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Skin temperature of middle distance runners after a maximum effort test

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ABSTRACT. The purpose of this study was to analyze skin temperature (Tsk) responses after a short-term maximum effort test in middle-distance runners. A quasi-experimental study was conducted with ten men (age 23.5±5.10 years) who trained 5 days per week, 2 to 3 hours per day, and were submitted to thermographic evaluation before and after Cooper's 12-minute run test (CRT). The mean temperature of the anterior-superior, posterior-superior, anterior-inferior, and posterior-inferior regions was compared between the sides (i.e., left and right) before and after CRT. The paired t-test showed a significant decrease in Tsk after CRT in the following regions: right pectoralis major (-3.4%), left pectoralis major (-3.4%), and abdomen (-5%) in the anterior-superior view ($p<0.01$); and in the upper right trunk (-1.9%), upper left trunk (-1.9%) and lower back (-2.9%) in the posterior-superior view ($p<0.05$). In the lower limbs, a significant increase in temperature of the left knee (1.6%), and right (3.6%) and left ankles (2.9%) in the anterior view ($p<0.05$), as well as in the right (4.3%) and left ankles (3.7%) in the posterior view ($p<0.05$) were observed. There was no difference in temperature between the right and left sides. In conclusion, the Tsk change of middle-distance runners was symmetrical between sides, decreasing in upper limbs and trunk and increasing in lower limbs after a short-term maximum effort test.

Keywords: thermography; athletes; physical exertion; running.

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Introduction

The skin temperature (Tsk) in athletes submitted to competition and training activities may be increased more than tenfold and remain elevated for several hours due to the rate of heat production (Lim, Byrne & Lee, 2008; Tanda, 2018). This increased heat production is associated with muscular work and shifts of blood flow (Hildebrandt, Raschner, & Ammer, 2010; Hildebrandt, Zeilberger, Ring, & Raschner, 2012; Lahiri, Bagavathiappan, Jayakumar, & Philip, 2012).

During exercise, the body thermoregulatory system controls the balance between the production and dissipation of body metabolic heat (Merla, Mattei, Donato, & Romani, 2009). Athletes may experience reduced performance during exercise and need a longer post-exercise recovery due to fluctuations in body heat regulation (Akimov & Son'Kin, 2011; Balci, Basaran, & Colakoglu, 2016). Thus, the Tsk alterations may provide information about post-exercise recovery, and musculoskeletal overload. Infrared thermography is a non-invasive and non-radioactive evaluation capable of detecting changes in Tsk (Merla et al., 2009; Fournet, Redortier, & Hevenith, 2015; Salvalaio, Silva, Pinho, & Pohlmann, 2011), which can assist in therapeutic decisions regarding the physical condition of athletes (Sillero-Quintana, Gomez-Carmona, & Fernandez-Cuevas, 2017; Ferreira et al., 2008; Côrte & Hernandez, 2016).

Tsk during exercise may be influenced by exercise intensity, level of physical fitness of the practitioner, and exercise practice environment (Tanda, 2018; 2015; Balci et al., 2016). In this sense, it was verified that the Tsk during exercise on a cycle ergometer exhibit different behaviors according to the intensity (maximum and submaximal), being that the average temperature during maximum exercise decreases more drastically at the beginning and does not increase after the eighth minute of exercise (Balci et al., 2016).

Some studies have evaluated Tsk during different exercises (treadmill running, cycle ergometer) (Tanda, 2018; 2015; Balci et al., 2016); however, it is still unclear whether body surface temperature changes in the post-exercise recovery period. The present study hypothesizes that Tsk should decrease in the upper limbs and increase in the lower limbs after a maximum effort test. Thus, this study aimed to analyze skin temperature responses after a short-term maximum effort test in middle-distance runners.

Material and methods

Participants

This is a quasi-experimental study in which ten male middle-distance runners (members of the Brazilian national team), age between 18 and 30 years, who trained for two to three hours per day and five times per week, and without muscle, joint or skin injuries (e.g. eczema, psoriasis, sunburn, or skin cuts and abrasions) were included. The sample also consisted of males who performed running as the only form of sport. All participants received detailed explanations about the aim of the study and gave their written informed consent prior to the examination. The study was conducted following the Declaration of Helsinki and approved by the Ethics Committee of the Federal University of Paraíba (number 972.410).

