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# Influence of knee skinfold thickness on assessing knee temperature by infrared thermography

Vjeran Švaic[1], Ozren Radenovic[1], Ivan Jurak[1]

1 University of Applied Health Sciences, Zagreb, Croatia

**SUMMARY**

**BACKGROUND: Skin thickness, subcutaneous fat, ambient climate influence temperature of the skin (Tsk) of the knee making infrared thermography as an assessment tool for medicine and sport causes more complex. The goal of this study was to quantify the influence of local skin folds, body temperature, ambient temperature, body mass index and gender on Tsk of the knees.**

**MATERIALS AND METHODS: The study was conducted on 61 healthy young adults. Measuring variables consisted of thermographic imaging of the knees and face, tympanic temperature, height, weight and skinfold thickness at knees. Correlation and linear regression analysis was completed in order to explore and quantify the influence of different variables on knee temperature.**

**RESULTS: Mean difference in temperatures between right and left knees was calculated with overall results of 0.16 ± 1.12°C for both males and females. Strong correlations were found between forehead temperature and both right and left knee temperatures (r = 0.79 and r = 0.80, respectively), and between ambient temperature and right and left knee temperatures (r = 0.80 and r = 0.81, respectively). Knee Tsk in females did not differ statistically from males, while the skinfold thickness of the knees was statistically significantly higher in females. Our model showed that when controlling for forehead Tsk and ambient temperature, right knee Tsk is lower by 0.79 °C and left knee Tsk by 0.50 °C in females, while skinfold thickness did not have any significant correlation with knee Tsk.**

**CONCLUSIONS: Ambient temperature and forehead Tsk are highly correlated with the resting Tsk of the knees, so that, they should be included as controlling variables in thermography assessments. Gender influences knee Tsk and should be taken into consideration in IRT. Body mass index and knee skinfolds have not shown a significant influence on the anterior knee Tsk in normal weighted healthy subjects.**

**KEY WORDS: anterior knee, healthy subjects, skinfold thickness, body mass index, forehead temperature**

**EINFLUSS DER DICKE DER KNIEHAUT AUF DIE BEURTEILUNG DER KNIETEMPERATUR MITTELS INFRAROT-THERMOGRAFIE**

**HINTERGRUND: Hautdicke, Unterhautfettgewebe, Umgebungsklima beeinflussen die Temperatur der Haut (Tsk) des Knies, was die Infrarot-Thermografie als Beurteilungsinstrument für Medizin und Sport komplexer macht. Das Ziel dieser Studie war es, den Einfluss von lokalen Hautfalten, Körpertemperatur, Umgebungstemperatur, Body-Mass-Index und Geschlecht auf Tsk der Knie zu quantifizieren**

**MATERIAL UND METHODEN: Die Studie wurde an 61 gesunden jungen Erwachsenen durchgeführt. Die Messgrößen bestanden aus der Thermografie der Knie und des Gesichts, der Trommelfelltemperatur, der Größe, des Gewichts und der Hautfaltendicke an den Knien. Korrelations- und lineare Regressionsanalysen wurden durchgeführt, um den Einfluss verschiedener Variablen auf die Knietemperatur zu untersuchen und zu quantifizieren.**

**ERGEBNISSE: Der mittlere Temperaturunterschied zwischen rechtem und linkem Knie wurde mit Gesamtergebnissen von 0,16 ± 1,12°C für Männer und Frauen berechnet. Es wurden starke Korrelationen zwischen der Stirntemperatur und den Temperaturen des rechten und linken Knies (r = 0,79 bzw. r = 0,80) sowie zwischen der Umgebungstemperatur und den Temperaturen des rechten und linken Knies (r = 0,80 bzw. r = 0,81) gefunden. Die Knie-Tsk bei Frauen unterschied sich statistisch nicht von der von Männern, während die Hautfaltendicke der Knie bei Frauen statistisch signifikant höher war. Unser Modell zeigte, dass bei der Kontrolle der Stirn-Tsk und der Umgebungstemperatur die Tsk des rechten Knies um 0,79 °C und die Tsk des linken Knies um 0,50 °C niedriger ist, während die Dicke der Hautfalten keine signifikante Korrelation mit der Tsk des Knies aufwies.**

**SCHLUSSFOLGERUNGEN: Die Umgebungstemperatur und der Stirn-Tsk korrelieren stark mit der Tsk der Knie in Ruhe, so dass sie als Kontrollvariablen in die Thermografie-Beurteilung einbezogen werden sollten. Das Geschlecht beeinflusst die Knie-Tsk und sollte in der IRT berücksichtigt werden. Der Body-Mass-Index und die Hautfalten des Knies zeigten keinen signifikanten Einfluss auf den vorderen Knie-Tsk bei normalgewichtigen gesunden Probanden.**

**SCHLÜSSELWÖRTER: Knie, gesunde Personen, Hautfaltendicke,Body Mass Index, Stirntemperatur**

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## Introduction

During the last thirty years infrared thermography (IRT) found its use in sports medicine and exercise science where studies are usually based on skin temperature (Tsk) changes in different climate conditions, changes during and after different types of exercise, in overuse symptoms, injuries, etc. [1, 2]. Control of heat transfer with the environment plays a fundamental role for body temperature regulation. Heat is carried away from the body by conduction, convection, radiation and evaporation [3]. As deep tissue metabolic activities such as circulatory changes, inflammatory and degenerative process can influence Tsk, infrared thermography could be valuable in evaluation of bone, muscle, ligament and neurological structures in the human body. [4-6] However, in order to better understand and thus use thermography as an assessment tool, it is essential to provide standardised Tsk norms of healthy non-exercising subjects.

