -0.25]) and a positive moderate correlation between UAMA (rho = 0.535; p=0.022; CI=[-0.01, 0.89]) and TskB. No significant correlation was observed between TskB and BMI, the bicipital skinfold, the arm fat percentage, the arm lean mass, the UAC and the UAA.

The scatterplot matrix in figure 2 contains all the pairwise scatter plots of the variables with higher correlation coefficients with TskB: body fat %, UAFP, tricipital skinfold and the sum of 8 skinfolds evidencing the association between the variables.

The association between the anthropometric variables - body fat %, UAFP, tricipital skinfold and sum of 8 skinfolds - is evident. Correlation coefficients between these variables vary from 0.854 and 0.978 - meaning that the correlation is high or very high - and all are statistically significant at the 0.01 level. None of these variables correlated significantly with BMI.

Figure 2
Scatterplot matrix of TskB, Body fat %, UAFP, tricipital skinfold and the sum of 8 skinfolds. Diagonal histograms represent the variable distribution.

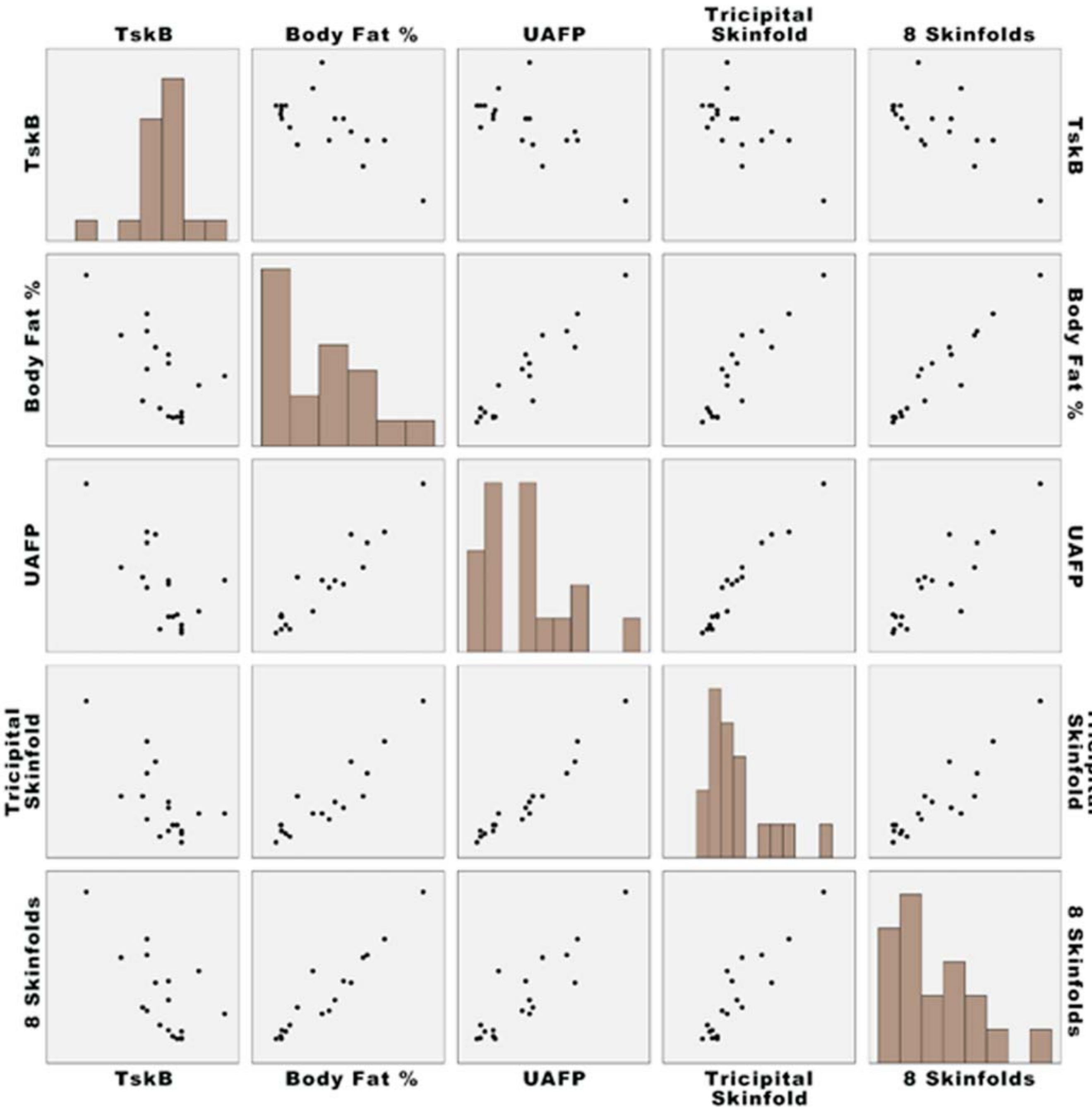

Table 3
Differences between groups based on the median value of the UAFP. Results for significance and 95% confidence intervals.

Variable	Median UAFP	Mean ± SD	*p* value [a]	Median Difference Estimate [b]	95% Confidence Interval
Age (years)	<= 26.9	23.8 ± 3.2	0.605	1.000	[-3.000, 3.000]
	>26.9	23.0 ± 3.1			
BMI (Kg/m^2)	<= 26.9	22.9 ± 2.7	0.222	1.600	[-1.400, 4.000]
	>26.9	21.7 ± 2.4			
Sum of 8 skinfolds (mm)	<= 26.9	83.6 ± 25.4	0.001**	-61.500	[-94.000, -29.000]
	>26.9	146.8 ± 44.7			
Bicipital skinfold (mm)	<= 26.9	5.1 ± 2.9	0.004**	-4.000	[-9.000, -2.000]
	>26.9	9.8 ± 4.0			
Tricipital skinfold (mm)	<= 26.9	8.4 ± 1.5	<0.001**	-7.000	[-13.000, -4.000]
	>26.9	17.3 ± 6.4			
Body fat (%)	<= 26.9	10.1 ± 3.1	<0.001**	-10.800	[-15.000, -6.300]
	>26.9	21.0 ± 6.3			
UAC (cm)	<= 26.9	29.9 ± 3.7	0.05*	3.200	[0.400, 6.500]
	>26.9	26.9 ± 2.3			
UAA (cm^2)	<= 26.9	72.2 ± 17.3	0.05*	13.700	[1.732, 29.626]
