24rd Thermological Symposium of the Austrian Society of Thermology Quantitative Thermal Imaging in Medicine

12th November 2011 Raddisson BLU Palais Hotel, Parkring 16, 1010 Vienna

Programme

Chair: Prof Dr. Anna Jung (Poland), Prof James B Mercer (Norway)

8.30-8.50 **Rod Thomas** (UK)
High performance Computing in Wales and Related Thermographic Advancements
8.50-8.55 Discussion

8.55-9.15 **Rosie E.Richards,** J.Allen, RE.Smith, KJ.Howell (UK)
Evaluation of three thermal imagers for skin temperature measurement using the Land P80P blackbody source and a spatial resolution test object.
9.15- 9.20 Discussion

9.20.-9.35 **Ricardo Vardasca** (Portugal)
The impact of compression algorithms over thermographic data transmitted via network
9.35-9.40 Discussion

9.40- 10.00 **Ring EFJ**, Jung A, Kalicki B, Zuber J, Rustecka A, Vardasca R (UK/Poland)
Infrared Thermal Imaging for Fever Detection in Children
10.00-10.05 Discussion

10.05-10.25 **Simone Westermann** (Austria)
The effect of draft on the temperature profile of the distal front limb of the horse
10.25-10.30 Discussion

10.30- 11.00 Coffee Break

Chair: Prof Dr. Francis Ring (UK), Prof Dr Kurt Ammer (Austria)

11.00- 11.20 Linn Eva Hauvik, **James B. Mercer** (Norway)
Thermal distribution patterns of the skin surface of the head in bald-headed male subjects measured by dynamic infrared thermography (DIRT) .
11.20-11.25 Discussion

11.25- 11.45 **Manuel Sillero Quintana**, Fernández Cuevas I, Gómez Carmona PM, García de la Concepción MA (Spain)
Application of thermography as injury prevention method in sports
11.45- 11.50 Discussion

11.50- 12.10 **Joseph Gabrhel** , Z.Popracová, H.Tauchmannová, Z Chvojka (Slovak Republic/Czech Republic)
Thermographic and sonographic examination of painfull knees in young athletes.
12.10-12.15 Discussion

12.15-12.35 **Gómez Carmona** PM, Sillero Quintana M, Fernández Cuevas I, Noya Salces J, Fernández Rodríguez (Spain)
Application of an injury prevention protocol based on infrared thermography in professional soccer players during pre-season
12.35-12.40 Discussion

12.40-12.55 **Kurt Ammer** (Austria)
Evaluation of various massage techniques by thermography
12.55-13.00 Discussion

13.00-13.25 **Francis Ring** (UK)
The scientific heritage of Ludwig Boltzmann
13.25- 13.30 Discussion

13.30 Close

Abstracts

THE SCIENTIFIC HERITAGE OF LUDWIG BOLTZMANN

EFJ Ring

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Infrared thermal imaging in medicine provides an objective means of imaging skin surface temperature distribution. As the infrared energy is naturally emitted from the skin, the whole principle of this technology is based on the radiometric capture of thermal radiation, which peaks at around 9 microns. Modern radiation theory is now well developed, but we owe a great deal to European scientists , especially those from Vienna University.

Ludwig Boltzmann was one of the key pioneers in establishing the major principles of radiation theory. Born in Vienna, he studied physics at Vienna University from 1863, where he gained a PhD in 1866 under the supervision of Joseph Stefan. After teaching in Graz, Heidelberg and Berlin Universities, he became Professor of Mathematics in Vienna in 1876. His contributions to science were numerous, but we rely today on Boltzmann's law, in the calculations of temperature from infrared radiation. Over the years, Medicine and Physics have benefitted from many discoveries that have been associated with the famous University of Vienna.

In modern Vienna, we have had many standards laid by our Austrian colleagues, and are particularly indebted to Prof. Kurt Ammer (himself a medical graduate of Vienna University) for the series of meetings and conferences held in Vienna on medical thermography. The international community working in this field also recognise the invaluable contribution that he has made in his own research, and founding and editing the Journal, from Thermologie Österreich, to the present Thermology international. Throughout the past 21 years Prof Ammer has been an active Secretary General for the European Association of Thermology , which has been a practical organisation linking the different groups, individuals and Societies throughout Europe.