Ammer was the first author to give a complete standardised protocol of human skin measurement by using infrared thermography [7]. By following this protocol infrared thermography was raised to the level where it can be used as a high reliability tool, especially when using it to determine bilateral differences in the human body. Mean Tsk of the anterior knee in healthy subjects measured by IRT stands within 29.5 ± 1.6 °C with side difference of 0.2 ± 1.0 °C [8], while Liu et al. indicate that temperature differences greater than 0.6 - 1.1 °C can be considered abnormal and can potentially indicate physiological or anatomical differences in the locomotor system [9]. According to Gómez Carmona et al. (2020) the use of IRT can help reduce the presence of injuries by identifying athletes potentially at risk and as a result, reducing the injury severity and days lost as a consequence by implementing prevention protocol when a bilateral Tsk difference ≥0.5 °C is found [10].

While assessing Tsk by IRT other factors like skin thickness, subcutaneous fat, thermal conductivity of tissue, ambient/climate temperature and humidity influence recorded temperature of the skin, making evaluation of the internal tissue more complicated and smaller differences harder to detect. Knee joint together with patellar tendon represent one of the easiest assessable joints that can be used as a good starting point for assessing joint and tendon temperatures.

In the study of Lubkowska & Knyszynska (2023) absolute and percentage of body fat of athletes was correlated with the magnitude of temperature changes in some areas of the body after partial body cryostimulation (PBC). The drop in Tsk after PBC for most of the body areas was greater the higher was the content of adipose tissue in the subjects. Regarding of the knees statisticaly significant correlation was found with absolute body fat values [11]. Neves et al. (2015) determined relationships between the subcutaneous fat layer and the Tsk in two body regions, subscapular and triceps. Their findings showed statistically significant negative correlation at subscapular region in male participants but did not find significant correlation at triceps region in female participants [12]. Similar to this subcutaneous fat layer also influences the Tsk of the biceps brachii muscle at resting and during and after high intensity and energy demand anaerobic exercise with the arm flexors [13]. Salamunes et al. (2017) observed that increased fat percentage reduced Tsk up to 0.74 °C in upper limb segments and 0.51 °C in lower limb segments. Their research was conducted in 30 regions of interest on healthy adult women 26.11 ± 4.41 years old [14]. According to the studies it can be said that subcutaneous fat influences Tsk as an insulation layer at rest and during exercise making the Tsk less influenced by heat generated inside the body. However, looking locally at the certain regions of the body, in this case knees, that influence has not yet been quantified nor has its practical significance been clarified.

The goal of this study was to compare different body temperature measurements of healthy individuals together with skin folds of the knees and body mass index (BMI) and quantify the influence of those measures on Tsk of the knees. According to the authors knowledge no such comparison with the direct measure of skin folds at region of the anterior knee has yet been made.

## Methods

A convenience sample of 61 students of University of Applied Health Sciences Zagreb was used for this study. All the measurements were conducted in a closed room with no air flow and direct sunlight to ensure minimal environmental effect on infrared thermography measurements. Room temperature and humidity have been measured in order to control for any oscillations throughout the day. The measuring of all the variables and participants was conducted in small groups throughout the morning hours. Participants were instructed not to consume alcoholic beverages, caffeine and cigarettes nor to be engaged in any sports activity or therapy process in the morning prior to the measuring. They were dressed in sports shorts to have easy access to the anterior part of both legs. During the acclimatisation phase, which lasted 10 minutes, students were instructed to sit in a comfortable position with nothing touching their thighs, knees and shins. During that period they filled in a short questionnaire addressing pain and function of the knees. Only healthy subjects have been included in the study. After the acclimatisation period two thermograms of the anterior part of the knees and one thermogram of the face were taken. Two thermograms of the knees are taken in a way that the second one is taken while the camera is rotated by 180°. It is therefore used as a controlling thermogram later in the analysis so that any measurement errors found on a horizontal plane, while comparing left and right knee, can be nullified. Infrared thermography has been conducted by following the guidelines of the standardised Glamorgan Protocol [7]. Thermal imaging has been conducted with the camera perpendicular to the regions of interest (ROI) and approximately 1 meter away from the ROI. Emissivity of the camera was set to 0.98. For the knees we used guidelines for both knees anterior view (Glamorgan protocol code:BKA) while for face we used again anterior view (Glamorgan protocol code:FA). Rectangular markers were used for acquiring maximum, average and minimum temperature values at measuring

