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Can body mass index influence the skin temperature of adolescents? A preliminary study with the use of infrared thermography

O índice de massa corporal pode influenciar a temperatura da pele de adolescentes? Um estudo preliminar com o uso da termografia infravermelha

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Abstract – Infrared thermography (IRT) has been used to assess skin temperature (Tsk), especially during the COVID-19 pandemic, as an important tool in medical screening not only of the general population, but also of young athletes. However, the subcutaneous adipose tissue can act as an insulator when the Tsk is assessed by IRT, modifying the normal Tsk data and leading to their misinterpretation. Considering that the body mass index (BMI) is an important predictor of obesity, the objective of this study was to verify if the Tsk measured by IRT is affected by the BMI in adolescents. A preliminary study was carried out being four participants intentionally selected, all 16 years old, each one classified in a different BMI range according to the criteria of the World Health Organization for the adolescent population: underweight, healthy weight, overweight and obesity. Four thermograms of each participant were recorded and the ThermoHuman® software was used to evaluate 82 regions of interest (ROI), which were integrated into 6 body regions. Using healthy weight subjects as a reference, it was found a progressive reduction in Tsk in all ROI compared to overweight and obese participants, with emphasis on the anterior region of the trunk (3.04% and 6.69% less respectively), and an increase in the Tsk of all body regions for the underweight subject. There are indications that BMI can influence the Tsk value in adolescents and should be taken into account when analyzing thermograms for a correct evaluation of thermal normality.

Keywords: Adiposity; Adolescent; Body composition; Body temperature regulation.

Resumo – *A termografia infravermelha (TI) tem sido uma técnica empregada para avaliar a temperatura da pele (T_p), especialmente durante a pandemia do COVID-19. Contudo, existem indicações que o tecido adiposo subcutâneo pode agir como uma camada isolante, alterando o comportamento da T_p, o que pode dificultar a interpretação da normalidade térmica. Tendo em vista que o índice de massa corporal (IMC) é considerado um importante preditor de obesidade, o objetivo deste estudo foi verificar se a T_p sofre interferência de diferentes classificações de IMC em adolescentes. Foram selecionados 4 participantes de maneira intencional, todos com 16 anos, cada um foi classificado em uma diferente faixa de IMC para população de adolescentes segundo a classificação proposta pela Organização Mundial de Saúde para essa idade: baixo peso, peso normal, sobrepeso e obesidade. Foram feitos quatro termogramas, avaliados no software ThermoHuman®, que avalia 82 regiões corporais de interesse (RCI), que foram integradas em 6 regiões corporais. Utilizando os indivíduos com peso normal como referência, foi encontrada uma redução progressiva na T_p comparada aos participantes com sobrepeso e obesidade, com ênfase para a região anterior de tronco (3.04% e 6.69% menores, respectivamente), e um aumento na T_p de todas as regiões corporais comparadas ao sujeito com baixo peso. Isso indica que o IMC pode influenciar nos valores da T_p em adolescentes e deve ser levado em consideração para uma avaliação correta da normalidade térmica.*

Palavras-chave: *Adiposidade; Adolescente; Composição corporal; Regulação da temperatura corporal.*

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INTRODUCTION

Infrared thermography (IRT) is a portable, radiation-free, non-invasive method capable of measuring and portraying organic conditions by checking the skin temperature (Tsk) in real time[1], which has been commonly used for tracking the condition of hyperthermia during the COVID-19 epidemic[2]. In recent years, the usage of IRT has shown interesting results in different areas of knowledge, especially in the medical field, acting as an auxiliary tool in the diagnosis of diseases such as skin cancer, diabetic neuropathy, vascular disorders and muscle injuries[1,3,4]. However, it is important to know how internal and external factors influence the Tsk registry. The review by Fernández-Cuevas et al.[5] reported different factors that must be considered to avoid a misdiagnosis of a hyper- or hypo-irradiating area, such as body fat, which can act as a possible influencing agent.

It is important to highlight that, due to its thermal insulating effect[6], the adipose tissue thickness has a potential effect interfering in Tsk, which can be considered as a confounding factor in the interpretation of the human thermal pattern. Knowing the influence of adipose tissue on the Tsk, it is especially important to establish whether a subject is in a state of thermal normality, an essential element assessing hyperthermia, especially in temperature control points at airports and shopping centers as a preventive method against COVID-19.

