Research Square

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Comparison of FLIR and INFIRAY thermal cameras for thermographic monitoring in physiotherapy

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Abstract

Background

Thermal imaging is a reliable method for identifying inflammatory changes in joints and can serve as a useful tool for physiotherapists when assessing joint condition before exercise therapy. Although high-performance thermal cameras are costly, more affordable smartphone-based alternatives have recently become available, offering potential for broader daily clinical use.

Purpose

This study aimed to determine whether low-cost smartphone-mounted thermal cameras provide sufficient measurement accuracy, fidelity of thermal-radiation distribution, and image-resolution quality compared with a high-end research-grade thermal camera. The study also evaluated the suitability of these camera models for human thermography in physiotherapy.

Methods

Quantitative and qualitative comparisons were performed between two smartphone-based thermal cameras (Infiray P2 Pro and Infiray T3 Pro) and a reference-standard device (FLIR T620bx). All three cameras were used to image 57 forearms. Thermal images were analyzed using Fiji software to quantify thermal-distribution characteristics, and visual assessments were conducted to compare thermal patterns and identify similarities or discrepancies across devices.

Results

The average image-quality correspondence between the FLIR T620bx and the P2 Pro was 65% (SD 15). For the T3 Pro, the corresponding value was 55% (SD 12). Thermal-pattern similarity was higher: agreement between the T620bx and the P2 Pro reached 96% ($\kappa = 0.89$, $p<.001$), while agreement between the T620bx and the T3 Pro reached 84% ($\kappa = 0.60$, $p<.001$).

Conclusions

The agreement between smartphone-based and high-end thermal cameras appears adequate to support their use in physiotherapy practice. Smartphone-based thermal imaging provides a compact, patient-friendly, and cost-effective option for routine clinical assessment of joint status in physiotherapy.

1. BACKGROUND

Abnormal body temperature is a natural sign of illness [1]. In the context of tissue injury, the release of inflammatory mediators enhances blood flow to the affected area, thereby leading to an increase in local tissue temperature [2]. Thermography is a safe and non-invasive research method in which the temperature differences of an object can be observed visually on a color scale as well as numerically [1, 2]. Thermography is used in various medical fields, such as vascular surgery to assess blood flow to the

lower limbs, heart surgery to monitor temperature conditions in the operating area, and dermatology for early detection of skin cancer [3]. Thermography has been found to be effective in the detection of arthritis. For instance, elevated local temperature has been observed in knee joint inflammation, which is one of the clinical findings in inflammatory conditions [4]. However, the wider use of thermography has been limited due to the high acquisition costs of the imaging equipment [3].

In recent years, smartphone-compatible thermal cameras have become increasingly common in medical applications because of their compact size, affordability, and ease of use. These devices enable precise and rapid real-time imaging of the temperature distribution across target measurement area [3]. Nowadays, artificial intelligence (AI) has also been incorporated into thermographic applications. One of the key objectives in AI development has been to enhance the efficiency and objectivity of tasks traditionally performed by humans. In addition, AI can be utilized to assist in the analysis of thermal images. Artificial intelligence has particularly improved the detection of abnormalities within thermal regions [5].

In biomedicine, Forward Looking Infrared (= FLIR) camera models have been used particularly for diagnostic purposes. They provide both quantitative and qualitative data, for example, from the skin and deeper anatomical structures, to support the identification of biomedical abnormalities. The high thermal sensitivity of FLIR cameras has enabled more precise and reliable outcomes in human thermography [6]. To the authors' knowledge, no scientific publications have reported the use of Infiray thermal camera models for human thermographic imaging. The aim of this study was to examine how the thermal image quality produced by the Infiray P2 Pro, Infiray T3 Pro, and FLIR T620bx differs from one another. In addition to overall image quality, the symmetry of the thermal distributions within the images was also evaluated. Furthermore, the study aimed to assess whether these thermal camera models would be suitable for human thermographic imaging, particularly in physiotherapy where thermal patterns can support treatment planning and monitoring of recovery. Thermography has the potential to become a valuable diagnostic tool in future medical practice and therefore warrants further investigation.