Thermal images acquisition and processing

Thermal images were taken before and after Cooper's 12-minute run test (CRT) using a digital infrared camera (T-360; FLIR Systems, USA), with infrared (IR) resolution of 320 x 240 pixels, with a temperature range of -20 to 120°C, thermal sensitivity of 0.05°C and accuracy of ± 2%. The thermal images were obtained in the Thermography Laboratory (LabTerm) of the Federal University of Paraiba.

Subjects were instructed to avoid tobacco, alcohol, or drugs that may affect the body's thermogenesis, as well as moderate or intense physical activity up to twenty-four hours before the thermal images acquisition. They were also instructed to avoid the use of oils or moisturizers on the examined regions.

Before the thermographic evaluation, subjects were instructed to remain at rest for 15 minutes in a room for acclimatization with the environment, dressed only with shorts. The temperature and relative humidity of the air in the acquisition room were monitored using a meteorological station (Oregon Scientific, WMR86, China) and maintained between 22 and 24°C and <50%, respectively.

Four images (anterior and posterior views of the trunk and upper limbs, and anterior and posterior views of the lower limbs) were taken in each subject before and after CRT (Figure 1) according to the Glamorgan protocol (Hildebrandt et al., 2010). The IR camera was fixed on a tripod, one meter above the ground, 3.5 meters from the subject, and perpendicular to the assessed area.

Figure 1. Infrared thermal images of the anterior (A) and posterior (B) body of a representative male subject at rest pre-test.

The obtained images were analyzed using the FLIR software (Thermacam Reporter software, version 8.2). The mean temperature of the regions of interest (ROI) (i.e., trunk, abdomen, lumbar, shoulder, arm, elbow, forearm, thigh, knee, leg, and ankle) was used as the dependent variable.

Runners performed the CRT on different days and only in the afternoon (3:00-5:00 p.m.) in order to minimize the effect of circadian rhythm among athletes. During the test, environmental conditions (temperature, relative humidity, air velocity) were not controlled.

Immediately after the first thermographic evaluation, the athletes performed the CRT on an athletic track. This test consists of a race of maximum effort and short duration, in which the endurance of the athlete is evaluated and then classified according to the distance traveled, age, and gender (Costa, Guerra, Guerra, Nunes, & Pontes Junior, 2007). The aerobic capacity after the test can be classified as very weak, weak, average, good, excellent, and superior. Athletes received verbal encouragement to maintain maximum effort and pace throughout the test. All athletes performed the test using only shorts and running shoes. Immediately after the test, subjects were conducted to a room for acclimatization during 15 minutes, followed by the second thermographic acquisition in the evaluation room.

Statistical analysis

Data are presented as mean ± standard deviation. Mean percentage differences were also computed. Data normality was evaluated by the Shapiro-Wilk's test and the homogeneity of the variances by the Levene's test. The means between the right and left sides of the limbs were compared using the unpaired t-test, while the pre- and post-test means were compared using the paired t-test. Effect sizes (ES) (Cohen's d) were calculated to assess the magnitude of the effect, and values were interpreted as small (0.2), moderate (0.5), and large (0.8). Statistical procedures were performed in the Statistical Package for the Social Sciences (SPSS - 20.0, IBM®, USA), and a significance level of 5% (2-tailed) was adopted.

Results

The basic characteristics of the participants are shown in Table 1. The estimated mean maximal oxygen consumption (VO_2) maximum during the test was 60.68 ± 6.10 mL kg^{-1} min^{-1}, and all volunteers presented a score classified as "excellent" considering the distance traveled according to age and gender.

Table 1. Characteristics of the participants (n=10).

Parameter	Mean ± SD
Age (years)	23.50 ± 5.10
Weight (kg)	63.75 ± 6.55
Height (m)	1.74 ± 0.05
BMI (kg m^{-2})	21.02 ± 2.00
Distance covered in the Cooper's 12-minute run test (m)	3220 ± 273

BMI: body mass index; SD: standard deviation; kg: kilograms; m: meters.