The modern infrared camera technology of today has dramatically improved, and computer processing has facilitated the clnical use of this technique for the study of human body temperature. In many ways, the ancient city of Vienna, is a most fitting venue for modern scientific exchange on infrared imaging in medicine.

EVALUATION OF THREE THERMAL IMAGERS FOR SKIN TEMPERATURE MEASUREMENT USING THE LAND P80P BLACKBODY SOURCE AND A SPATIAL RESOLUTION TEST OBJECT.

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BACKGROUND: Calibration is defined as establishing a relationship between a measuring instrument and a measurement standard. The importance of thermal camera calibration is often overlooked in medical applications of thermography. Manufacturers' specifications typically claim an accuracy of ±2°C for un-cooled FPA thermal imagers. This accuracy would be unacceptable in clinical measurements where it would account for approximately 20% of the range of temperatures encountered.

AIM. To investigate the performance of modern thermal imagers in practice.

METHODS. We evaluated three un-cooled FPA infrared cameras, the FLIR A320G and A40M (320x240 pixels) and the E30 portable (160x120 pixels), to ascertain the drift after switch on, linearity, stability with varying ambient temperature and uniformity of the devices. Our standard was a LAND P80P blackbody source with a traceable platinum resistance thermometer standard to verify cavity temperature. We also evaluated spatial resolution for all three cameras using the Glamorgan test object. Following calibration the A320G and E30 were used to obtain a small sample of normothermic facial images and images of the fingertips during a cold challenge re-warming test, images from which will be presented at the meeting.

RESULTS. Comparison of the camera reading with the black body source between 20 and 39°C showed that the offset of the thermal cameras was considerably less than ±2°C. The offset bias between the readings (PRT temperature minus camera) during the linearity test was found to be 0.8°C (SD 0.7°C), 0.1°C (SD 0.3°C) and -0.1°C (SD 0.2°C) for the A40M, E30 and A320G respectively. The drift in the camera reading after switch on was measured every 15 seconds for one hour and was found to be minimal for both the A320G and A40M, settling to within ±0.1°C after 28 minutes and 10 minutes respectively. The E30 camera initially showed greater fluctuation over 30 minutes, but the discrepancy was reduced to ±0.2°C after 42 minutes and ±0.1°C after 46 minutes. The spatial resolution was, as expected, lower for the E30 than for the A320G and A40M. Our preliminary findings were that the lower resolution E30 may be suitable for many clinical applications.

CONCLUSIONS. The results highlight the importance of calibration for quality assurance of medical thermography. All cameras performed within specification, but there was considerable difference in offset bias and confidence intervals between the three devices. The drift after switch on is an important consideration, although even the portable E30 device showed acceptable stability well within an hour. Modern uncooled FPA thermal cameras are suitable for clinical measurements provided appropriate quality assurance is in place.

THE IMPACT OF COMPRESSION ALGORITHMS OVER THERMOGRAPHIC DATA TRANSMITTED VIA NETWORK .

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Technology is evolving, the usage of mobile devices and network transmission are becoming increasingly common. Thermographic devices had always followed the technological evolution becoming smaller and with more features. However in network transmissions a problem of reliability remains related with the amount of data to be transmitted and its error rate. The only existent solution is to code and compress the data to be transmitted over the network, it will decrease its size and make it more robust preserving confidentiality. Mobile devices such as smartphones or tablets can have applications to control thermographic cameras and transmit the data over a network to a server. These devices have a small capacity of storage. The purpose of this study is to investigate which of the available methods for compressing images are more suitable to be used in infrared images and to characterize the impact of each lossless and lossy method in each parameter of temperature measurement (maximum, mean and minimal temperature and standard deviation). 20 thermal images of faces were selected from a database, its temperature values registered. The images data was exported to radiometric files and these files processed by algorithms coded in Matlab generating a compressed file per each method and image, which were transmitted over the Internet to a remote computer that had the exactly same Software to decompress those images and analyse its temperature parameters. The most suitable methods for infrared medical im-

ages are the lossless and of these the technique that produced the best results was the Run-length encoding. This information is important when considering to develop future software for handling medical infrared images in a network environment with poor network conditions.