2. METHODS

The study included 57 Finnish participants who volunteered to take part in the study. They were recruited from clients of the local arthritis association and a massage therapy school, as well as from the researchers' personal networks. Among the study participants, 33 (58%) were women and 24 (42%) were men. The age range of the participants was 20–80 years, and the mean age was 43 years (SD 18). In 53% of the participants, clinical symptoms of arthritis were present in the examined upper-limb joints.

The study was comparative in design and incorporated both quantitative and qualitative elements. A real-time cross-sectional study design was used, in which each participant took part in a single measurement session. The measurements for one individual lasted approximately 35 minutes. After the first two measurement days, an interim evaluation was conducted before continuing with the remaining measurements. The interim evaluation was performed once 22 participants had been measured. During

this evaluation, the quality of the thermographic images was assessed, and the consistency of the measurement procedures was verified. After the interim evaluation, the remaining participants were measured, and the data analysis was carried out. The design of the study can be seen in Fig. 1.

The present study was informed by prior studies on thermographic imaging. The measurement devices used in the study were FLIR T620bx [7], Infiray P2 Pro [8] and Infiray T3 Pro [9] thermal cameras which are presented in Table 1. The study applied the guidelines of the golden standard developed for human thermography [5]. Two grayscale images of each participant's upper limbs were captured with each thermal camera. The images included the participant's upper limb from the fingertips to the mid-upper arm. Prior to imaging, the participant was required to keep both upper limbs exposed for 15 minutes to allow the skin temperature to equilibrate with the ambient room temperature. During the measurements, participants were not allowed to wear wristwatches, rings, or have any lotions on the skin. The study was conducted in a biomechanics laboratory designed for research purposes.

Table 1
Technical specifications of the thermal cameras

Technical specifications of the thermal cameras			
Thermal camera	FLIR T620bx	Infiray P2 Pro	Infiray T3 Pro
Resolution	640 x 480	256 x 192	384 x 288
Thermal sensitivity	< 0.04°C @ 30°C	≤ 50 mK @ 25°C	≤ 50 mk
Spectral range	7.5–14 µm	8–14 µm	8–14 µm
Accuracy	± 2°C	± 2°C	± 2°C
Temperature range	-40°C ~ 650°C	-20°C ~ 550°C	-20 ℃ ~ +400 ℃
Frame rate	30 Hz	25 Hz	25 Hz

Thermal images of both upper limbs were captured with the limbs extended and positioned on a marked area on a table 72 cm in height, while the participant was seated on a chair that was 38 cm in height. Participants were instructed to keep their upper limbs as relaxed as possible to prevent muscle tension from influencing skin temperature. A layer of foam material was placed under the forearms to prevent heat transfer from the skin to the table surface. One image was taken with the upper limbs extended and the forearms and palms externally rotated. A second image was taken with the upper limbs extended and the forearms and palms internally rotated.

The thermal cameras were mounted on a tripod and adjusted to point downward toward the measurement area as shown in Fig. 2. For each camera, the distance was standardized by measuring the space between the camera lens and the tabletop. The Infiray T3 Pro and the FLIR T620bx were positioned 118 cm above the table surface, whereas the Infiray P2 Pro was positioned at a height of 83 cm. The distances were adjusted according to the optical characteristics of the cameras to ensure that

the upper limbs appeared in a consistent manner in all thermal images, from the mid-upper arm to the fingertips.

