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Time required to stabilize thermographic images at rest

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HIGHLIGHTS

- Standardizing the acclimatization time is crucial for a right T_{SK} assessment by IRT.
- Time for reaching T_{SK} balance in rest is different for young men and women.
- 10 min is enough for acclimatization when the external temperatures are not extreme.

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ABSTRACT

Thermography for scientific research and practical purposes requires a series of procedures to obtain images that should be standardized; one of the most important is the time required for acclimatization in the controlled environment. Thus, the objective of this study was to identify the appropriate acclimatization time in rest to reach a thermal balance on young people skin. Forty-four subjects participated in the study, 18 men (22.3 ± 3.1 years) and 26 women (21.7 ± 2.5 years). Thermographic images were collected using a thermal imager (Fluke®), totaling 44 images over a period of 20 min. The skin temperature (T_{SK}) was measured at the point of examination which included the 0 min, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20. The body regions of interest (ROI) analyzed included the hands, forearms, arms, thighs, legs, chest and abdomen. We used the Friedman test with post hoc Dunn's in order to establish the time at rest required to obtain a T_{SK} balance and the Mann–Whitney test was used to compare age, BMI, body fat percentage and temperature variations between men and women, considering always a significance level of $p < 0.05$. Results showed that women had significantly higher temperature variations than men ($p < 0.01$) along the time. In men, only the body region of the abdomen obtained a significant variance ($p < 0.05$) on the analyzed period, both in the anterior and posterior part. In women, the anterior abdomen and thighs, and the posterior part of the hands, forearms and abdomen showed significant differences ($p < 0.05$). Based on our results, it can be concluded that the time in rest condition required reaching a T_{SK} balance in young men and women is variable, but for whole body analysis it is recommended at least 10 min for both sexes.

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1. Introduction

In humans, core body temperature (CT) is maintained nearly constant by physiological mechanisms that maintain a balance between the internal heat and heat released to the environment [1]. These adjustments are essential to maintaining an inner temperature of approximately 37 °C, thus preserving vital metabolic functions. However, skin temperature (T_{SK}) varies widely, ranging from 10 to 42 °C [2]. The factors that affect T_{SK} include exposure to certain environmental conditions, such as extreme temperatures, humidity and solar radiation [3] for long periods performing exercise [4] and the presence of pathological conditions, such as fever [5] or cancer [6].

A cold environment causes vasoconstriction of the skin to preserve the internal heat of vital organs [1]. Under extreme heat conditions, the opposite occurs; vasodilatation facilitates heat loss,

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and the T_{SK} is elevated [7]. During exercise, when the CT is high, it is necessary to increase the mechanisms for releasing the excess body heat to avoid hyperthermia. One of the main mechanisms is increasing skin circulation, while the systolic volume is decreased. Increased flow of blood to the skin promotes heat exchange mediated by the evaporation of sweat and may increase the T_{SK} to 38 °C [8,9]. However, in a neutral thermal environment and at rest, T_{SK} tends to stay in balance, and a significant increase or decrease in its normal levels may indicate a pathological state.

The analysis of temperature using skin thermometry (thermography) is promising method in studies designed to examine the T_{SK}. Skin thermography is an objective and non-invasive procedure that measures temperature distribution using a thermal imager that receives and processes the infrared radiation emitted by the body surface [10]. The scientific use of thermography began in medical research, in which it has been used to diagnose vascular disease [11], inflammation [12], tumors [6,13], metabolic disorders and abnormalities in body temperature [12]. In the field of physical activity and sports, some studies have used the technique to study differences in thermogenesis between young and elderly people [14], the effect of exercise on hand temperature [8], and the distribution and variation of T_{SK} during progressive exercise [4].

Thermography for scientific research and practical purposes requires standardized procedures to obtain reliable images. In 2000, Ring and Ammer [15] conducted a review in which they proposed a methodology for collecting accurate thermal images. An important factor in their methodology is the time required for acclimatization in a controlled environment, which may be defined as the time necessary to achieve adequate stability in the subject's blood pressure and skin temperature. The authors recommend waiting 15 min for the optimal stabilization of T_{SK}, with a minimum of 10 min. However, when acclimatization exceeds 30 min, temperature oscillation can occur, creating an asymmetry between the left and right sides of the subject. Roy and collaborators [16] performed a study in which thermography was used to analyze the time necessary for the temperature in the region of the spine to stabilize and suggested a minimum time of 8 min and maximum of 16 min for reliable measurements [16]. The recommended acclimatization time varies between studies of skin thermometry, with periods of 10 min [14,17], 15 min [8] and 20 min [4] suggested for the subject to remain at rest in a room with controlled temperature and humidity. This variation may be influenced by environmental conditions, especially by the temperature outside the test room.