INFRARED THERMAL IMAGING FOR FEVER DETECTION IN CHILDREN

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In recent years pandemic influenza infections have raised concerns about the ever increasing mobility of the travelling public, bringing heightened risks of the speed and spread of infection. Thermal Imaging has been promoted as a convenient means of identifying people in airports who may have raised temperatures, and therefore potentially infectious.

In general, the use of thermal imaging in these situations has been more symbolic than useful. Surveillance of a moving crowd of people at a distance, which is the most common approach is fraught with problems, and the thermal and spatial resolution available is far below that required to separate a febrile from a non- febrile person. Added to this, there have been relatively few clinical studies to validate the general concepts, or to provide reference data to define the temperatures that can be used in reference.

An international team of experts have worked on a writing committee to draw up guidelines for a "screening thermograph", the necessary minimum performance required, and the optimal method for its deployment in a screening location. This also carries requirements for testing equipment, training and assessment of screening personnel, and maintenance of management record (1; 2).

The major requirement for image capture is for a close up image of the frontal face of a stationary subject using a radiometric calibrated infrared camera. A minimum of 9 pixels is required in the image over each inner canthus of the eyes.

METHOD: The authors set out to investigate this methodology in children attending the hospital clinic, and in whom clinical evidence of early fever, or its absence was established. Little if any evidence on the measurement of temperature in this way in children could be found in the literature. Traditional clinical thermometry at the axilla for a full 5 minutes was used, together with tympanic membrane radiometry at the ear of patients who were examined by close up thermography of the face. An SC640 (FLIR) camera was mounted on a parallax free vertical stand, and the patients were seated close to the camera so that the thermogram of the face occupied at least 75% of the image captured. The regions around the inner canthi were measured, and a second area over the forehead was also measured.

RESULTS: A total of 402 children were examined between 2006 and 2011 in 3 recording sessions each year spanning the autumn to late spring. Of this group 354 were free from fever, (85%) and 52 (15%)cases of definite untreated fever were identified. There were 192 males and 210 females from 1 year to 17 years of age.

In the control subjects the mean temperatures recorded from the inner canthi of the eyes was 36.48°C (SD 0.49) and the corresponding mean temperature from the axilla thermometry was 36.4°C (SD 0.59). This compared with the fever group, where the mean temperature from the inner canthi was 38.9° (SD 0.8) and the axilla thermometry was 38.9°C (SD 0.68).

Using the Pearson Correlation it was shown that the eye measurements by thermography and the thermometry measurements from the axilla were the most highly correlated 0.51 non fever (P=0.0006) and in fever cases 0.59, (p=000). The forehead and ear measurements were poorly correlated with the axilla, especially in the fever cases.

CONCLUSION: This study is one of the first to be conducted according to the ISO standard recommendations, and does indicate that with careful technique and good thermal imaging equipment, it is possible to identify fever from a facial thermogram. Apart from fever screening, these data also suggest that the infrared technique can be used in a normal clinic. The inner canthi of the eyes are least affected by ambient temperature, according to preliminary studies, which merits further investigation, since controlled ambient conditions are less likely to be found in an airport screening booth.

REFERENCES

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2 ISO/TR 13154:2009 ISO/TR 8-600: Medical Electrical Equipment - Deployment, implementation and operational guidelines for identifying febrile humans using a screening thermograph.

THE EFFECT OF DRAFT ON THE TEMPERATURE PROFILE OF THE DISTAL FRONT LIMB OF THE HORSE

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INTRODUCTION: Thermography has been used as a diagnostic tool in veterinary medicine since years now. Particularly in the field of equine orthopaedics several studies have demonstrated that thermographic imaging is useful to detect inflammation. The reliability of thermographic images, however, has been described to be influenced by several external factors, such as sunlight and wind. Thus, many authors described that it is necessary to perform the thermographical examination in a draft free room. However, there are no studies that described the effect of draft on the temperature of the surface of horses.