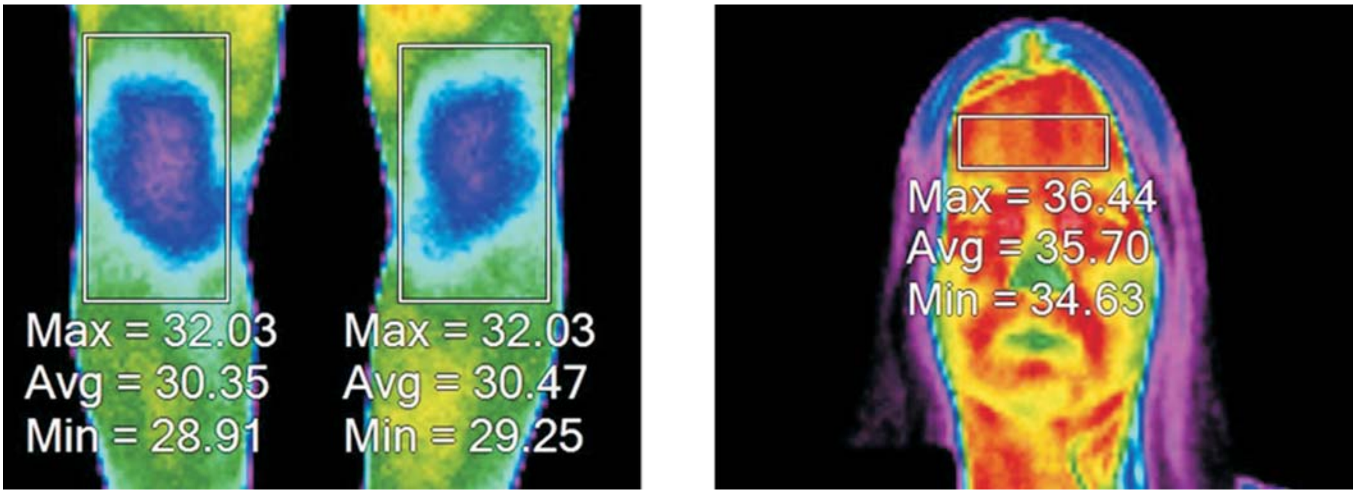


Figure 1.
Thermograms and measured ROI's
*High contrast colour palette, with 28-34 °C temperature level span for knees and 28-37.5 °C for face

sites (figure 1.). Fluke Ti25 infrared camera (Fluke Corporation) with thermal sensitivity ≤ 0.1 °C at 30 °C was used for recoding thermograms while for quantitative analysis of the thermograms the authors used Fluke SmartView 3.2 software (Fluke Thermography, USA). Mean Tsk of the anterior part of the knee was used in the analysis. Following the infrared measurements tympanic (ear) temperature was acquired by Braun ThermoScan 5 Ear Thermometer - IRT6500. Skinfold thickness was measured after thermographic imaging on three different sites including the suprapatellar (2 cm above the upper rim of the patella), patellar (directly above the mid portion of the patella) and infrapatellar (directly above middle part of the patellar tendon) region of the knee. In this study we did not use classical anthropometric methodology for assessing body skin folds, nor did we use the skinfolds in determining body composition. The skin folds have been measured directly at the region of interest of the thermographic imaging (anterior knees) in order to provide exact correlation between skin fold and Tsk. Skinfold thickness variable was calculated by adding all three measuring site values. John Bull calliper (British Indicators LTD) was used for skin fold measurements and it had been calibrated prior to the usage. The anthropometric measurement was conducted by individuals that have been trained to use John Bull calliper during the study courses at the University of Applied Health Sciences and Faculty of Kinesiology University of Zagreb (they are not accredited ISAK anhropometrists). Height and weight was measured using a stadiometer and calculated into a body mass index. Exclusion criteria was set for the participants with high fever, pathological thermograms of the knee and obesity [15-16]. As the goal of this study was to take into consideration only healthy young adults the authors did not want to have results interrupted by a few participants with the very high BMI. Therefore obese participants have been excluded. The study was approved by the Ethics Committee of the University.

Data were analysed using R statistical software (version 4.2.1). Descriptive statistics, including means, standard deviations, medians, and ranges, were calculated for each variable, stratified by gender and for the overall sample. The assumption of normality for all variables was evaluated using the Shapiro-Wilk test, supported by visual inspection of density plots. The results suggested that the assumption of normality held for all variables in the study. Differences between genders were compared with t-test for continuous variables and with Fisher's Exact test for frequencies, as appropriate. As part of the preliminary data analysis, Pearson's correlation coefficients were computed to assess the relationships between all pairs of variables. This provided an initial understanding of the associations and potential covariates to be controlled for in subsequent analyses. Subsequently, two multiple linear regression models were estimated to investigate the relationship between skin fold thickness at the knee and knee Tsk, one for each knee. The models included ambient temperature, forehead Tsk and gender as covariates to account for their potential influence. Before interpreting the results, the underlying assumptions of the linear regression models were thoroughly examined. This included tests for linearity, the normality of the residuals, homoscedasticity, and the absence of significant outliers. Moreover, the Variance Inflation Factor (VIF) was calculated for each predictor in the model to test for multicollinearity, and the Durbin-Watson statistic was computed to detect any autocorrelation in the residuals.

## Results

Of overall 61 participants, 5 have been excluded from the statistical analysis. One participant was declared with high fever (tympanic temp. 37.6 °C), three were declared as obese (BMI 30>) and one participants thermographic images showed pathological pattern. The sample included 56 participants, of which 16 were male and 40 were female (Table 1). The overall mean height of male participants was 182 cm (SD = 6.40) while the height of females was 168 cm (SD = 6.41). The weight of male participants ranged between 62.2 kg and 95.1 kg, with an average weight of 80.0 kg (SD = 10.4). Whereas for females the range was 53.5 kg and 92.8 kg, with an average weight 65.3 kg (SD = 8.69). The average BMI across the sample was 23.3 (SD = 2.30). Males had a slightly higher average BMI (mean = 24.2, SD = 2.60) compared to females (mean = 23.0, SD = 2.10). Expectedly, both height and weight were significantly different between genders, while the BMI was not. Measurements of skinfold thickness at the right knee indicated higher values in females (mean = 31.1 mm, SD = 6.30) than in males (mean = 25.4 mm, SD = 6.20). Similar results were observed in the skinfold thickness at the left knee for females (mean = 30.9 mm, SD = 6.92) and males (mean = 25.0 mm, SD = 6.22). Regarding skinfold thickness, the differences were statistically significant ($p = 0.02$ and $p < 0.01$, respectively). Missing data were noted for the skinfold thickness measurements, with 26.8% missing for the right knee and 5.4% missing for the left knee. The inner ear temperature measurements ranged between 35.9 - 37.5 °C, with a mean temperature of 36.9 °C (SD = 0.368) across all participants. Most of the participants were right-leg dominant (85.7%) and there were no statistically significant differences between genders regarding dominants leg (OR =1.23, 95% CI =0.19 to 13.92).