	>26.9	57.8 ± 9.9			
UAMA (cm^2)	<= 26.9	60.2 ± 15.5	0.002**	23.430	[14.580, 33.484]
	>26.9	36.7 ± 6.0			
UAFA (cm^2)	<= 26.9	12.0 ± 2.8	0.002**	-7251	[-14.180, -2.947]
	>26.9	21.1 ± 8.3			
TskB (ºC)	<= 26.9	33.7 ± 0.3	0.031*	0.600	[0.100, 1.100]
	>26.9	33.2 ± 0.9			

[a]. Mann-Whitney test.
[b]. Hodges-Lehmann test.
**. Significant at the 0.01 level (2-tailed).
*. Significant at the 0.05 level (2-tailed).

The results of the Mann-Whitney and Hodges-Lehmann tests after stratification based on the UAFP are presented in table 3.

No significant differences were found regarding age and BMI between the groups based on the median value of the UAFP. Significant differences were found for the UAC (p=0.05), UAA (p=0.05) and UAMA (p=0.002) with higher values in the group with less UAFP. The group with UAFP ≤ 26.90% presented significantly higher TskB (p=0.031) and significantly lower values of sum of 8 skinfolds (p=0.001), bicipital skinfold (p=0.004), tricipital skinfold (p<0.001), body fat % (p<0.001) and UAFA (p=0.002) than the group with more than 26.9% UAFP.

Discussion

This study determined the association between several anthropometric variables and the Tsk over the biceps, recorded at rest in healthy subjects. The results demonstrated a negative moderate correlation between TskB and the body fat percentage, the UAFP, the tricipital skinfold, the sum of 8 skinfolds and the UAFA, and a positive moderate correlation between UAMA and TskB, suggesting a negative association with the amount of fat tissue and a positive association with the amount of lean tissue.

Correlation coefficients are a measure of effect size and when squared and multiplied by 100 they represent the percentage of variance accounted for [25] TskB. From the values of rho^2 values we can see that the significant cor- relations account for 25.6%-43.8% of the variance observed in TskB, which according to Cohen [26] constitute a large effect size.