In practice a draft free room is not always available. Therefore, the objective of this study was to quantify the effect of draft at different velocity on thermographically determined temperatures at the distal frontlimbs.

MATERIAL AND METHOD: The study was conducted at the Equine Clinic for Orthopaedics and Surgery, University of Veterinary Medicine Vienna, in June 2011. A total of 7 clinically healthy horses, free of lameness at a walk, were included in the study.

Thermographic imaging was performed with a portable infrared camera (Variocam, Infratec, Germany) equipped with an uncooled microbolometer focal plane array detector and a spectral range between 7.5µm to 14µm. The emissivity was adjusted at 1.00.

Before the start of thermographic imaging, horses were brought into the examination room and fixed in a stock. After an equilibration of 30 minutes three replicates (R) were performed. Before each replicate a first thermographically determined temperature of the lateral aspect of the distal frontlimbs was used as a baseline temperature. Each replicate consisted of 15 minutes with draft and 15 minutes free of draft. In R1 the right frontlimb was exposed to draft, produced by a commercially available wind machine, with a velocity of approximately 0.5 m/s, in R2 of 1.0 m/s, in R3 of 2.0 m/s. The draft velocity was determined by Testovent 4000 (Testoterm, Lenzkirch, Germany). During each replicate every minute a thermographic image was taken. Between the replicates there was a 10 minute break.

The images were analyzed with an analytical software (IRBIS, Infratec). Maximum surface temperature was calculated from a region of interest (ROI) which was build with a polygon of the lateral third metacarpal bone and fetlock joint.

RESULTS: The mean baseline temperature of all seven horses before R1 was 31.87°C; before R2 32.04°C and before R3 31.96°C. Compared to the baselines, temperature decreased during exposure to draft by 0.42°C, 1.06°C and 1.37°C at R1, R2, and R3. This decrease occurred immediately with the exposure to draft and increased directly after stopping the wind machine.

During the draft free periods in R1 and R2 the temperature increased, compared to the baselines, slightly by 0.18°C and 0.06°C, and decreased by 0.15°C at R3.

Interestingly, the thermographically determined temperature of the left frontlimb, that was protected to some extent from exposure to draft by the right frontlimb, was less affected and showed a decrease in temperature during R1 to R3 by a maximum of only 0.5°C.

CONCLUSION: Windy conditions affect the thermographically determined temperature at the forelimbs even with a low velocity of approximately 0.5 m/s. With increasing velocity, temperature decreased by more than 1°C. This effect occurs immediately after exposure to draft and is less pronounced in the legs that are not directly exposed to draft.

In veterinary practice it is important for practitioners to know that even a slight draft does affect the thermographically determined temperature of both frontlimbs, depending on the direction of the wind and velocity. False positive or negative findings of thermographical examination may result. Thus, for a correct diagnosis by thermography a draft free area is essential.

THERMAL DISTRIBUTION PATTERNS OF THE SKIN SURFACE OF THE HEAD IN BALD-HEADED MALE SUBJECTS MEASURED BY DYNAMIC INFRARED THERMOGRAPHY (DIRT).

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Our knowledge concerning thermal distribution patterns of the face are well established. However, as far as we are aware, the thermal distribution patterns of the skin surface of other aspects of the head has only been investigated once previously in a study employing low resolution thermographic equipment (van Dulken & Heerma van Voss, 1970). The aim of this study was to re-examine the thermal distribution pattern of the skin surface of the entire head using a high definition infrared (IR) thermographic camera. In recruiting our experimental subjects we have taken advantage of a present fashion trend in modern Western society where people voluntarily have totally shaven heads despite the fact that they are not naturally bald. Twelve healthy male subjects, mean age 39 years, participated in the study. To monitor the thermal distribution patterns of the skin surface we employed dynamic infrared thermography (DIRT) using a Flir S65HS IR camera. The DIRT procedure involved taking thermal images (thermograms) before, during and after a two-minute local cooling of the skin using fans. Thermograms were taken of different aspects of the head (superior, anterior, lateral and posterior). To achieve homogenous skin cooling the subjects were rotated on a special stool during the cooling procedure. As expected the overall thermal patterns matched the vascular anatomy of the main underlying blood vessels which was also seen in the earlier study by van Dulken & Heerma van Voss. The thermal patterns in the left and right lateral thermograms for each individual were quite symmetrical, with helix, auricular lobule of the auricles and the nose being the coldest areas. The frontal thermograms were characterized by a clear warm area surrounding the eyes, especially around the inner canthus as well as cool nasal and cheek areas. In general, the thermal patterns seen in the other examined aspects of the head followed the anatomical location of the main superficial arteries and veins of the head, although there both intra- and inter-individual variations. The forehead and superior aspect (top of head) showed the largest variations in thermal patterns ranging from an asymmetrical distribution pattern to a lack of a clear thermal pattern.