Thermographic parameters were analysed and shown in Table 2. Forehead Tsk was consistent across genders with an overall mean of 35.1 °C (SD = 0.624). The mean temperature for males was 35.1 °C (SD = 0.481), and for females, it was also 35.1 C° (SD = 0.678). Knee Tsk differed slightly between genders. The right knee temperature averaged at 30.6 °C (SD = 1.26), with males having a slightly higher mean temperature of 31.1 °C (SD = 1.46) compared to females' mean of 30.4 °C (SD = 1.11). A single missing data point (1.8% of total data) was noted for the right knee Tsk, exclusively in the female subset. A similar pattern was observed for the left knee, with an overall mean Tsk of 30.5 °C (SD = 1.30), and slightly higher Tsk in males (mean = 31.0 °C, SD = 1.51) compared to females (mean = 30.3 °C, SD = 1.16). Again, one data point (1.8% of total data) was missing from the female subset. The ambient temperature of the room across the whole sample was mean of 25.7 °C (SD = 1.12). Ambient humidity also showed little variation, with an overall mean of 48.0% (SD = 9.77). Mean difference in Tsk between right and left knees was calculated with overall results of 0.16 °C (SD = 1.12) for both males and females, with minimum values 0.00 °C and maximum ± 0.59 °C.

Table 1
Anthropometric parameters of sample by gender

| | **Male (N=16)** | **Female (N=40)** | **Overall (N=56)** | **Test statistic** | **p** |
|---|---|---|---|---|---|
| **Height [cm]** | | | | t=7.03 | **<0.01** |
| Mean (SD) | 182 (6.40) | 168 (6.41) | 172 (8.79) | | |
| Median [Min, Max] | 183 [169, 192] | 169 [150, 187] | 171 [150, 192] | | |
| **Weight [kg]** | | | | t=5.02 | **<0.01** |
| Mean (SD) | 80.0 (10.4) | 65.3 (8.69) | 69.5 (11.3) | | |
| Median [Min, Max] | 81.8 [62.2, 95.1] | 63.9 [53.5, 92.8] | 66.1 [53.5, 95.1] | | |
| **BMI** | | | | t=1.69 | 0.10 |
| Mean (SD) | 24.2 (2.60) | 23.0 (2.10) | 23.3 (2.30) | | |
| Median [Min, Max] | 24.9 [19.6, 28.1] | 22.4 [19.6, 29.9] | 23.0 [19.6, 29.9] | | |
| **Dominant leg** | | | | Fisher's test | 0.99 |
| Right | 14 (87.5%) | 34 (85.0%) | 48 (85.7%) | | |
| Left | 2 (12.5%) | 6 (15.0%) | 8 (14.3%) | | |
| **RLK skin folds [mm]** | | | | t=-2.65 | **0.02** |
| Mean (SD) | 25.4 (6.20) | 31.1 (6.30) | 29.4 (6.72) | | |
| Median [Min, Max] | 24.4 [17.5, 39.5] | 30.4 [20.9, 42.9] | 28.1 [17.5, 42.9] | | |
| Missing | 4 (25.0%) | 11 (27.5%) | 15 (26.8%) | | |
| **LK skin folds [mm]** | | | | t=-2.99 | **<0.01** |
| Mean (SD) | 25.0 (6.22) | 30.9 (6.92) | 29.2 (7.18) | | |
| Median [Min, Max] | 22.5 [16.0, 38.0] | 29.8 [18.3, 44.5] | 28.5 [16.0, 44.5] | | |
| Missing | 1 (6.3%) | 2 (5.0%) | 3 (5.4%) | | |
| **Inner ear temp. [°]** | | | | t=-0.21 | 0.84 |
| Mean (SD) | 36.9 (0.332) | 36.9 (0.386) | 36.9 (0.368) | | |
| Median [Min, Max] | 36.9 [36.3, 37.4] | 36.9 [35.9, 37.5] | 36.9 [35.9, 37.5] | | |

Table 2.
Thermographic parameters and ambient parameters of sample by gender

| | Male (N=16) | Female (N=40) | Overall (N=56) | Test statistic | p |
|---|---|---|---|---|---|
| **Forehead Tsk [°]** | | | | t =0.21 | 0.83 |
| Mean (SD) | 35.1 (0.481) | 35.1 (0.678) | 35.1 (0.624) | | |
| Median [Min, Max] | 35.0 [34.4, 35.9] | 35.2 [33.8, 36.7] | 35.1 [33.8, 36.7] | | |
| **Right knee Tsk [°]** | | | | t =1.91 | 0.69 |
| Mean (SD) | 31.1 (1.46) | 30.4 (1.11) | 30.6 (1.26) | | |
| Median [Min, Max] | 31.1 [29.0, 33.6] | 30.6 [28.3, 32.5] | 30.6 [28.3, 33.6] | | |
| Missing | 0 (0%) | 1 (2.5%) | 1 (1.8%) | | |
| **Left knee Tsk [°]** | | | | t =1.67 | 0.11 |
| Mean (SD) | 31.0 (1.51) | 30.3 (1.16) | 30.5 (1.30) | | |
| Median [Min, Max] | 31.2 [28.9, 33.3] | 30.5 [28.1, 32.5] | 30.6 [28.1, 33.3] | | |
| Missing | 0 (0%) | 1 (2.5%) | 1 (1.8%) | | |
| **Ambient temp. [°]** | | | | t =0.47 | 0.64 |
| Mean (SD) | 25.8 (1.18) | 25.7 (1.11) | 25.7 (1.12) | | |
| Median [Min, Max] | 25.9 [24.4, 27.2] | 25.5 [24.4, 27.2] | 25.5 [24.4, 27.2] | | |
| **Ambient humidity [%]** | | | | t =0.05 | 0.96 |
| Mean (SD) | 48.1 (9.89) | 48.0 (9.85) | 48.0 (9.77) | | |
| Median [Min, Max] | 54.0 [34.4, 56.5] | 54.0 [34.4, 56.5] | 54.0 [34.4, 56.5] | | |

There are no statistically significant differences between genders in any of the variables presented in Table 2.