Marins et al.[7] found that women considered healthy have lower Tsk in most of their analyzed bodies regions when compared to men considered healthy. Although this study did not measure the percentage of fat, the authors speculated that the higher body fat levels of women could contribute to generate a different thermal profile between genders. The number of studies relating Tsk measurement by IRT and fat percentage and other anthropometric parameters are reduced[8-11], and all of those assess only adults, without verifying the influence of these parameters on Tsk in different age groups. It should be noted that only two of these studies[10,11] used body mass index (BMI) as an evaluation criteria among an adult female population, and only those with healthy BMI values (18.5–24.99 kg/m^2) were compared individuals with obesity (>30 kg/m^2) and underweight BMI levels (< 17 kg/m^2). Studies relating several BMI ranges to Tsk response among adolescent populations were not found, thus indicating that this study is a pioneer, onsetting an interesting possibility for practical application of interpretation of thermographic images within this group.

Considering the clinical possibilities and uses of thermographic images, implementing an exploratory study would be interesting to evaluate possible effects of nutritional status on Tsk, based on BMI, which is an excellent, easy to measure, and universally adopted clinical indicator of the under- and overweight conditions[12]. Thus, this study aims to verify if Tsk is influenced by different BMI classifications in adolescents. We hypothesize that BMI will influence the Tsk response, which may affect the interpretation of a normal thermal state, especially important against COVID-19.

METHODS

Participants

Four participants were intentionally selected, all male, aged 16 years, each one as a clear representative of the four BMI classification ranges according to the criteria established by the World Health Organization[12]: underweight (weight 60.00kg, height 1.89m, BMI 16.80kg/m^2), healthy weight (weight 65.50kg, height 1.75m, BMI 21.40kg/m^2), overweight (weight 82.50kg, height 1.79m, BMI 25.60kg/m^2) and obesity (weight 83.55kg, height 1.64m, BMI 31.10kg/m^2).

The following exclusion criteria considered were: smoking, musculoskeletal injuries in the last two months, skin burns (in the analyzed body regions), pain symptoms in the evaluated areas, skin allergies, sleep disorders, fever in the last seven days, medical or physical therapy with creams, ointments or lotions, as well as the use of antipyretics and/or diuretics, any nutritional supplement that could change water body homeostasis or body temperature in the last two weeks, and eating disorders (bulimia and anorexia)[5].

This study was conducted according to the guidelines defined in the Declaration of Helsinki and approved by local Institutional Review Board for Human Subject Protection (n° 40934275729). Written informed consent was obtained from all the participants partners prior to taking part in the study.

Procedures

After that, four thermograms were taken of each participant front and rear upper and lower limbs were obtained through a T420 imager (FLIR®, Stockholm, Sweden) with 2% accuracy, at 7.5-13 µm infrared spectral band, 60 Hz refresh rate, autofocus, and 320 x 240 pixels. The precision for detecting temperature change was ≤0.05 °C. The camera was turned on 30 min before the measurements to allow sensor stabilization; it was set up on a tripod at 2.4 meters from the volunteer, perpendicular to the regions of interest (ROIs). The emissivity of the camera was set at 0.98 as the recommended value for human skin. The thermograms were obtained in a room with controlled temperature (21.3 ± 0.7ºC) and humidity (55.3 ± 2.2%), following all the procedures recommended by Fernández-Cuevas et al.[5]. Thermograms were analyzed using ThermoHuman® software (PEMA THERMO GROUP S.L., Spain).

In order to reduce limiting factors that may influence the values obtained by IRT, each participant was always measured at the same time of the day, avoiding any changes regarding the circadian rhythm, which may affect the skin blood flow and, consequently, the recorded Tsk[13].

ThermoHuman® software provides the mean Tsk, standard deviations and number of pixels, which was automatically quantified for the 48 ROIs of the upper body and the 36 ROIs of the lower limbs (Figure 1).

Considering the mean Tsk and the number of pixels of each ROI, the integrated Tsk of the arms (14 ROIs in the frontal and 14 ROIs in the rear views, in dark gray), trunk (10 ROIs in the frontal and 10 ROIs in the rear views, in gray) and legs (18 ROIs in the frontal and 18 ROIs in the rear views, in soft gray) were obtained.

All the calculations were performed in SPSS® software (version 22.0).

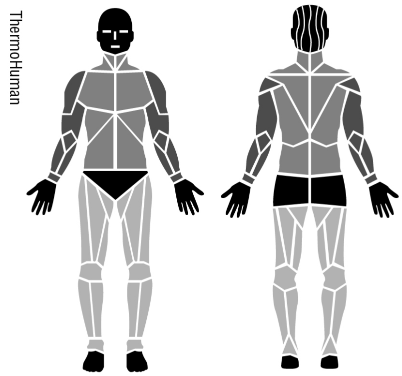

Figure 1. ROIs analyzed using ThermoHuman®. Note: arms: dark gray; trunk: gray and; legs: soft gray.