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APPLICATION OF THERMOGRAPHY AS INJURY PREVENTION METHOD IN SPORTS

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Infrared thermography has been considered as a valid and non-invasive diagnostic method (Barnes, 1967) of different pathologies (Gargiola & Giani, 1990; Ammer & Ring, 1995). Modern equipments make possible more accurate and objective recording of the body surface with a single picture.

Body temperature of 23 professional players of the C.D. Toledo S.A.D. (Age= 24,9; SD= ± 3,5) were during 24 days of its 2-months preseason period. Two thermographic pictures for each player (frontal and dorsal, of the trunk and lower limbs) were taken with a ThermaCAM TM SC640 (FLIR SYSTEMS, Portland) before starting the training season. Average temperatures of the main muscular groups were calculated from the pictures by the software "ThermaCAM Reporter". In addition, the level of nuisance of those areas was assessed every day by the player from 1 (no pain) to 10 (injured). Temperatures were compared with the declared level of nuisance considering three groups (1 = No pain; 2 - 3 = Low pain; > 4 = High pain).

ANOVA results point out a direct relationship between the declared level of nuisance of the area and its temperature both in ankles ($F[AR] = 9.20$; $p < 0.05$ and $F[AL] = 3.99$; $p < 0.05$) and knees ($F[PKR] = 5.34$; $p < 0.05$ and $F[PKL] = 9.14$; $p < 0.05$). There were also found significant differences for temperatures (~ 0.5 degrees) between the painful and non-painful limb on the knee ($F[AK] = 14.36$; $p < 0.05$) and hamstring ($F[H] = 3.09$; $p < 0.05$) results. None serious injury has been produced among the players during the 2-months of the study.

We concluded that infrared thermography is a valid, fast and convenient method of preventing soccer injuries. We suggest that this technique could also be applied to monitor and diagnose injuries and to quantify training loads in sports.

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THERMOGRAPHIC AND SONOGRAPHIC EXAMINATION OF PAINFULL KNEES IN YOUNG ATHLETES

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The knee, an intermedial joint in kinematic chain of lower extremity, is a very stressed anatomical region from the mechanic, thermic and vascular point of view. Pain of knee is one of the most frequent complaints in young athletes visting a medical doctor. With regard to the frequency of the knee pain which has tendency to aggravate with duration of symptoms it is important to provide the clinician with precise information required for decision of adequate treatment.

The authors have researched the thermographic examination of the locomotor system in experimental setting and also in clinical practice for 25 years,. During this time they have recorded and analysed about 30 000 thermograms from different localisation of locomotor system. Out of this number approximately 5000 thermograms are thermal images of the knee in all views..

As a result of these analyses, temperature patterns has been identified for overloading the knee in different sports, knee disorders or injuries.

This study reports the results of combined examinations with thermography and musculoskeletal ultrasound imaging in painful knees of young athletes.

We describe differences in images of so called "growth knee pain"compared to juvenile rheumatoid arthritis, patellofemoral chondropathy, aseptic osteonecrosis, malformation of tibia and fibula due to tumour. Injuries such as distorsion of the knee, rupture of ligaments, bursae and cysts, villonodular synovial hyperthrophy, enthesopathies caused by overweight, all may affect the thermal image of a painful knee due to modification of sympathic efferences induced by nociception..