The analysis of Pearson's correlation coefficients presented in Table 3, shows several relationships as expected. Notably, a very strong positive correlation was identified between right knee (RK) and left knee (LK) Tsk ($r = 0.99$), suggesting that the Tsk at these two sites are almost perfectly linked. Additionally, strong correlations were also found between forehead Tsk and both RK and LK Tsk ($r = 0.79$ and $r = 0.80$, respectively), as well as between ambient temperature and RK and LK Tsk ($r = 0.80$ and $r = 0.81$, respectively). These results indicate that forehead and knee Tsk, as well as knee Tsk and ambient temperatures, generally increase and decrease together. Our study showed statistically significant correlation between height and both RK and LK skin folds being moderately negative ($r = -0.40$ and $r = -0.37$, respectively), indicating that taller individuals tend to have thinner skin folds at the knee. The correlation between forehead Tsk and ambient temperature was moderate ($r = 0.65$), as was the correlation between forehead Tsk and ambient humidity ($r = 0.56$). This suggests that changes in these ambient conditions are associated with changes in forehead Tsk, but the relationship is not as strong as between knee and forehead Tsk. There was also, as expected, a very strong correlation between the skin folds of the RK and LK ($r = 0.91$).

Overall, these results highlight the strong interconnectedness of thermographic parameters and the influence of ambient conditions on these measures.

Two linear regression models were utilized to explore the influence of skin fold thickness on knee Tsk, while controlling for the effects of ambient, forehead Tsk and gender (Table 4).

The first model, predicting right knee Tsk ($F(4,35) = 23.8$, $p < 0.01$, adjusted $R^2 = 0.73$), revealed that while increase in ambient temperature and forehead Tsk increases knee Tsk, RK skin fold is not a statistically significant predictor. Intoningly, when controlling for forehead Tsk and ambient temperature, knee Tsk is lower by 0.79 °C in females even though initial t-test suggested there were no statistically significant differences (Table 2). Similarly, the second model, predicting left knee Tsk ($F(4,47) = 46.55$, $p < 0.01$, adjusted $R^2 = 0.78$), showed that LK skinfold is not a statistically significant predictor, and that left knee Tsk is lower by 0.5 °C while controlling for forehead Tsk and ambient temperature.

Knee joint in healthy young adults does not have a thick layer of skin fold and knee Tsk is influenced highly by factors like ambient temperature, forehead Tsk and gender. A small portion of the total variability produced by gender might however be influenced by skin fold differences between male and female participants, but this has not been

Table 3
Correlation table of measured variables (Pearson's correlation coefficient)

| | FH Tsk | RK Tsk | LK Tsk | Ambient humidity | Ambient temp. | Height | Weight | BMI | Ear temp. | RK skinfold | LK skinfold |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FH Tsk** | 1 | r = 0.79 p < 0.01 | r = 0.8 p < 0.01 | r = 0.56 p < 0.01 | r = 0.65 p < 0.01 | r = -0.01 p = 0.74 | r = -0.05 p = 0.98 | r = -0.04 p = 0.76 | r = 0.65 p < 0.01 | r = 0.26 p = 0.13 | r = 0.22 p = 0.09 |
| **RK Tsk** | | 1 | r = 0.99 p < 0.01 | r = 0.59 p < 0.01 | r = 0.8 p < 0.01 | r = 0.14 p = 0.25 | r = 0.09 p = 0.36 | r = 0.05 p = 0.72 | r = 0.47 p < 0.01 | r = -0.03 p = 0.80 | r = -0.02 p = 0.99 |
| **LK Tsk** | | | 1 | r = 0.6 p < 0.01 | r = 0.81 p < 0.01 | r = 0.17 p = 0.23 | r = 0.12 p = 0.32 | r = 0.07 p = 0.64 | r = 0.47 p < 0.01 | r = -0.04 p = 0.77 | r = -0.01 p = 0.96 |
| **Ambient humidity** | | | | 1 | r = 0.79 p < 0.01 | r = -0.04 p = 0.91 | r = -0.09 p = 0.66 | r = -0.11 p = 0.61 | r = 0.54 p < 0.01 | r = 0.35 p = 0.07 | r = 0.12 p = 0.59 |
| **Ambient temp.** | | | | | 1 | r = 0.06 p = 0.91 | r = 0.02 p = 0.81 | r = 0.03 p = 0.74 | r = 0.6 p < 0.01 | r = 0.14 p = 0.49 | r = 0.014 p = 0.79 |
| **Height** | | | | | | 1 | r = 0.84 p < 0.01 | r = 0.31 p = 0.04 | r = -0.08 p = 0.32 | r = -0.4 p = 0.01 | r = -0.37 p = 0.004 |
| **Weight** | | | | | | | 1 | r = 0.75 p < 0.01 | r = -0.12 p = 0.70 | r = -0.13 p = 0.28 | r = -0.13 p = 0.55 |
| **BMI** | | | | | | | | 1 | r = -0.06 p = 0.67 | r = 0.23 p = 0.224 | r = 0.2 p = 0.08 |
| **Ear temp.** | | | | | | | | | 1 | r = 0.13 p = 0.27 | r = 0.26 p = 0.01 |
| **RK skinfold** | | | | | | | | | | 1 | r = 0.91 p < 0.01 |
| **LK skinfold** | | | | | | | | | | | 1 |

Abbreviations: FH Tsk = forehead skin temperature [°C]; RK Tsk = right knee skin temperature [°C]; LK Tsk = left knee skin temperature [°C]; Ambient temp. = ambient temperature [°C]; BMI = body mass index; Ear temp. = ear temperature [°C]; RK skinfold = right knee skin fold [mm]; LK skinfold = left knee skin fold [mm];