Few studies have addressed the relationship between the skin temperature and anthropometric variables [e.g. 4, 5, 7, 8, 12, 13, 15] and fewer have studied specifically the Tsk over the biceps [4, 5].

Heush and McCarthy [15] reported a negative and significant correlation between body fat percentage and whole-body Tsk but considering only normal BMI subjects, and no significant correlation was found between BMI and whole body temperature. Our sample was constituted by subjects with normal BMI and no correlation was found between this parameter and TskB. Karki and colleagues [8] reported that skinfold thickness above the patella had no significant effect on knee Tsk and found no correlation between the two measures. In fact, comparing Tsk between genders, women had higher Tsk and higher skinfold thickness and fat percentage. In the study of Bandeira et al. [7] a significant low negative correlation was found between the tsk over the adductor longus and the thigh skinfold and a significant moderate negative correlation was found between the tsk above the vastus medialis and rectus femoris and the thigh skinfold. Chudecka and colleagues [12] analysed the correlation between Tsk in several body areas and BMI, body fat percentage, visceral fat mass and subcutaneous fat mass in obese women. The authors reported a significant correlation between BMI and hand front (positive), abdomen and thigh front and back (negative). A significant correlation between body fat percentage and hand front (positive), abdomen and thigh front and back (negative) and a significant correlation (negative) between subcutaneous fat mass and abdomen and thigh (front and back) were also reported in the same study. Using a similar methodology in young women and men Chudecka and Lubkowska [13] reported low negative, but significant, correlations between the upper back, chest, lower back and abdomen and BMI and body fat percentage in women. The authors reported the same results for men except for the upper back where the correlation was not significant. In these two studies by the group of Chudecka the Tsk of the anterior arm and forearm was studied using a single region of interest and no significant correlation was found with the various anthropometric variables analysed.

Although the results of these studies are not consistent, the trend suggests that Tsk decreases when the amount of fat tissue increases, except in the study of Karki et al. [8] and in the study of Chudecka and colleagues [12] for the anterior aspect of the hands. Karki's results are in line with the results of Selfe et al. [11] reporting higher Tsk in the anterior aspect of the knee in subjects with higher patellar skinfold. However, Chudecka and Lubkowska [13] reported that women had significantly higher body fat percentage and subcutaneous fat mass and expressed significantly lower Tsk in the anterior aspect of the thigh and shank. The results of Chudecka and colleagues [12] in obese women are in line with the results of Savastano et al. [14]. Despite the fact that they did not correlate Tsk with any variable, they reported that mean fingernail-bed temperature was significantly higher in obese participants.

Neves et al. [5] studied two groups of healthy male volunteers, stratified by biceps brachii skinfold measured by ultrasonography, and found significant differences between Tsk over the biceps of both groups, with higher Tsk in the group with smaller values of bicipital skinfold. In the same study, a negative moderate and significant correlation between bicipital skinfold and Tsk was also reported. In our study, no significant correlation was found between TskB and the bicipital skinfold. However, a moderate negative and significant correlation was found between TskB and the tricipital skinfold. The discrepant results regarding the bicipital skinfold may be related to method of assessment of the skinfold but further research is needed to support or refute this claim.

The same group, in another study [4], reported a significant moderate negative correlation between UAMA and the difference between core temperature (tympanic temperature) and TskB, a significant moderate negative correlation between UAA and the difference between core temperature and TskB, and no significant correlation between UAFP and the difference between core temperature and TskB. In the current study UAFP was one of the variables with higher association with TskB and, being a local measure of the amount of fat tissue, was the selected variable to stratify the participants in two groups. In line with the previous study, the UAMA evidenced a significant moderate positive correlation with TskB but the UAA did not correlate significantly with TskB.

TskB was significantly higher in the group with lower values of UAFP, which is in line with the results of several studies reporting that Tsk is significantly lower in groups with higher amount of fat tissue [e.g. 12, 14]. Regarding BMI, no significant differences were found between the groups. BMI is very commonly used in the literature to characterize study participants. In this study, BMI evidenced low association with TskB and with other anthropometric variables (body fat %, UAFP, tricipital skinfold and sum of 8 skinfolds). These results question the use of BMI to characterize participants in thermal imaging studies focusing on the upper arm. Chudecka and Lubkowska [13] reported negative moderate correlations between BMI and Tsk but only in the chest, abdomen, upper and lower back and not in the upper and lower limbs.