Combining thermographic and musculoskeletal ultrasound examination helps in localisation of pain origin, establish information on the type of pain, differentiate single pain syndroms according to the thermal images, assist in differentiation of the structural damage and can quantify the structural damage.

This technique offers quick diagnosis and assists early decision about an adequate treatment and rehabilitation.

APPLICATION OF AN INJURY PREVENTION PROTOCOL BASED ON INFRARED THERMOGRAPHY IN PROFESSIONAL SOCCER PLAYERS DURING PRE-SEASON.

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In the field of professional soccer, injuries involve, in addition to the difficult process of rehabilitation for the player, a reduced athletic performance and a great economic cost to the team (Woods et al., 2002). This study implements an injury prevention protocol based on infrared thermography into a group of Spanish first division soccer players during the pre-season, which is the period of a highest injury incidence.

Thirty-five subjects of a Spanish professional soccer team participated during the 2008 and 2009 pre-seasons. The injuries of the team were recorded during both pre-seasons by means of the questionnaire REINLE (Noya Salces et al., 2008).

Two thermographic pictures from each player (frontal and dorsal, of the trunk and lower limbs) were taken with a ThermaCAM ™ SC640 (FLIR SYSTEMS, Portland) every morning before starting the training season. Average temperatures of the main muscular groups were calculated from the pictures by the software "ThermaCAM Reporter" and data were reported to the members of the medical and technical team. It was carried out a specific protocol on injury prevention, in which the technical and medical team supported their work on temperatures reports of the different body areas of each single player.

Results of this study show a significant reduction on days of absence of work dues to injuries of the team players, and a significant reduction in the probability of a player injury between both pre-seasons. Injury rate was decreased from 2008 to 2009 preseason from 10,36 to 4,02 injuries per 1000 hours of exposition. If our results are compared with those of Walden et al. (2005), they represent an important reduction of the pre-season injury rate (8,2 injuries per 1000 hours of exposition.)

We conclude that, according to our data, a daily thermal report could an important tool for the medical and technical team in order to prevent injuries caused by the soccer practice.

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EVALUATION OF VARIOUS MASSAGE TECHNIQUES BY THERMOGRAPHY

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INTRODUCTION: Thermal imaging was used in the past for investigation the effects of massage. A recent paper from England found different effects of massage techniques which are deployed to the subcutaneous or the myofascial tissue (1).

OBJECTIVE : Do superficial and deep massage techniques differ in resulting changes of skin temperature of the forearm?

METHOD: In a pilot study, 1 subject with latent myofascial trigger points of the long extensor carpi muscle received 4 different massage treatments, a control intervention or no treatment. After acclimatisation with bare forearms to a room temperature of 23±1°C for 20 minutes a thermal image of the forearm in a lateral view was recorded and at an interval of 5 minutes a total of eight other images were taken in the trial without treatment. Each treatment lasted approximately 10 minutes and immediately after the treatment a thermal image and at an interval of 5 minutes 8 other images were recorded.

Ischaemic myofascial trigger point compression in combination with soft tissue mobilisation and stretching of the affected extensor muscle was one treatment. Connective tissue massage and lymphatic drainage in the region of the lateral forearm were two other massage techniques. Classical "Swedish massage" was the third technique investigated. Touching the area over the latent trigger point with two fingers, but avoiding any manipulation of the underlying tissue served as control intervention

RESULTS: An increase of temperature in the treatment area became visible after trigger point treatment, which returned to baseline readings within 30 minutes (figure 1). A slight temperature elevation was observed after connective tissue massage which resolved within 10 minutes after end of the therapy (figure 2). No difference in temperature were seen between touching the