Table 4.
Linear regression analyses showing association between knee Tsk with change in ambient temperature, forehead Tsk and knee skin folds

| **y = Right knee Tsk; F (4,35) = 23.8; $p$ < 0.01; $R^2_a$ = 0.73** | | | | | |
|---|---|---|---|---|---|
| *Term* | *b* | *95% CI (b)* | *SE (b)* | *t – statistic* | *p - value* |
| Amb. temp. | 0.25 | 0.02, 0.48 | 0.11 | 2.17 | 0.04* |
| FH Tsk | 1.30 | 0.88, 1.72 | 0.21 | 6.31 | < 0.01* |
| Gender: Female | -0.79 | -1.22, -0.35 | 0.21 | -3.70 | < 0.01* |
| RK skin fold | -0.02 | -0.05, 0.01 | 0.01 | -1.05 | 0.30 |
| **y = Left knee Tsk; F (4,47) = 46.55; $p$ <0.01; $R^2_a$ = 0.78** | | | | | |
| *Term* | *b* | *95% CI (b)* | *SE (b)* | *t – statistic* | *p - value* |
| Amb. temp. | 0.48 | 0.26, 0.70 | 0.11 | 4.42 | < 0.01* |
| FH Tsk | 1.13 | 0.74, 1.51 | 1.19 | 5.93 | < 0.01* |
| Gender: Female | -0.50 | -0.91, -0.10 | 02.0 | -2.49 | 0.02* |
| LK skin fold | -0.01 | -0.04, 0.01 | 0.01 | -1.78 | 0.25 |

Abbreviations: Amb. temp. = ambient temperature [°C]; FH Tsk= forehead skin temperature [°C]; RK skin fold = right knee skin fold [mm]; LK skin fold = left knee skin fold [mm]; * = statistically significant at p <0.05

tested in our study. These findings suggest that personal differences in skinfold thickness are too small to influence practical significance of assessing knee Tsk with IRT.

## Discussion

Skin temperature is influenced by the environment and changes with the temperature and humidity of the surroundings [17-18]. This was confirmed within our study by finding positive correlation of Tsk of face and knees with ambient temperature and humidity. Other than the ambient temperature, blood perfusion and epidermis thickness are the primary factors responsible for the skin temperature variations [18]. High correlation of knee Tsk with forehead Tsk and ambient temperatures seems to be one of the indicators in determining normal knee Tsk while resting after acclimatization period and a good starting point in the assessment of pathological states of the knee which are subjective to temperature changes, due to inflammation or low blood circulation. Normal bilateral differences in temperature of healthy knees have been shown to exist in our study similar to the review of the knee Tsk conducted by Ammer (2012) [8]. In the studies by Reiss et al. (2023) and Lubkowska & Knyszysnka (2023) correlation between BMI and Tsk of the posterior and anterior parts of the body was show to be statistically significant [11,19]. According to our study, on the other hand, Tsk above the anterior knee of healthy individuals is not under influenced of BMI. Skinfold thickness did not have any influence in lowering the Tsk when controlling for ambient, forehead Tsk and gender. We can argue that knees of healthy young adults do not have a thick layer of subcutaneous fat thus making variables like body fat percentage and BMI practically irrelevant in application of IRT. These findings go in favour of infrared thermography making it even more accessible in evaluation of the structures below the skin (i.e. patella, patellar tendon, quadriceps tendon). De Marziani et al. (2023) studied knee temperatures of osteoarthritis patients and found higher knee Tsk correlating positively with higher BMI [20]. By realizing this we can argue that local regions of interest differ in the influence of the skin folds and BMI on thermal evaluation. Information on normal Tsk distribution of the knee can be beneficial in preventive medicine as well as rehabilitation process. Menezes et al. (2018) showed in their study that infrared thermography could be valuable investment tool for a sports club with having detect 61 of 69 injuries (88.40%) and censored 44 cases: muscular (22.81%), articular (33.33%), trauma (25.00%), and tendinous (45.45%) [21]. In a recent study by Molina-Payá et al. (2023) athletes with patellar tendinopathy showed a more pronounced thermal differences and a moderate positive correlation with pain and function questionnaire scores [22].

We can conclude that according to the known Tsk distribution of healthy knees it is expected to find differences of average 0.16 ± 0.12 °C, within the range 0.00 ± 0.59 °C, between left and right knee to be of normal values. Ambient temperature and forehead Tsk, being highly correlated with the resting Tsk of the knees, should be included as controlling variables in thermography assessments. Body mass index within a normal range and skin folds in healthy young adults do not have significant effect in Tsk evaluation of the knees when using infrared thermography as a detection tool in both genders. Gender has an effect on knee Tsk and should be taken into consideration whenever using IRT. However, additional research is needed in order to provide results according to the age. Although obese participants were excluded in this study, knowing that higher weight could place higher stress on the knees and therefore affect Tsk, it would be of a value to include these participants in the future research. Further focus should also be placed on the study of the relation of pathology and pain on thermal distributions in order to make any further conclusions on the possibilities of using infrared thermography as an assessment tool.

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*Address for correspondence*

Vjeran Švaic
University of Applied Health Sciences,
Zagreb, Croatia
email: vjeran.svaic@zvu.hr

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# News in Thermology

## Gold medal in Powerlifting at the World Championship 2023

MuDr Jozef Gabrhel is a busy man. He is running a private clinic for treatment, rehabilitation, acupuncture, and thermal imaging diagnostics in Trencin, Slovakia. Jozef documented his vast experience with sonographic and thermal imaging of the locomotor apparatus in articles and a book series with 5 volumes covering the upper and lower extremities. One volume is dedicated to thermal imaging in acupuncture and moxibustion.