Conclusion

Moderate negative correlations between TskB and the body fat percentage, the UAFP, the tricipital skinfold, the sum of 8 skinfolds and the UAFA and a positive moderate correlation between UAMA and TskB were observed. The value of UAFP significantly influenced TskB. Higher values of TskB were observed in subjects with lower UAFP.

The results of this study question the use of BMI as a measure of body composition to characterize subjects in studies focusing on the skin temperature of the arm. Local measures of body composition, such as UAFP, should be used instead.

The association between Tsk and anthropometric variables is dependent on the site being assessed and future research should focus in the analysis of this relationship in body areas that have not been studied.

Conflict of interest

The authors have no conflict of interest to declare.

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News in Thermology

21st Congress of the Polish Association of Thermology (PTA)

Prof Dr Anna Jung, vice-president of the EAT and president of Polish Association of Thermology, announced at the end of the well-attended 20th Conference of PTA, held in Gdansk in July 2016, that the conference will return to Zakopane in spring of 2017. The conference will be organised at the weekend after Easter 2017, on 21 to 23 April 2017. In addition to the scientific programme, which usually attracts experts in thermology from around Europe, an EAT Board meeting is scheduled.

EAT webpage under reconstruction

EAT secretary Dr Ricardo Vardasca, Visiting Professor at the University of Valencia, is currently reconstructing the EAT web site, which was established by the former EAT president Prof James Mercer. The layout of the EAT will be modernised and section restricted for EAT members will be included in the new webpage. The membership area will become accessible by using the same username and password, that provides access to "Thermology international". Besides a section of reports on interesting publications related to thermology and temperature measurements, a series of tutorials is planned covering terminology and standard procedures for thermal image recording and evaluation. A section related to equine thermography is also planned. Instructions how to read or write a scientific publication, introductions into basics of statistics and into clinical trial planning will complete this education section of the member area.

14th European Conference of Thermology 2018

Preparations for the next European Conference in 2018 were discussed at the last EAT board meeting. EAT president Dr Kevin Howell has meanwhile contacted officials of National Physics Laboratory (NPL) in Teddington and sorted out details of conference organisation. The conference date was fixed to 4-7 July . This date avoids collision with QIRT2018 that will be in held in Berlin at the last week of June 23 to 28th. The format of the EAT 2018 will be registration and welcome on the evening of 4 July, two full days of scientific sessions 5 - 6 July, and ending with a visit to Hampton Court palace on the morning of Saturday, 7 July.

A pre-conference instructional course is planned, but not yet confirmed. The most likely date and venue for that course is July 4th at NPL's postgraduate teaching centre.

2016

September 9th, 2016.
AAT Pre-Meeting Physician Member Certification Course

10th- 11th September 2016
Annual Scientific Session of the American Academy of Thermology (AAT) in Greenville, South Carolina.

Venue: Bon Secours St. Francis Hospital campus at the Bernadine Center.

2016 Programme

General Sessions: Saturday, September 10th, 2016

08:00am - Registration

08:30am - Welcoming Remarks - *Jeffrey Lefko,* Greenville, SC, Executive Director, American Academy of Thermology

8:35-9:15am Keynote Address

Use of Thermal Imaging for Hypothermia in Surgery- Relationship between Hypothermia in Surgical Centers and in Mountain Climbing - *Hisashi Usiki*, M.D., Chief Director of Japanese Association of Thermology, Clinical Professor and Director of Surgical Center, Kagawa University Hospital, Japan

9:15am - 10:45am Session 1: Revised AAT Guidelines, AAT Thermography Atlas Update,

Moderator: Dr. *Robert Schwartz*, MD, Greenville, SC, Chairman of American Academy of Thermology

9:15-9:45am Presentations of 2016 Revisions of Thermography Guidelines and Clinical Applications in Animal Physiology - Dr. *Tracy Turner,* DVM, Elk River, MN, Board Member, American Academy of Thermology

9:45- 10:15am Update on the AAT Thermography Atlas of Medical Conditions - J*ames Campbell*, MD, Clemmons, NC, Chair of Members Only Website Thermography Atlas project