This lack of consensus [4,8,14–17] makes it difficult to determine the optimal acclimatization protocol because each study recommends a different acclimatization period to achieve a stable T_{SK} to ensure the homogeneity of results and allow consistent interpretation and comparison of results between studies. Consequently, the objective of this study was to identify the time required to achieve a stable T_{SK} at rest in a group of young men and women.

2. Materials and methods

2.1. Sample

A convenience sample of 44 physical education students at the Federal University of Viçosa participated in the study: 18 men (age: 22.3 ± 3.1 years; height: 177.3 ± 4.9 cm; body mass: 76.1 ± 9.1 kg; body mass index [BMI]: 24.3 ± 3.3 kg/m^2; and% of body fat [%BF]: 19 ± 6.2%) and 26 women (age: 21.7 ± 2.5 years; height: 163 ± 5.2 cm; body mass: 56.8 ± 5.3 kg; BMI: 21.4 ± 1.8 kg/m^2; and%BF: 28 ± 5.4%). The subjects did not report any pain or problems in their daily activities and did not consume any medication for 2 weeks before the measurements. The exclusion criteria were smoking and any pathological condition that could alter skin temperature. These requirements were verified in advance with a questionnaire. All subjects signed an informed consent form, and the ethics committee of the Viçosa Federal University approved the study procedures.

2.2. Procedures

The subjects were instructed not to consume alcohol or caffeine after breakfast, use any type of moisturizer or cream in the 6 h preceding the measurements or perform vigorous physical exercise in the 24 h preceding the measurements. The subjects were informed of these requirements when they enrolled, and their adherence to the requirements was verified with a questionnaire administered immediately before the data were collected. All measurements were performed in the morning. The T_{SK} of the regions of interest (ROI) of the body was analyzed from thermographic images following the criteria described by Ring and Ammer [15].

The evaluations were performed at the Human Performance Laboratory (LAPEH) of the Federal University of Viçosa from October to November of 2010 (spring in Brazil). The average temperature outside was 23 °C with 60% relative humidity. The subjects were instructed to change clothes into a swimsuit or shorts (men) or a top and shorts (women). They were then directed to an air-conditioned room (temperature: 19 °C ± 0.3 °C and humidity: 65.8 ± 3.8%) where the thermographic images were collected. Forty-four thermograms were recorded for each subject at 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 min.

Every 2 min, 4 images were recorded, including two images (of the lower limbs and upper limb and trunk) of both the anterior and posterior sides of the body. After entering the air-conditioned room, the subject was instructed to stand on a rubber mat 4 m from the infrared imager. The subject remained standing in the anatomical position for 20 min while images were collected. The subjects were asked to avoid moving during the procedure, including sitting, crossing their arms or scratching. The ROIs analyzed included the hand, forearm, upper arm, thigh, leg and left and right sides. Additionally, the chest, abdomen, lower back and upper back were also analyzed. The average T_{SK} of each rectangular ROI was collected using Smartview software (Fluke, Everett, USA). The configuration of the rectangles was determined using anatomical landmarks as follows: (a) the hand ROI was measured from the junction of the 3rd metacarpal with the 3rd proximal phalanx to the ulnar styloid process; (b) the forearm ROI was measured from the distal forearm to the cubital fossa; (c) the arm ROI was measured from the cubital fossa to the axillary line; (d) the abdomen ROI was measured from the xiphoid process to 5 cm below the umbilicus; (e) the chest ROI was measured from the nipple line to the top edge of the sternum; (f) the thigh ROI was measured from 5 cm above the superior border of the patella to the inguinal line; and (g) the leg ROI was measured from 5 cm below the inferior border of the patella to 10 cm above the malleolus. The corresponding points on the posterior of the body were marked using a tape measure encircling the analyzed region parallel to the ground. Fig. 1 shows an example of the images taken of a single subject after 20 min with the ROIs labeled. Finally, the temperatures obtained were collected in an Excel spreadsheet (version 2010).

ATIR-25 camera (Fluke, Everett, USA) with a measurement range of −20 to +350 °C, accuracy of ±2 °C or 2% of the measurement, sensitivity of ⩽0.1 °C, infrared spectral band from 7.5 μm to 14 μm, refresh rate of 9 Hz and resolution of 160 × 120 pixels FPA (focal plane array) was used to obtain the thermograms. Before the data collection, the camera was running for the same period of acclimatization than the subject, this provided time enough for the camera sensor to make a calibration. A fixed area of the black

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