Figure 1
Deadlift

In addition, Jozef is an active sportsman performing powerlifting for decades. He participated in the recent world powerlifting championship, which took place from 9th to 15th October 2023 in Kiskunfelegyhaza, Hungary. Jozef started in the age category under 70years and the weight category under 75 kg and won a gold medal with a performance of 395 kg.

We congratulate the world champion MuDr Jozef Gabrhel to his performance.

The figures1-3 show the 3 disciplines of power lifting: deadlift, bench, and squat.

Figure 2
Bench

Figure 3
Squat

## 2023

### 30th October-November 3rd Abu Dhabi, UAE
### QIRT Asia Conference

The conference, 4th QIRT Asia 2023 will be held in Abu Dhabi, United Arab Emirates

Website: https//qirt-asia-2033.org

The biannual Quantitative InfraRed Thermography (QIRT) Conference is a meeting of the scientific and industrial community interested and actively working in research, application, and technology related to infrared thermography. All conference topics are intended for quantitative results comprising temperature values as well as further parameters on the tested materials and structures. The latter ones are usually obtained through active thermography, e. g. by exploiting non-stationary heat transfer processes activated by additional heat sources or by considering wavelength-dependent effect

### Venue

The conference will be held at Khalifa University, Abu Dhabi, U.A.E

### List of Topics

- Applications of AI and CNN
- **Biomedical applications**
- Calibration and metrology
- Civil Engineering and Buildings
- Electronics and semiconductors
- Environment
- Fluid dynamics and energetics
- Image and data processing
- Induction thermography
- Industrial applications
- IR signature, Image Processing and Recognition
- Microscale applications
- Modeling
- Monitoring and maintenance
- NDE and its applications to composite structures
- Novel technique
- Photothermal techniques
- Remote sensing
- Thermographic Systems & Components
- Thermomechanics
- Vibrothermography
- Works of Art

## 2024

### 1st - 5th July 2024 Zagreb, Croatia,

### QIRT 2024

17th Quantitative InfraRed Thermography (QIRT) Conference

*Contact:* ENERGETIKA MARKETING d.o.o. Sokolska ulica 25, HR-10000 Zagreb, Croatia

*Email*: ege@ege.hr

*Website*:https://www.energetika-marketing.hr /qirt-2024 /en/contact/

### 6th September 2024, Wroclaw, Poland

### Short Course on Medical Thermography

*Contact*: www.eurothermology.org/education html

### 7th -8th September 2024, Wroclaw, Poland

### XVI Congress of the European Association of Thermology

*Contact*: www.eurothermology.org/XVI Congress.html

# CALL FOR ABSTRACTS

WROCŁAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

# XVI Congress of the European Association of Thermology

***6th – 8th September 2024***

***Faculty of Biology and Animal Science***

***Wrocław University of Environmental and Life Sciences***

***Wrocław, Poland***

XVI Congress of the European Association of Thermology

Wrocław POLAND 2024

www.eurothermology.org/XVICongress.html

The EAT and Wrocław University of Environmental and Life Sciences are delighted to invite you to participate in the XVI EAT Congress in Wrocław, Poland from 6th to 8th September 2024.

The European Association of Thermology exists to promote, support and disseminate research in thermometry and thermal imaging in the fields of human and veterinary medicine and biology. We do this through our peer-reviewed journal Thermology International, regional seminars around Europe, and our flagship Congress, which takes place every three years.

Following on from the most recent meetings in Porto (2012), Madrid (2015), London (2018) and online (2021) the Congress heads to eastern Europe for 2024 to Wrocław in Poland.

The Organising Committee looks forward to welcoming you to Wrocław University of Environmental and Life Sciences in the summer of 2024.

Dr. Kevin Howell
EAT President

## VENUE.

Wroclaw lies on the banks of the River Oder in western Poland, and is the capital of the Lower Silesian Vovoideship. It was the European Capital of Culture in 2016, and won the "European Best Destination" title in 2018.

Our venue will be the Faculty of Biology and Animal Science at the prestigious University of Environmental and Life Sciences on Chelmonskiego Street in the eastern suburbs of Wrocław. The Faculty building boasts excellent conference facilities including a large lecture theatre, ample lobby space for networking and poster presentations, and a spacious restaurant for lunch breaks. This is the perfect environment for delegates to present their thermological research at Europe's flagship biomedical temperature congress.




## ORGANISING COMMITTEE

**Maria Soroko-Dubrovina (POL), Chair**

Kurt Ammer (AUT)
Kevin Howell (GBR)
Anna Jung (POL)
Adam Roman (POL)
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## KEY DATES.

Abstract submission will open online on 4th September 2023, and authors will be notified of acceptance for oral or poster presentation by 4th March 2024.

**May 2023**. Publication of the First Announcement.
**31st July 2023.** Publication of the "Call for Abstracts" document.
**4th September 2023.** Opening of abstract submission and registration.
**15th January 2024.** Abstract submission deadline.
**4th March 2024.** Acceptance notification to authors.
**6th May 2024.** End of Early Registration and deadline for registration of presenting authors.

## REGISTRATION FEES (*)

| | Early Registration (Until 06 MAY 2024) | Late Registration (After 06 MAY 2024) |
|---|---|---|
| **EAT MEMBER** | €360 | €410 |
| **Non-Member** | €440 | €490 |
| **One-day registration** | €200 | €250 |
| **Student** | €200 | €250 |
| **Accompanying person** | €120 | €120 |

(*) Further information about the registration process is online at www.eurothermology.org/XVICongress.html Registration includes access to all congress sessions, congress lunch and coffee breaks, the Gala Dinner, and other congress social programme events.