Fiji (ImageJ, version 2.16.0), a software developed for research use [10], was employed for editing, analyzing, and comparing the thermal images with comparisons based on grayscale images. The cropping tool in the software was applied to the thermal images captured with the FLIR T620bx and Infiray P2 Pro cameras so that the same anatomical region could be analyzed in all images, following the region captured by the Infiray T3 Pro. Primarily, the resolution was adjusted to match that of the Infiray T3 Pro thermal images (288 x 384). The resolution of the FLIR T620bx images was reduced and that of the Infiray P2 Pro images increased to ensure comparability. All images were normalized to achieve consistent brightness and contrast.

For each participant, the correspondence between thermal images from the three cameras was assessed pairwise. Colocalization analysis was performed using Fiji software with the Coloc2 plugin to compare thermal images of the participants' forearms acquired with the three thermal cameras. The analysis was conducted on regions of the forearm that exceeded the automatically determined intensity thresholds. Background signal was removed, and intensity thresholds were defined using the automatic Costes thresholding method implemented in Coloc2 [11]. This approach was used to distinguish true signal from background and to determine the intensity values included in the analysis.

An automatic threshold scale was applied, in which an intensity value of 0 corresponds to black and a value of 255 corresponds to white in the image representation. Colocalization was quantified using Pearson's correlation coefficient (r) and Manders' overlap coefficients (M1 and M2), calculated from the thresholded intensity values [12]. Pearson's r was used to evaluate the linear correspondence of temperature intensity patterns across images acquired with different cameras, whereas Manders' coefficients described the proportion of overlapping signal between the thermal images.

In both camera comparisons, the Manders coefficients were defined such that M1 corresponds to the FLIR camera channel and M2 to the comparison camera channel. The M2 value indicates how well the pixels of the comparison camera correspond to those of the M1 camera, whereas the M1 value reflects correspondence in the opposite direction. A value of 1 indicates complete (100%) correspondence. Results are reported as mean values in Tables 2 and 3, and all analyses were performed using identical settings for all images.

Statistical analyses were performed using SPSS and Microsoft Excel. The threshold for statistical significance was set at ($p<.05$). Thermal images were cross-tabulated in pairs. The T620bx thermal camera was used as the reference device for the P2 Pro and T3 Pro cameras, as the T620bx provides the highest accuracy and yields numerical data. Color scale was added to gray scale thermographs afterwards. Thermal pattern similarity was visually evaluated by the authors and cross-tabulated. In the visual comparison, the correspondence of thermal-anomaly regions between the P2 Pro and T3 Pro cameras was compared to the thermal images captured by the FLIR T620bx. Thermal anomalies were examined in the regions of the wrist and elbow joints. In this study, thermal-anomaly regions refer to

deviations that appear as red areas in the thermal images. A Cohen's kappa coefficient (κ) was calculated from the cross-tabulations. In color-scaled Fig. 3A-C, both arms are examined with the forearms and palms externally rotated.

3. RESULTS AND DISCUSSION

The thermal images obtained with the T620bx and P2 Pro corresponded to each other by 96% (κ = .89, p<.001). The thermal images from the T620bx and T3 Pro showed a correspondence of 90% (κ = .84, p<.001). Based on the comparison, the correspondence between the thermal images obtained with the T620bx and P2 Pro cameras was on average 65% (SD 15), r=.35, as shown in Table 2. The correspondence between the images captured with the T620bx and T3 Pro cameras averaged 55% (SD 12), r=.36, as shown in Table 3. The grayscale Fig. 4A-C, present the thermal images from the different cameras in comparison-ready form after cropping and normalization.

Table 2. Mean values of Fiji analysis for FLIR T620bx and Infiray P2 Pro thermal images

Fiji analysis for camera comparison		
	T620bx	P2 Pro
Automatic threshold	60 (SD 30)	91 (SD 47)
Manders tM1 (above threshold)	.76 (SD .09)	
Manders tM2 (above threshold)	.65 (SD .14)	
Pearson R (above threshold)	.35 (SD .23)	

Table 3
Mean values of Fiji analysis for FLIR T620bx and Infiray T3 Pro thermal images