When comparing pre- and post-test values for each ROI in the anterior-superior view, a decrease in Tsk was observed for the trunk and upper limbs areas (Figure 2) in the right pectoral (-3.4%; p<0.01; *d*=1.45), left pectoral (-3.4%; p<0.01; *d*=1.37) and abdominal (-5.0%; p<0.01; *d*=2.11) regions. When analyzing the Tsk in the posterior-superior view, a significant decrease was found in the upper right trunk (-1.9%; p<0.01; *d*=0.85), upper left trunk (-1.9%; p<0.01; *d*=0.85) and lumbar region (-2.9%; p<0.01; *d*=1.05). There were no significant changes in Tsk in the other regions, as shown in Table 2.

In the analysis of the lower limbs (Figure 3), a significant increase in Tsk was observed in the anterior view in the left knee (1.6%; p=0.048; *d*=0.69), right ankle (3.6%; p=0.025; *d*=0.93) and left ankle (2.9%; p=0.047; *d*=0.61). In the posterior view, only the right (4.3%; p=0.015; *d*=1.28) and left ankles (3.7%; p=0.022; *d*=0.89) presented a significant increase in Tsk (Table 3).

Regarding Tsk changes between the right and left sides in the pre- and post-evaluation, no significant differences were found (p> 0.05) in both the upper and lower limbs.

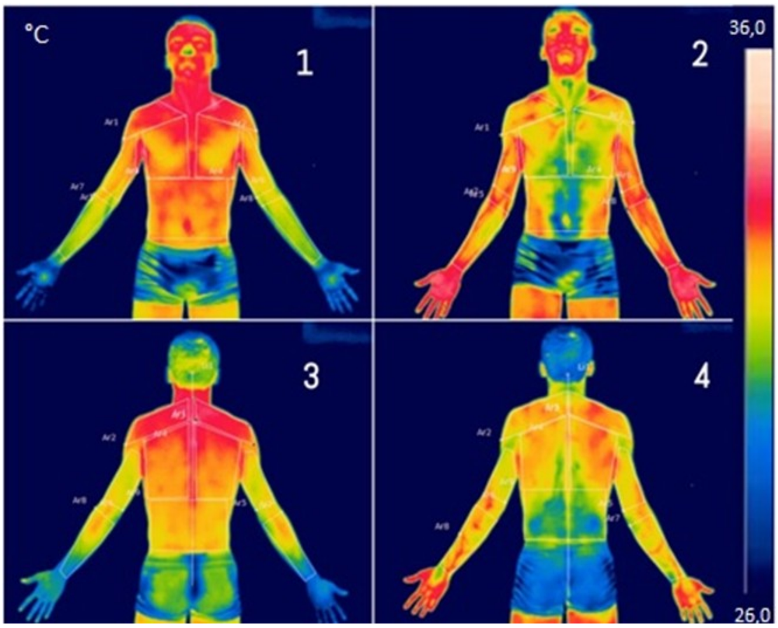

Figure 2. Infrared thermal images. 1: anterior-superior view obtained pre Cooper's 12-minute run test; 2: anterior-superior view obtained post-Cooper's 12-minute run test; 3: posterior-superior view obtained pre Cooper's 12-minute run test; 4: posterior-superior view obtained post-Cooper's 12-minute run test.

Table 2. Mean±SD of temperature (°C) before and after the Cooper's 12-minute run test in the anterior-superior and posterior-superior views.

ROIs	Anterior-superior view				ROIs	Posterior-superior view			
	Pre	Post	p	ES		Pre	Post	p	ES
Right shoulder	32.9±0.9	32.3±0.9	0.114	0.66		33.2±0.8	32.8±0.7	0.164	0.52
Left Shoulder	32.9±0.8	32.3±0.9	0.067	0.70		33.1±0.7	32.8±0.7	0.193	0.42
Right Pectoralis	32.5± 0.8	31.4± 0.7	0.001*	1.45	Right upper torso	32.6±0.7	32.0±0.7	0.012*	0.85
Left Pectoralis	32.5± 0.8	31.4± 0.8	0.001*	1.37	Left Upper Torso	32.6±0.7	32.0±0.7	0.008*	0.85
Right arm	32.3± 0.9	32.1± 1.3	0.452	0.17		31.3±1.0	31.8±1.1	0.120	0.47
Left arm	32.1± 0.8	32.0± 1.1	0.824	0.10		31.3±1.0	31.6±1.1	0.382	0.28
Right Forearm	31.5± 1.0	31.4± 1.7	0.751	0.06		31.2±0.8	31.3±1.9	0.895	0.06
Left Forearm	31.2±1.0	31.7±1.8	0.404	0.32		30.9±0.7	31.6±1.8	0.189	0.44
Abdomen	32.6± 0.8	31.0± 0.7	0.001*	2.11	Lumbar	32.1±0.8	31.2±0.9	0.005*	1.05