## ACCOMMODATION

Recommended hotels:

1. **Hotel ZOO**

Address: ul. Wroblewskiego 7, 51-627 Wroclaw
website: http://zoo-hotel.pl/

2. **Radisson Blu Hotel Wroclaw*****

Address: ul. Purkyniego 10, 50-156 Wroclaw
website: https://www.radissonblu.com/pl/hotel-wroclaw

3. **Grape Hotel & Restaurant*****

Address: Parkowa 8, 51-616 Wroclaw
website: https://www.grapehotel.pl

4. **PURO Wroclaw Old Town*****

Address: Pawła Włodkowica 6, 50-072 Wroclaw
website: https://purohotel.pl/pl/wroclaw

5. **HOTEL EUROPEUM *****

Address: ul. Kazimierza Wielkiego 27A, 50-077 Wroclaw
website: https://europeum.pl

6. **Hotel Mercure Wroclaw Centrum******

Address: pl. Dominikański 1, 50-159, Wroclaw
website: https://www.accorhotels.com/pl/hotel-3374-hotel-mercure-wroclaw-centrum/index.shtml

## ACCOMPANYING PERSONS

All accompanying persons will be invited to join the Congress Gala Dinner and full social programme upon payment of the appropriate €120 fee.

## KEY MEETING THEMES

- Infrared thermography in biomedicine.
- Temperature measurement in animal welfare, veterinary applications and equine physiology.
- Contact temperature measurement.
- Hardware and software solutions for infrared imaging.
- Biomedical applications: surgery, neurology, vascular and pain syndromes.
- Thermometry in exercise physiology, rehabilitation, and human performance research.
- Calibration and traceability in biomedical thermometry.

## ABOUT WROCŁAW

Wrocław is also called "The Venice of the North" due to the fact that, after Amsterdam, Venice and St. Petersburg, it has the biggest number of bridges and footbridges in Europe.

Notable landmarks include the 10th century Cathedral, the Centennial Hall from 1913 (one of the UNESCO world heritage sites), and the distinctive architecture of the Town Hall and Market Square. Wrocław is also host to the Racławice Panorama, a 114m-long cycloramic painting from 1894, commemorating the 100th anniversary of the Battle of Racławice. In recent years Wrocław has also become well-known for its "little people" or "dwarves": small figurines scattered across the city streets which were first conceived as part of the city's anti-communist movement in 2005. These now number more than 350, and can be located with the help of a dedicated tourist map. Wrocław Zoo, close to our congress venue, is the oldest zoo in Poland, and the third largest zoological gardens in the world in terms of the number of species on display. In summertime, large numbers of visitors are attracted at night to Wrocław's "Multimedia Fountain" close to the Centennial Hall. This is one of the largest operating fountains in Europe, and stages dramatic light shows set to music.

## TRAVEL

COPERNICUS AIRPORT WROCŁAW is about 10 km from the city centre, and connects Wrocław with Warsaw, Gdansk, and destinations throughout Europe. From the airport you can reach the city centre by a shuttle bus (journey time about 30 minutes), or by bus No. 106, which leaves every 15 minutes (journey time about 40 minutes) or by taxi. Wrocław's main rail station, WROCŁAW GŁÓWNY, connects the city to other major destinations across Poland and eastern Europe. Wrocław's central bus station is located at 1/11 ul. Sucha, adjacent to the main railway station, and connects the city by road to all major Polish and European destinations.

**Preliminary Schedule.**

**XVI Congress of the European Association of Thermology, 6th – 8th September 2024, Wrocław University of Environmental and Life Sciences.**

| Time | Friday | Saturday | Sunday |
|---|---|---|---|
| 8.30 | Course Registration | Congress registration | Morning session 1 followed by prizegiving, close of congress |
| 9.00 - 10.30 | Short Course on Medical Thermography | Morning session 1 | |
| 10.30 - 11.00 | | Coffee break | Coffee break |
| 11.00 – 12.30 | | Morning session 2 | EAT General Assembly |
| 12.30 – 13.00 | | Poster viewing | |
| 13.00 – 14.00 | | Lunch | |
| 14.00 – 15.30 | | Afternoon session 1 | Tour around Wrocław's Old Town and Ostrów Tumski  |
| 15.30- 16.15 | | Tea break | |
| 16.15 – 18.00 | | Afternoon session 2 | |
| 18.30 – 20.00 | Congress registration | | |
| 19.30- 22.00 | | Gala dinner | |

# European Association of Thermology

## Short Course on Medical Thermography

### *Friday 6th September 2024, Wrocław University of Environmental and Life Sciences Wrocław, Poland*

Following on from successful courses in Porto, Madrid, London, and online in 2021, the next EAT Short Course on Medical Thermography will take place immediately prior to the EAT 2024 Congress in Wrocław, Poland. The course aims to deliver a thorough introduction over one full teaching day to basic thermal physiology and the principles of infrared thermography for human body surface temperature measurement. It will be taught by an experienced faculty of EAT clinicians, biomedical researchers and imaging scientists. Aspects of reliable thermogram capture will be demonstrated in a laboratory session, and students will have the opportunity to practice thermal image analysis in a supervised "hands-on" session.

### Syllabus

- Physical principles of heat transfer
- Principles of thermal physiology/skin blood perfusion
- Standardisation of thermal imaging, recording and analysis
- Quality assurance for thermal imaging systems
- Producing a thermographic report
- Provocation tests
- Image analysis
- Hands-on supervised practice
- Educational resources

### Registration

The course fee (inclusive of lunch and coffee breaks) is €220

Register from 1st January 2024: details online at [www.eurothermology.org/education.html](www.eurothermology.org/education.html)

Questions? Contact the EAT at [eurothermology@gmail.com](mailto:eurothermology@gmail.com)

XVI Congress of the European Association of Thermology
Wrocław POLAND 2024

**XVI EAT CONGRESS, 6th – 8th September 2024, Wrocław**