10:15-10:45am Walking Through the Steps of an AAT Atlas Case Submission: Start to Finish - J*ames Campbell*, MD, Clemmons, NC, Chair of Members Only Website Thermography Atlas project
Q&A/ Discussion

10:45am -11:15am Break

11:15am -12:30 pm Session 2: Advancements in Uses of Infrared Imaging Cameras, Equipment, and Translational Applications within the Infrared Spectrum

11:15-11:30am Infrared Imaging Artifacts - *Robert Schwartz,* MD, Chairman of AAT Board of Directors

11:30-11:50am Spectrums of Infrared Imaging Defined - *James Campbell*, MD, Member, AAT Board of Directors

11:50-12:30pm Near Infrared Spectroscopy & Acute Compartment Syndrome: Lessons Learned - *Michael S, Shuler*, MD, Athens, GA
Q&A/ Discussion

12:30pm - Lunch (provided)

1:30pm -3:00pm Session 3: Clinicians Corner: Thermography as an Extension of the Physical Exam for Use in Diagnosis and Treatment

Moderator: Dr. Robert Schwartz, MD, Greenville, SC, Chairman of AAT

1:30-1:50pm Integrating a Thermal Imaging Lab within a Medical Practice: Clinical Applications and Practical Pitfalls - *George Schakaraschwili*, MD, AAT Certified Physician Member

1:50-2:10pm Use of Thermal Imaging In An Occupational Medicine Practice - Tashof Bernton, MD, Denver, CO

2:10-2:30pm SSR and Breast Thermography as a Driver for Musculoskeletal Diagnosis and Treatment - *Dr. Robert Schwartz*, MD, Greenville, SC

2:30-3:00pm Breast Thermographic Imaging as an Extension of the Osteopathic Physical Exam - *Bruce Rind*, MD, AAT Certified Physician Member
Q&A/ Discussion

3:00pm - Break

3:30pm -5:00pm Session 4: Thermal Imaging Research Issues and Challenges

3:30-3:50pm Medical Thermology as a Sports Medicine Training and Performance Assessment - *Adam Kiefer,* PhD, Cincinnati Medical Center

3:50-4:05pm Breast Infrared Imaging Changes as a Marker for Extracellular Matrix Signaling - Jan Crawford, RN, Member, AAT Board of Directors

4:05- 4:20pm Advances in Use of Infrared Imaging for Hand Evaluations - James Campbell, MD

4:20-4:50pm Dental Pathology and the Use of Thermography - *Alexander Mostovoy*, HD, DHMS, AAT Certified Physician, Toronto, Ontario, *Tirza Derflinger*, AAT Certified Technician, Erie, CO

4:50-5:00pm Integration of Thermography into PMR, Educational Components of Medical Residency Programs - *Bryan O'Young,* MD, Geisinger, PA., President, AAT Board of Directors.

5:00pm - Annual Scientific Session Wrap Up and Remarks

5:30pm - Session Ends

Shuttle back to Crowne Plaza Hotel

6:30- 7:30pm - Meet and Mingle Reception with the Leadership at the Crowne Plaza Hotel

Presentation of AAT 2016 Achievement Award

Sunday September 11th, 2016
Committee Meetings

07:30am - Shuttle from Crowne Plaza Hotel

08:00am - Committee Meetings (Committee members and other attendees):

- Membership Committee including:
  - Sub Committee on Complimentary Alternative Medicine (CAM) and Allied Health
  - Sub Committee on Technicians/Technologists.
- Devices and Equipment Committee
- Journal/Newsletter
- Website Committee
- Education Committee
- Advocacy Committee

09:15am - General Session (all in attendance)

10:15am - General Session Ends

10:30am - Shuttle returns to Crowne Plaza Hotel

10:15am - Board of Directors Meeting (board members only)

1pm - Board of Directors Meeting Ends

Further Information:

http://aathermology.org/

October 19th-26th - 2016
4th Mediterranean International Workshop on Photoacoustic & Photothermal Phenomena in Erice-Sicily

Further information on page 98

2017

April 21st-23rd 2017
XXI National Congress of the Polish Association of Thermology in Zakopane, Poland

ABSTRACT DEADLINE March 15th 2015

Contact : a.jung@spencer.com.pl

LOCAL ORGANIZING COMMITTEE

Prof. Anna Jung (Chair) Dr Janusz Zuber (Deputy Chair)