Fiji analysis for camera comparison		
	T620bx	**T3 Pro**
Automatic threshold	57 (SD 27)	117 (SD 30)
Manders tM1 (above threshold)	.76 (SD .11)	
Manders tM2 (above threshold)	.55 (SD .12)	
Pearson R (above threshold)	.36 (SD .28)	

Human thermal imaging is developing rapidly, and therefore long-term advancements in thermographic technology may limit the generalizability of the present measurement results. A comprehensive literature search was conducted to ensure the methodological relevance of the study design and to identify

existing research evidence on the topic. Previous studies on human thermography have predominantly focused on diseases characterized by increased or decreased blood flow resulting from inflammation [4, 13]. The present study concentrated on evaluating the quality of different thermal cameras. This focused selection offers new insights into camera models that have not been systematically evaluated in prior research. In doing so, this study broadens the existing knowledge base by providing new reference points for future comparative investigations.

The gender distribution of the study participants was moderately balanced, and the wide age range represented in the sample enhances the applicability of the findings across diverse demographic groups. Although participants were not selected through randomization, the inclusion of individuals with varied backgrounds contributes to a more comprehensive understanding of the phenomena examined and supports the broader generalizability of the results.

The external validity of the study is weakened by the non-random selection of participants. Nevertheless, the study demonstrates partial external validity, as a heterogeneous sample may provide a broader understanding of the potential applications of thermal imaging. In the long term, advances in thermal camera technology may limit the external validity of the study.

The measurement protocol and the devices were standardized. The guidelines of the established golden standard for human thermography were followed in preparing the participants [5]. Providing participants with preparation instructions in advance reduced the risk of exclusion and dropout. After the first two measurement days, an interim review was conducted to ensure the repeatability and consistency of the measurements. The use of three thermal cameras enabled a comparison of measurement results across devices and facilitated a broader assessment of the reliability of thermographic measurements. The consistency of the measurement outcomes reduced the risk of device-specific random variation. However, differences in image resolution, color mapping, and contrast between the cameras made the visual comparison of the thermal images more challenging. The similarity of the thermographic images was evaluated using cross-tabulation. The cross-tabulation contained interpreter-specific variability, as the method relied on the researchers' subjective observations.

Fiji software, developed for research purposes, was used for the visual comparison of thermal images obtained from the different thermal cameras. The software enabled adjustment of image resolution to a uniform level and normalization of the images. Standardized settings and automated functions supported the reliability of the results. However, because the resolution of one camera's images had to be reduced and that of another increased to match the resolution of the third camera, this process may have degraded image quality and reduced the reliability of the comparisons.

The measurements were conducted under laboratory conditions. During the measurements, the mean temperature of the room was 25.15°C (SD 1.33), and the mean relative humidity was 49.31% (SD 8.8). The measurement conditions did not fully comply with the guidelines of the established gold standard for human thermography, which reduced the internal validity of the study. The measurement period coincided with a heatwave, which contributed to fluctuations in the laboratory's indoor temperature.

The study demonstrated partial internal validity. Internal validity was strengthened by the standardization of the measurement methods, the consistent instructions provided to participants, the interim review, and the use of three different thermal cameras together with the Fiji software. Internal validity was weakened by variability in the measurement conditions and by the need to modify the resolution of the thermal images. The interpreter-dependent variability observed in the assessment of thermographic image concordance also diminishes the internal validity of the study and increases the risk of bias in the results.

In the thermal-camera comparison, the FLIR T620bx demonstrated the highest capability to resolve temperature distribution patterns. The Infiray T3 Pro and Infiray P2 Pro did not reach the accuracy level of the T620bx. Based on these findings, the FLIR T620bx appears to be the most suitable option for human thermographic imaging. Nevertheless, the results indicate that human thermal images can also be captured with the Infiray T3 Pro and P2 Pro cameras, albeit with lower accuracy than with the FLIR device. In their study, Obinah et al. [14] compared high-end and low-end thermal cameras by imaging the thighs of human subjects. The study found that the diagnostic differences between high-end and low-end thermal cameras were clinically insignificant. These findings support the results of the present study, indicating that low-end thermal cameras can also be used reliably for human thermography.