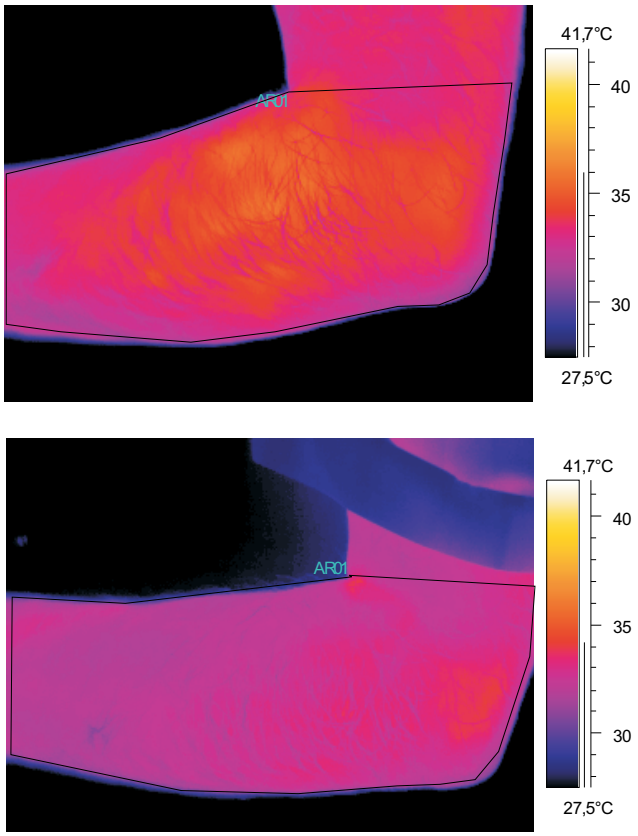

Figure 1
Forearm immediately and 30 minutes after trigger point treatment

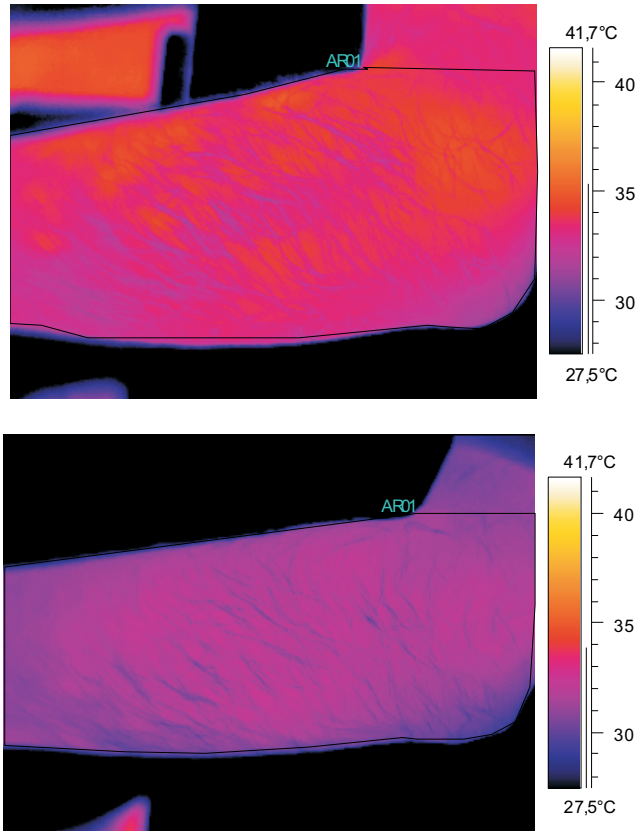

Figure 2
Forearm immediately and 30 minutes after the connective tissue massage

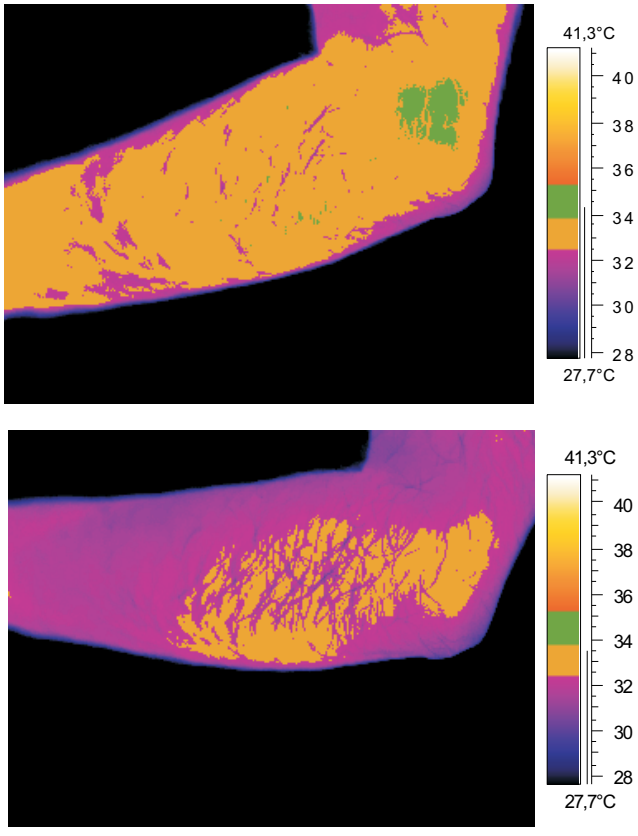

Figure 3
Forearm immediately and 30 minutes after the control intervention (touching) the trigger point area. The two top isotherms are marked in green and yellow

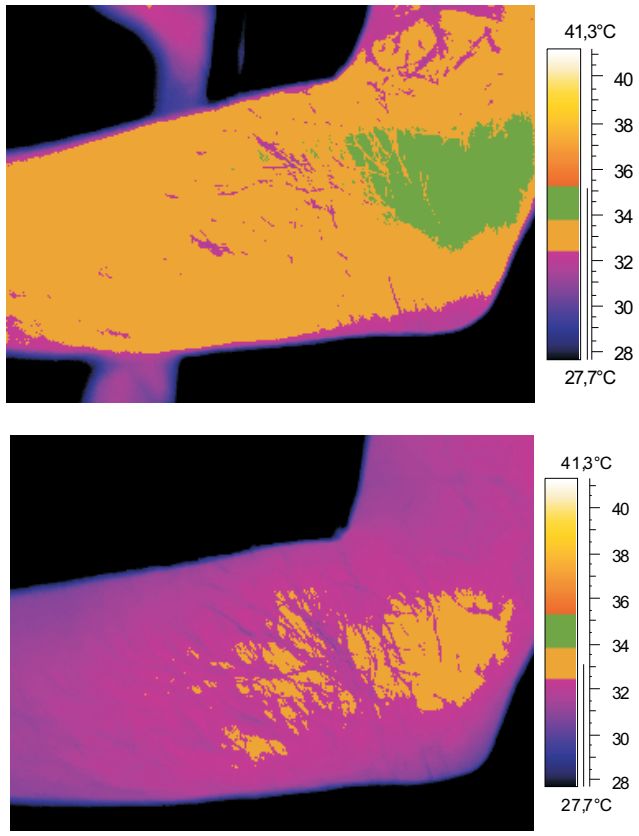

Figure 4
Forearm immediately and 30 minutes after lymphatic drainage The two top isotherms are marked in green and yellow

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Table 1
Mean, minimum and maximum temperature of the forearm without treatment and after connective tissue massage

	temperature	At start	After 5	After 10	After 15	After 20	After 25	after30
Without treatment	Mean±SD	32.8±0,8	32.9± 0.7	32.3±0.6	31.8±0.6	31.9±0.6	31.7±0.6	31.9±0.6
	maximum	34.4	34.1	33.8	33.2	33.1	33.1	33.1
	Mean±SD	32.4 ± 0.7	32.3 ±0.6	31.9 ± 0.6	32.0 ± 0.6	31.8±0.5	31.8±0.6	31.9 ± 0.6
	maximum	33.7	33.6	33.1	33.1	32.9	32.9	32.9
Control (touching)	Mean	33.0±0.7	32.8±0.6	32.5 ± 0.6	32.9±0.7	33.0±0.6	32.4±0.8	32.2±0.5
	maximum	34.4	34.0	33.7	34.2	34.2	33.9	33.5

kin (figure 3) and lymphatic drainage (figure 4). Table 1 shows mean and maximum temperature of the forarm after the control treatment and without treatment.

CONCLUSION: Mechanical stimulation of deep tissue layers of the forearm result in more heat dissipation from the skin than soft strokes over superficial tissue layers.

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