INTERNATIONAL SCIENTIFIC COMMITTEE

Prof. Jung Anna MD,PhD (Poland)

Prof. Ring Francis D.Sc. (UK)

Prof. Ammer Kurt MD,PhD (Austria)

Prof. Wiêcek Boguslaw PhD (Poland)

Kalicki Boleslaw MD,PhD (Poland)

Zuber Janusz MD,PhD (Poland)

Prof. Vardasca Ricardo PhD (Portugal)

Dr Howell Kevin MSc, PhD (UK)

Prof. Sillero Quintana PhD (Spain)

Aderito SeixasMSC (Portugal)

Registration fee for non Polish participants will be paid in cash on arrival at the conference.

Registration by e-mail is required before March 1st to ensure hotel reservation. After registration number is issued, delegates are committed to payment of the fee.

Registration includes: welcome dinner Friday 21th lunch and accomodation..

Extra night + breakfast : 70 .-Euro

Accompaning person : 200 .-Euro

July 2nd-6th 2017
2nd Asian Conference on Quantitative InfraRed Thermography in Daejeon, Korea

Venue: Interciti Hotel, 92 Oncheon Ro, Yuseong-gu Daejeon, 34189, Rep of Korea

Important Dates

Abstrac submission deadline: February 28, 2017

Abstract acceptance notification: April 15, 2017

Full paper submission deadline: May 30, 2017

Furter information

www.qirtasia2017.com

Contact : Prof Wontae Kim
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«ETTORE MAJORANA» FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE
TO PAY A PERMANENT TRIBUTE TO GALILEO GALILEI, FOUNDER OF MODERN SCIENCE AND TO ENRICO FERMI, THE "ITALIAN NAVIGATOR", FATHER OF THE WEAK FORCES

INTERNATIONAL SCHOOL OF QUANTUM ELECTRONICS

4th Mediterranean International Workshop on Photoacoustic & Photothermal Phenomena

FOCUS on BIOMEDICAL, NANOSCALE IMAGING and NON DESTRUCTIVE EVALUATION

ERICE-SICILY: OCTOBER 19-26 - 2016

Directors of the Workshop: R. LI VOTI and A. MANDELIS

Sponsored by: • Italian Ministry of Education, University and Scientific Research • Sicilian Regional Government
Sapienza Università di Roma - Thermal Nanoscience and Nanoengineering CNRS European Network - FLIR - EOS – SIOF - GESCA

PURPOSE OF THE WORKSHOP

The aim of the workshop is to bring together all scientists, technology developers and technology users who are investigating or exploiting optically and electromagnetically excited acoustical and thermal phenomena for the investigation of a large variety of material properties and applications. The wealth of photoacoustic and photothermal (PA/PT) topics indicate that this field has developed a broad range of tools for fundamental and applied research. PA/PT research has reached a mature state, with an established position in measurement technology and materials characterisation and future progresses are guaranteed by the close synergy with advances in laser and measurement technology. This fourth workshop acknowledges the explosive growth of biomedical photoacoustics and tissue imaging, and the presence of an ever growing biomedical photoacoustics research community around the world and in Europe, in particular. It also acknowledges the significant and growing contributions of photoacoustic and photothermal non-destructive evaluation / characterization to nanoscale and other advanced materials (with connections to biomedical imaging by use of nanoparticles). Participants are encouraged to present their own results in the field. Special oral sessions will be scheduled for participant presentations during or following the lecturers' talks. In addition, students and newcomers to the field will for the first time have the opportunity to attend the Summer School, which will run in parallel to the workshop.

LOCATION & HISTORY

The conference site is the «Ettore Majorana» Foundation and Centre for Scientific Culture (EMFCSC) in Erice – Italy. EMCFSC has a long tradition in the organization of Schools, Workshops and International Conferences, covering all branches of Science. EMCFSC is situated in the old pre-mediaeval city of Erice where 3 monasteries (one of which was the residence of the Viceroy of Sicily during the XIV and XV Centuries) provide an appropriate setting for high intellectual endeavor.

Erice is a historic town in Sicily, Italy. It is located on top of Mount Erice, at around 750m above sea level, overlooking the city of Trapani, the low western coast towards Marsala the dramatic Punta del Saraceno and Capo san Vito to the north-east, and the Aegadian Islands on Sicily's north-western coast.

