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Thermal body patterns for healthy Brazilian adults (male and female)

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ABSTRACT

The aim of this study was to establish the skin temperature (T_{sk}) thermal profile for the Brazilian population and to compare the differences between female and male Brazilian adults. A total of 117 female and 103 male were examined with a thermographic camera. The T_{sk} of 24 body regions of interest (ROI) were recorded and analyzed. Male T_{sk} results were compared to female and 10 ROI were evaluated with respect to the opposite side of the body (right vs. left) to identify the existence of significant contralateral T_{sk} differences (ΔT_{sk}). When compared right to left, the largest contralateral ΔT_{sk} was 0.3 °C. The female vs. male analysis yielded significant differences ($p < 0.05$) in 13 of the 24 ROI. Thigh regions, both ventral and dorsal, had the highest ΔT_{sk} by sex (≈ 1.0 °C). T_{sk} percentile below P_5 or P_{10} and over P_{90} or P_{95} may be used to characterize hypothermia and hyperthermia states, respectively. Thermal patterns and T_{sk} tables were established for Brazilian adult men and women for each ROI. There is a low T_{sk} variation between sides of the body and gender differences were only significant for some ROIs.

1. Introduction

Infrared Thermography (IRT) is a technique that allows visualization of the heat radiated from a body using infrared emission, a spectrum that is not visible to humans (Hildebrandt et al., 2010; Pascoe et al., 2008). This technology is used in the medical field, where it can provide doctors with information about the physiological responses associated with skin temperatures (T_{sk}) to identify different types of pain syndromes (Al-Nakhli et al., 2012), changes in the T_{sk} (Park et al., 2012, Howell et al., 2009, George et al., 2008), vascular deficiencies (Huang et al., 2011; Brisoschi et al., 2003), or neurological problems (Zaproudina et al., 2006); provide assistance in cardiac interventions (Brisoschi et al., 2003); or help in cancer diagnosis and monitoring (Arora et al., 2008). Recently, thermography has also been proposed as a way to prevent sports injuries (Sillero-Quantana et al., 2011; Gómez-Carmona et al., 2011), control training load (Akimov et al., 2010), or study thermal responses during and after exercise (Hildebrandt et al., 2010; Merla et al., 2010; Marins et al., 2012a, 2012b; Merla and Romani 2008; Garagiola and Giani, 1990). Most thermography studies evaluate contralateral T_{sk} differences (ΔT_{sk}) existing in pathological conditions such as cancer (Acharya et al., 2012; Arora et al., 2008) or spinal disorders (Ammer, 2010). In those cases, contralateral ΔT_{sk} is usually the main focus. A good thermal state of the body structure is based on thermal symmetry between symmetrical parts of the body always between a temperature range. Higher contralateral differences in T_{sk} could mean an imbalance or impairment between symmetrical parts of the body.

There are clear indications that thermography is a valid (Ammer and Ring, 2008; Zaproudina et al., 2006) technology, which is both non-invasive and low-cost, that rapidly produces a non-contact recording of the energy irradiated from the body (Han et al., 2010; George et al., 2008; Jiang et al., 2005). It has been recently shown that a high resolution thermal image can provide interesting information about the complex thermoregulation system of the body (Pascoe et al., 2008). The development of fast and easy IRT monitoring tools allows us to obtain a general or local thermal profile of humans, including their main body regions of interest (ROI).

For an appropriate interpretation of an individual thermographic profile, it is necessary to establish a reference thermal pattern for each population group (for example, by age group, by race or for a particular disease). Although these types of studies are uncommon, some studies in adult populations with different ethnic characteristics such as Chinese (Zhu and Xin, 1999), Finish (Zaproudina et al., 2008), Portuguese (Vardasca, 2011), Taiwanese (Niu et al., 2001), or Mexican children (Kolosovas-Machuca and González, 2011) have attempted to establish population thermal patterns. Having a thermal reference allows us to evaluate normal T_{sk} in different body segments and the proportion of bilaterally

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(side-to-side). According to Niu et al. (2001) and Uematsu (1985), a ΔT_{sk} greater than 0.5 °C between two body segments strongly indicates a functional disorder in the assessed ROI.

Thermographic records also show the complex physiological response to strength training involving the skeletal muscle (metabolism), the cardiovascular system (blood flow), the nervous system (central and local) and the adrenergic system (Johnson and Kellogg, 2010; Cheuvront et al., 2010). The regulation of body temperature to maintain internal temperature at adequate levels is complex. The hypothalamus and multiple sensors and effectors act together, providing feedback to control the system (Werner, 2010) and consequently affect the T_{sk}.

To adequately interpret thermographic data, a set of internal factors such as age (Falk and Dotan, 2011; Charkoudian, 2010; Niu et al., 2001), gender (Falk and Dotan, 2011), level of fitness (Magalhães et al., 2010; Merla et al., 2005), and external factors including the degree of hydration (Charkoudian, 2010), clothing (Gonzales et al., 2011) or environmental conditions (Morris et al., 2005) should be considered. Furthermore, an appropriate protocol for infrared imaging is crucial to obtain quality thermographic images (Ammer and Ring, 2008). Our study has followed their guidelines considering the dark background, the distance from the camera, the position of the camera, the range of temperature and the resolution.