There was variability among participants in the percentage correspondence of the thermal images, which may partly be explained by differences in the technical characteristics of the cameras and the grayscale temperature scaling applied at the time of image acquisition. The variability was also observed in the Pearson correlation coefficients calculated by Fiji when comparing the thermal images. This may be attributed to differences in image brightness and contrast, as well as the extent to which the comparison tool excludes pixels outside the threshold range due to variations in the color scale between cameras.

For clinical physiotherapy practice, Infiray's thermal cameras would be more practical due to their compact size, lower cost, and compatibility with smartphones. Based on the findings of this study, the Infiray devices appear to provide sufficient accuracy for detecting temperature variations on the human body. This enables, for instance, the monitoring of inflammatory processes during a physiotherapeutic treatment period. Tracking inflammation can offer physiotherapists valuable insight into the effectiveness of the intervention. Thermal imaging also provides an additional tool for assessing and quantifying musculoskeletal disorders. Thermal images may further support patient education by allowing clinicians to visually explain how therapeutic exercises or manual therapy influence tissue responses, or which areas of the body are experiencing increased load. However, thermal imaging cannot differentiate between specific tissue structures, and it is sensitive to external environmental conditions, which increases the risk of measurement distortion. In clinical practice, maintaining optimal measurement conditions can be challenging, and the imaging procedure may become too time-consuming.

Previous thermography studies have investigated, for instance, joint and rheumatic diseases as well as conditions affecting circulation [4, 13, 15]. In the present study, the inclusion criteria did not specify the presence of an acute-phase rheumatic, joint, or circulatory disorder. The thermal cameras used in this study have not been previously utilized for human thermographic imaging. The study also applied the guidelines of the established golden standard for human thermography used in existing research [5]. The marginally too high temperature of the measurement environment in this study differs from previous studies, particularly in terms of room temperature and humidity. Thermography studies that focus on a single body region or a single diagnosis can be considered more reliable, as their results are more readily comparable within the study.

4. CONCLUSIONS

The study demonstrated that low-end Infiray thermal camera models do not capture thermal distribution patterns as accurately as the high-end FLIR camera model. The image quality produced by the Infiray cameras was also inferior compared with the FLIR T620bx. Based on the findings, the most suitable option for diagnostic purposes among the cameras examined is the FLIR T620bx thermal camera. However, the Infiray models provide sufficient accuracy for physiotherapy practice. Their use in clinical work is further facilitated by their compact size and compatibility with smartphones. Thermal imaging can be utilized in monitoring the effectiveness of physiotherapy interventions, in the assessment of musculoskeletal disorders, and as a tool to support patient education. According to the results, each thermal camera included in the study could be employed within physiotherapy. The findings offer physiotherapists new options for clinical measurement and assessment, while also providing novel insights into the comparison of FLIR and Infiray camera models in human thermography.

Abbreviations

AI = Artificial Intelligence, FLIR = Forward Looking Infrared, SD = Standard Deviation

Declarations

Ethics approval and consent to participate

This study was reviewed by the Ethics Committee for Human Sciences at LUT Universities, which determined that formal ethical approval was not required in accordance with institutional and national regulations. As no formal ethical approval was required, no reference number was issued. The study was conducted in accordance with the Ethical Principles of Research with Human Participants and Ethical Review in the Human Sciences in Finland (Finnish National Board on Research Integrity TENK guidelines, 2019) and complied with the principles of the Declaration of Helsinki, where applicable. All participants were informed about the purpose and procedures of the study, participation was voluntary, and written informed consent was obtained from all participants prior to data collection.

Consent for publication

The authors consent to the publication of the article.

Availability of material and data

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors received no funding for this work.