In Erice you can admire the Castle of Venus, the Cyclopean Walls (~800 B.C.) and the Gothic Cathedral (~1300 A.D.). Erice is at present a mixture of ancient and medieval architecture. Other masterpieces of ancient civilization are to be found in the neighborhood: at Motya (Phoenician), Segesta (Elymian), and Selinunte (Greek). On the Aegadian Islands — theatre of the decisive naval battle of the first Punic War (264-241 B.C.) — suggestive neolithic and paleolithic vestiges are still visible: the grottoes of Favignana, the carvings and murals of Levanzo. Splendid beaches are to be found at San Vito Lo Capo, Scopello, and Cornino, and a wild and rocky coast around Monte Cofano.

SESSIONS & TOPICS

The workshop intends to cover different thematic sessions:

A) Biomedical and Biological PA & PT (Chair. **A.Mandelis**)
B) Nanoscale Heat Transfer and Imaging (Chairs: **S.Volz** and **G.Tessier**)
C) Non Destructive Evaluation & Testing (Chairs:**C.Glorieux** and **X.Maldague**)
D) Thermophysical Properties (Chairs **R. Li Voti** and **A.Mandelis**)

INVITED SPEAKERS

Guillaume Baffou - Institut Fresnel, Marseille - France
Paul Beard - University College London – UK
Paolo Bison – CNR - Italy
Jean Dumoulin - IFSTTAR - France
Mladen Franko – University of Nova Gorica - Slovenia
Daniel Jaque - Universidad Autonoma de Madrid - Spain
Jean-Claude Krapez – ONERA - France
Arantza Mendioroz - Universidad del País Vasco UPV/EHU - Spain
Alexander A. Oraevsky - University of Houston, Texas - USA
Markus Sigrist - ETH Zürich - Switzerland
Wiendelt Steenbergen - University of Twente - The Netherlands
Xinwei Wang - IOWA State University – USA

Information about the majority of the lecturers is on the web site with a few more lecturers to be announced

INTERNATIONAL SUMMER SCHOOL:

The Summer school "**Basic Photothermal and Photoacoustic Techniques: Theory, Instrumentation and Applications**", will be organised in parallel to the Workshop for students and beginners in the field, **with no additional fee**. The Summer School is organised in collaboration with the Graduate School of the University of Nova Gorica and will be directed by prof. Mladen Franko. The list of renowned lecturers is available at the Summer school web site: http://sabotin.ung.si/~isschool/2016Erice/lectures.htmlThe University of Nova Gorica offers a transfer of **10 ECTS credit points** to participanting students.

CONFERENCE FEE

The Workshop fee is **800** Euro for each **participant** and **480** Euro for **accompanying persons**. It will cover full board and lodging.

1. Registration to the Workshop
2. Accommodation (for the whole period October 19-26, 2016)
3. All meals (for the whole period October 19-26, 2016)
4. Social Dinner
5. Excursion
6. Transfer to and from the local Airports (Trapani or Palermo)

Both Trapani and Palermo Airports are served also by Alitalia, Ryanair, Vueling and other companies. (see http://www.ryanair.com).

APPLICATION and FURTHER DETAILS

To submit the application to attend the Workshop and the Summer School, you are kindly asked to send a short email not later than **September 15th , 2016** to the conference Secretariat at WorkshopErice@uniroma1.it

Each participant is kindly asked to send the following info by email:

1) Name and affiliation of the participant
2) Option: poster presentation, oral presentation, none of them.

The Secretariat will reply by email providing all the requested information to complete the registration. Participants interested in attending the Summer school, must carbon copy their e-mail application also to the Summer school Secretariat at e-mail: nadja.lovec@ung.si

All information about the Workshop and the Summer School can be found on the websites http://www.sbai.uniroma1.it/conferenze/photoacoustic-photothermal/ and http://sabotin.ung.si/~isschool/2016Erice/index.html

DIRECTORS OF THE WORKSHOP: R. LI VOTI - A. MANDELIS
DIRECTOR OF THE SUMMER SCHOOL: M. FRANKO
DIRECTOR OF THE SUMMER SCHOOL: S. MARTELLUCCI - A.N. CHESTER
EMFCSC PRESIDENT AND DIRECTOR OF THE CENTRE: A. ZICHICHI