RESULTS

Figure 2 presents a qualitative demonstration of the observed Tsk values in each of the individuals with a standardized thermal field (35ºC to 26ºC) in order to compare easily the thermal pattern of the subjects. The Tsk values observed in the anterior and posterior regions of the body, according to the classification by BMI, for all the considered integrated ROIs are presented in Table 1.

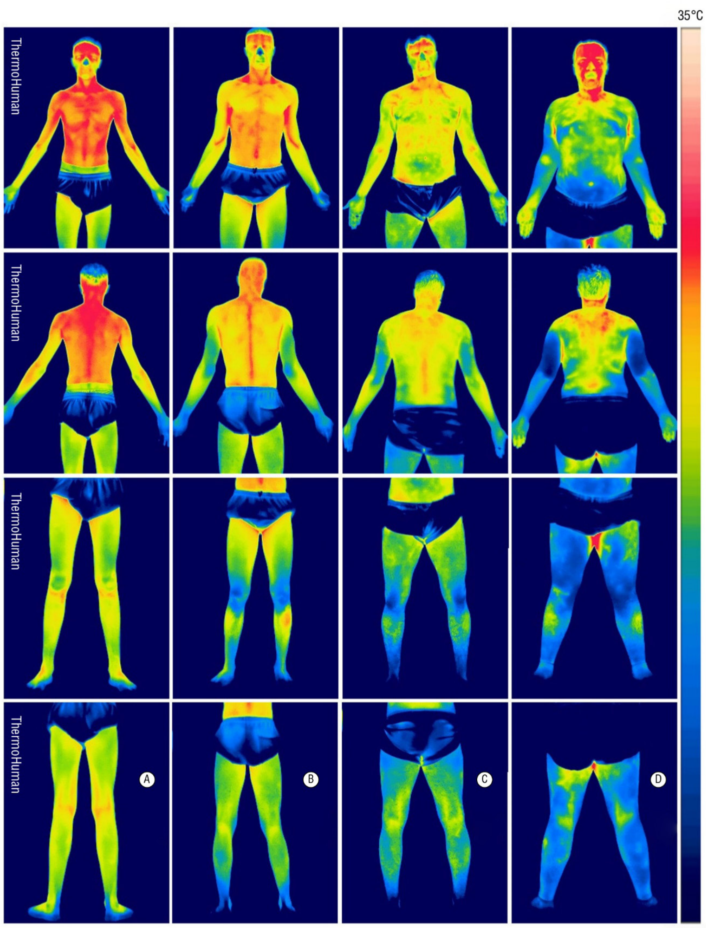

Figure 2. Thermograms of all four analyzed participants, upper and lower body, in front and rear views.

Table 1. Mean Tsk values for the considered integrated ROIs.

Integrated ROI	TskMean (±SD) °C			
	Underweight (A)	Healthy weight (B)	Overweight (C)	Obesity (D)
Frontal view				
Arms	33.14±0.55	31.35±0.63	30.77±0.54	30.45±0.75
Trunk	34.20±0.39	32.90±0.43	31.90±0.56	30.70±0.81
Legs	33.00±0.82	31.28±0.82	30.84±0.74	30.71±0.95
Rearview				
Arms	32.51±0.62	30.35±0.73	29.81±0.65	28.98±0.75
Trunk	30.41±0.28	29.39±0.33	28.74±0.56	28.05±0.77
Legs	31.60±0.61	30.60±0.74	29.20±0.71	29.10±0.69

Note: Tsk - Skin temperature; SD – Standard deviation; ROI - Regions of interest.

Table 2 presents the absolute differences in °C and in percentage when comparing a healthy weight subject to the other classification ranges for all considered integrated ROIs.

Table 2. Absolute mean Tsk differences in °C and its percentage for the considered integrated ROIs, comparing healthy weighted subjects to the other classification groups.

ROI	Δ°C (% of the total value of the healthy weighted)		
	Underweight	Overweight	Obesity
Frontal view			
Arms	1.79 (+5.71%)	-0.58 (-1.85%)	-0.90 (-2.87%)
Trunk	1.30 (+3.95%)	-1.00 (-3.04%)	-2.20 (-6.69%)
Legs	1.72 (+5.50%)	-0.44 (-1.41%)	-0.57 (-1.82%)
Rear view			
Arms	2.16 (+7.12%)	-0.54 (-1.78%)	-1.37 (-4.51%)
Trunk	1.02 (+3.47%)	-0.65 (-2.21%)	-1.34 (-4.56%)
Legs	1.00 (+3.27%)	-1.40 (-4.58%)	-1.50 (-4.90%)

Note: ROI - Regions of interest.