Data for T_{sk} can help to establish standards of normality in different parts of the body. Establishing the standard thermal patterns in different population groups may help to identify hyperthermic or hypothermic areas, to detect contralateral ΔT_{sk} as signs of functional problems or diseases and to determine the relationships between central and peripheral temperatures, thus reducing the subjectivity in the evaluation. Establishing the values for normal resting conditions may also contribute to understanding the thermal changes of the skin during and after any physical activity.

Local thermal information is relevant not only for practitioners but also for sports physiotherapists, dieticians and coaches who advise and provide training and therapy to normal people or athletes.

Given that age factor (Kolosovas-Machuca and González, 2011; Niu et al., 2001) is crucial in thermal responses, specific data by gender for well-defined age groups such as children, adolescents, adults and elderly people are required. Therefore, the aims of this study were (a) to establish the T_{sk} data for Brazilian adults and (b) to compare ΔT_{sk} between males and females.

2. Material and methods

2.1. Participants

A sample of two hundred and twenty young adults participated in the study, 103 men [age: 21.3 ± 2.19 years, height: 1.78 ± 0.7 m, body mass: 72.5 ± 7.8 kg, and Body Mass Index (BMI): 23.0 ± 2.3 kg/m^2] and 117 women [age: 21.9 ± 2.2 years, height: 1.64 ± 0.05 m, body mass: 59.8 ± 7.1 kg, and BMI: 22.2 ± 2.4 kg/m^2]. They did not report any pain or problems in their daily activities and did not consume any medication in the 2 weeks prior to the measurements. Exclusion criteria were smoking or any pathological condition that could alter the T_{sk}. All individuals signed a consent inform and the ethics committee of the Viçosa Federal University, Brazil approved the study procedures.

2.2. Procedures

Before the assessment, subjects were instructed to avoid consuming alcohol or caffeine, using any type of moisturizer or cream and performing vigorous physical exercise in the 24 h preceding the measurements. These recommendations were given on the day of enrollment and were assessed via questionnaire immediately before the early morning data collection.

The T_{sk} of the body ROI were obtained from thermographic images following the criteria described by Ring and Ammer (2012, 2008). Evaluations were performed at the Human Performance Laboratory (LAPEH) of the Federal University of Viçosa from October 2010 to March 2011 (spring and summer season in Brazil). Subjects were instructed to change clothes, using a swimsuit or shorts (men) or a top and shorts (women). Soon after, they were directed to a conditioned room (Temperature: 21 °C ± 0.3 °C and humidity: 67.8 ± 3.8%) where, after 15 min of adaptation to the room conditions, four thermograms for each subject were recorded including two images each (lower limbs and trunk/upper limb) of the anterior and posterior sides of the body.

Just after entering the data collection room, the subject was instructed to stand on top of a rubber mat that was 4 m away from the infrared imager and 0.4 m from the wall. The wall was covered with a black background to avoid any kind of reflection. Subjects were asked to refrain from making any type of movement, sitting, crossing their arms or legs, or scratching throughout the procedure.

The T_{sk} analysis included the left and right sides of the hand, forearm, upper arm, thigh and leg. In addition, T_{sk} data of the chest, abdomen, lower back and upper back were also collected. The T_{sk} averages from 24 ROI were collected by the software Smartview® (Fluke®, Everett, USA). The ROI were rectangles determined by anatomical landmarks, namely (a) hand: the junction of the 3rd metacarpal with the 3rd proximal phalanx and the ulnar styloid process, (b) forearm: the distal forearm and cubital fossa (c) arm: cubital fossa and axillary line, (d) abdomen (and low back): xiphoid process and 5 cm below the umbilicus; (e) chest (upper back): nipple line and top edge of the sternum; (f) thigh: 5 cm above the superior border of the patella and the inguinal line; (g) leg: 5 cm below the inferior border of the patella and 10 cm above the malleolus. The points corresponding to the posterior region of the body were marked using a tape measure parallel to the ground. Fig. 1 shows an example of images taken of the evaluated ROI.

The thermographic imager was a TIR-25 camera (Fluke®, Everett, USA) with a measurement range of −20 to +350 °C, an accuracy of ± 2 °C or 2% of the measurement, a sensitivity below 0.1 °C, an infrared spectral band from 7.5 μm to 14 μm, a refresh rate of 9 Hz and a resolution of 160 × 120 pixels FPA (Focal Plane Array). Images were obtained assuming a skin emissivity of 0.98 (Ring and Ammer, 2012) and analyzed using the Smartview® software, version 3.1.

After thermographic data collection, the subjects were weighed with an ID-M scale (Filizola®, São Paulo, Brazil), and their heights were measured with a standard wall-stadiometer (Sanny®, São Bernardo do Campo, Brazil).

2.3. Statistical analysis

We applied descriptive statistics including the means and standard deviations for data presentation. General and by gender absolute regional contralateral ΔT_{sk} were calculated for each of the 10 ROI pairs by subtracting the mean T_{sk} of the left side from the mean T_{sk} of the right side.

After confirming the normal distribution of the variables using a Shapiro–Wilk test, significant differences between the 10 contralateral ΔT_{sk} values were calculated by a paired samples Student's t-test, and the differences between the T_{sk} of the 20 gender-common ROI by an independent samples Student's t-test. A significance level of $\alpha = 0.05$ was set for the statistic tests in the software SigmaPlot 11.0 (Systat, Chicago, USA).