Authors' contributions

All authors contributed to the design of the study. Joni Imeläinen and Eero Ellmén were responsible for data analysis and manuscript preparation. Kari Kauranen served as the supervisor of the study.

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Figures

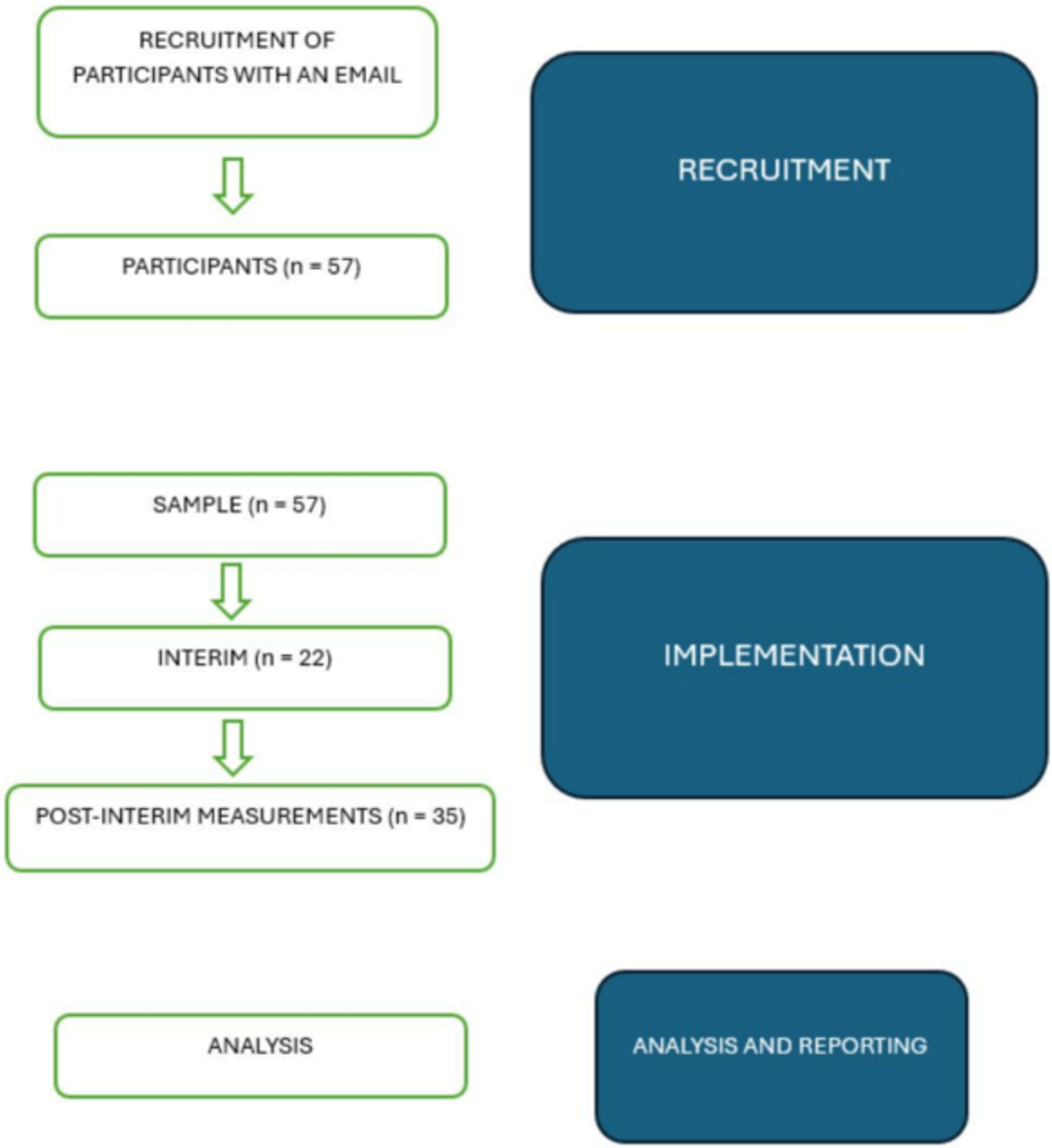


Figure 1

Study design

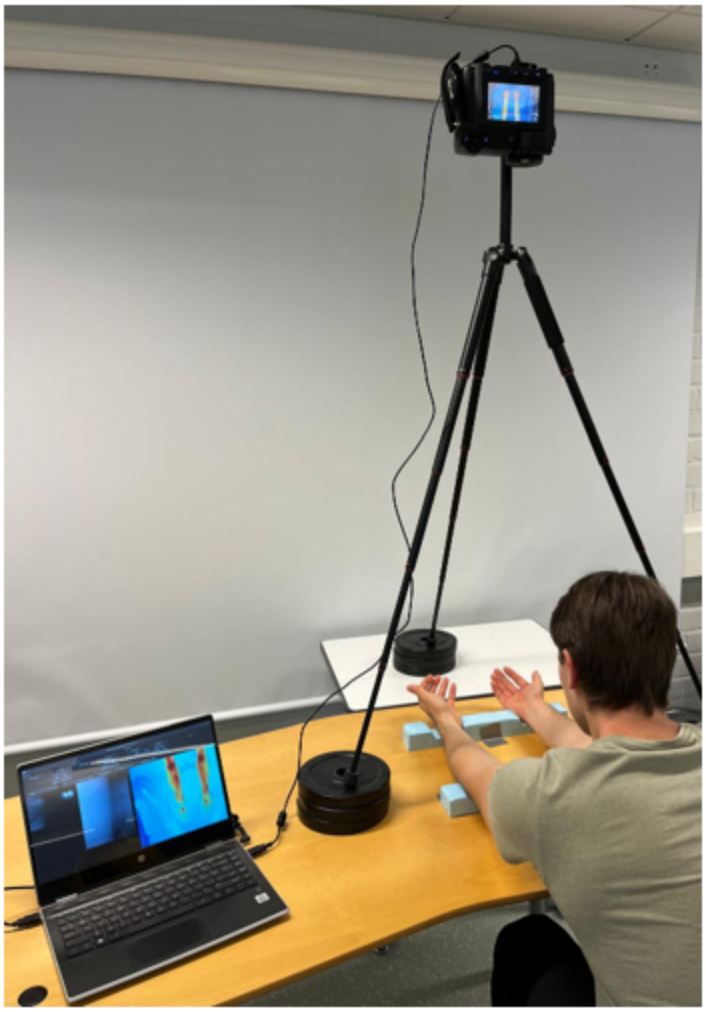


Figure 2

Measurement position with the participant’s forearms and palms externally rotated