In all six analyzed ROIs, a decrease of Tsk was observed within the individuals with overweight and obesity in which the greatest difference obtained was (-2.20°C; -6.69%) in the anterior trunk of the subject with obesity and the smallest difference was (-0.58°C; -1.85%) in the anterior arms of the individual with overweight. On the other hand, subject with underweight exhibited increased Tsk values for all the considered ROIs, with the higher differences in the frontal and rear arms (1.79ºC and 2.16ºC, respectively), which represents increments of +5.71% and 7.12%.

DISCUSSION

The aim of this study was to verify if Tsk is interfered with by different BMI classifications in adolescents. The preliminary results obtained in this study clearly point out that the existing BMI patterns (underweight, healthy weight, overweight and obesity) could be related to the Tsk, tending towards a progressive reduction when the BMI increases, and increasing dramatically in case of low BMI. This indicates that thermal normality studies should consider the BMI range as an influence factor, as this anthropometric indicator has an important relationship with the body fat. This analysis becomes especially relevant when considering IRT to be the technique used as a reference standard to characterize one of the possible conditions of COVID-19 diagnosis, for example.

It is noteworthy that this study was conducted based on the hypothesis suggested by Marins et al.[7], who observed lower Tsk in women, a characteristic also observed by Chudecka et al.[10], associating this reduction with a greater amount of body fat. The preliminary results obtained in the present study reinforce the findings of Neves et al.[8], in which they observed that the highest %BF value (assessed through DXA) is related to the reduction of Tsk in the trunk of men and women aged 18 to 28 years. Similar results were also found by Chudecka et al.[10], who found a reduction in Tsk through different %BF ranges (measured by bioimpedance) in a sample of women with obesity, especially in the abdominal region. However, despite the hypotheses suggestion[7,14] and the results observed by other authors[8,10], all studies were conducted with adults, with no specific studies being found with adolescents, which makes further exploration in this context necessary. It is also noteworthy that professionals who use IRT do not always have access to DXA or bioimpedance; however, BMI is an easily obtainable measure.

Chudecka et al.[10], in their evaluation of women with obesity, used the comparison between BMI > 30kg/m^2 to healthy BMI (18.5–24.99 kg/m^2) and found reductions in mean Tsk in the anterior and posterior regions of arms, trunk and lower limbs of women with obesity. In another comparison[11], also with healthy BMI (18.5–24.99 kg/m^2), they observed that women with anorexia (BMI <17kg/m^2) had greater mean Tsk in the anterior and posterior regions of the trunk and thighs. Thus, our results integrate and confirm the results from those two different studies, and would reinforce the relationship between mean Tsk and BMI not only in adult populations but also in youngsters.

It is interesting to underline that the higher differences on Tsk compared to the subject with healthy weight were obtained in the anterior trunk, both in the subject with overweight (-1.00ºC, a 3.04% less) and in the one with obesity (-2.20˚C; a 6.69% less). This area corresponds to the area with a higher concentration of body fat in males[15,16]. On the contrary, even when the subject with underweight exhibited increased Tsk values for all the considered ROIs, the higher increments in the frontal and rear arms with Tsk increments of +5.71% and 7.12%.

Our results indicate the need to be stricter when establishing the thermal profile in humans. Studies with this aim developed within adults by Marins et al.[7] with a Brazilian population, by Zaproudina et al.[17] with the Finns, by Zhu and Xin[18] with the Chinese, and by Kolosovas-Machuca and González[19] with Mexican children, do not consider the effects of BMI or body composition when establishing a thermal profile in different body regions. In this way, an inadequate reference can be generated to establish whether a subject is hyper or hypothermic.

Noteworthy that the data evaluated in this study only refer to differences in Tsk within BMI ranges. It is important to consider, after the results of this preliminary study, the analysis of a greater sample based on the BMI classification in order to establish thermal normality tables for each ROI, thus helping interpretating the thermograms and classifying the ROIs as hyper- or hypo-irradiating. According to our results, we consider that BMI should be included in the characterization of the sample in studies in which IRT is the measurement method.

CONCLUSIONS

The results demonstrated a progressive reduction of Tsk for all the ROIs comparing the participant with healthy weight to the ones with overweight and obesity, and a strong increasement of Tsk for the one with underweight. This finding suggests that BMI can influence the value of Tsk in adolescents and should be taken into consideration when analyzing thermograms, including BMI data in the characterization of the sample.

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COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the Human Research Ethics Committee of the Federal University of Viçosa, under nº 40934275729, and the protocol was written in accordance with the standards established by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interest to declare.

Author Contributions

Conception and design of the experiment: HHTR, CJB, AGS, JCBM; Experiments: HHTR, AGS, MSC; Data analysis: HHTR, AGS, FZW; Article writing: HHTR, CJB, AGS, MSQ, VETR, FZW, IFC, MSC, JCBM. All authors read and approved the final version of the manuscript.

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