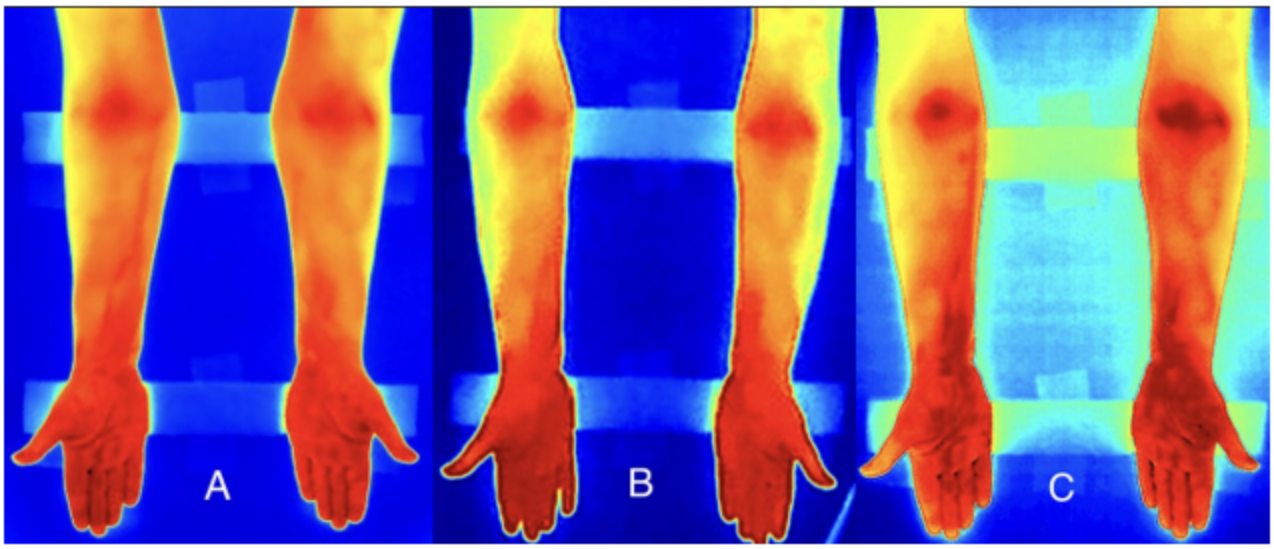


Figure 3

Colored gray scale images A, FLIR T620bx B, Infiray P2 Pro C, Infiray T3 Pro

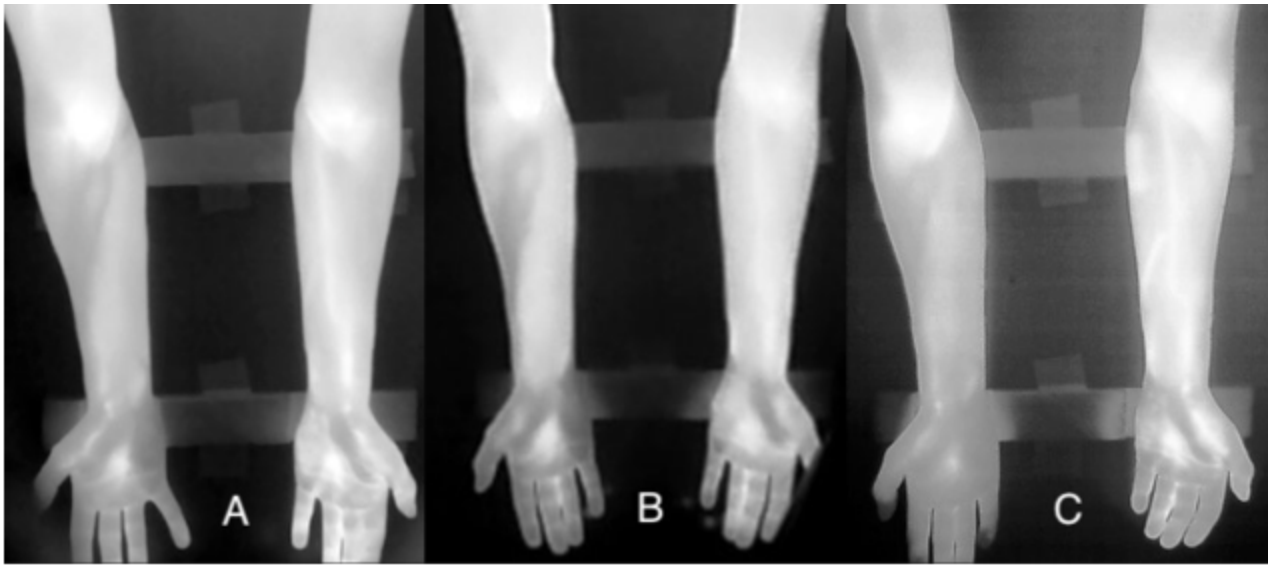


Figure 4

Normalized gray-scale images A, Flir T620bx B, Infiray P2 Pro C, Infiray T3 Pro