ROIs: Regions of Interest; ES: Effect size; * Significant difference between pre and post Cooper's 12-minute run test.

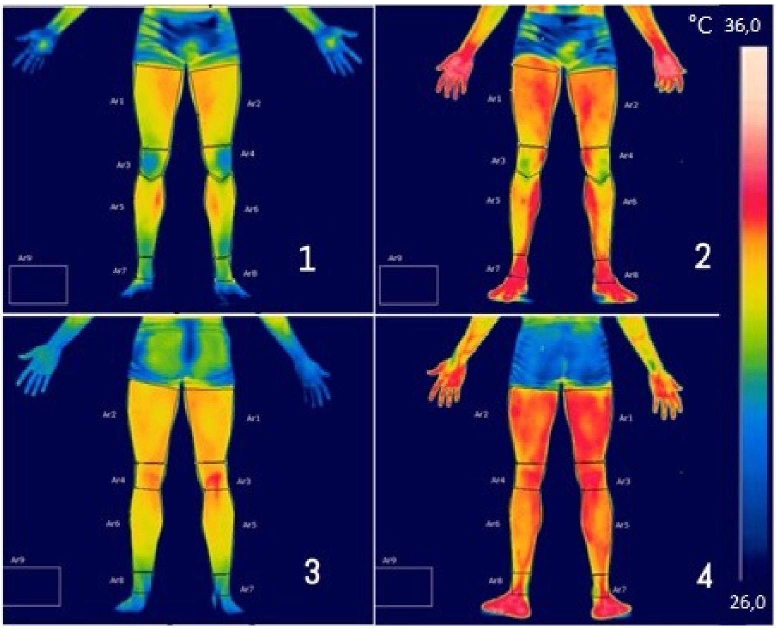

Figure 3. Infrared thermal images. 1: anterior-inferior view obtained pre Cooper's 12-minute run test; 2: anterior-inferior view obtained post-Cooper's 12-minute run test; 3: posterior-inferior view obtained pre Cooper's 12-minute run test; 4: posterior-inferior view obtained post-Cooper's 12-minute run test.

Table 3. Mean±SD of temperature (°C) before and after the Cooper's 12-minute run test in the anterior-inferior and posterior-inferior views.

ROIs	Anterior-inferior view				Posterior-inferior view			
	Pre	Post	P	ES	Pre	Post	p	ES
Right thigh	31.6±0.8	32.1±0.8	0.075	0.62	31.8±0.8	32.2±1.0	0.183	0.43
Left thigh	31.6±0.7	32.1±0.8	0.068	0.66	31.9±0.8	32.2±1.0	0.234	0.32
Right knee	30.5±0.7	31.0±0.9	0.090	0.61	32.0±0.6	32.2±0.8	0.177	0.27
Left knee	30.6±0.6	31.1±0.8	0.048*	0.69	32.0±0.6	32.2±0.7	0.317	0.30
Right leg	31.4±0.5	31.6±0.9	0.634	0.25	31.2±0.7	31.7±0.9	0.099	0.61
Left leg	31.4±0.6	31.4±0.9	0.939	0.01	31.2±0.6	31.7±0.9	0.106	0.62
Right ankle	30.2±1.0	31.3±1.3	0.025*	0.93	29.6±0.9	30.9±1.1	0.015*	1.28
Left Ankle	30.3±1.5	31.2±1.4	0.047*	0.61	29.6±0.9	30.7±1.4	0.022*	0.89

ROIs: Regions of Interest; ES: Effect size; * Significant difference between pre and post Cooper's 12-minute run test.

Discussion

Our study showed that after a short-term maximum effort test, the middle distance runners presented a decrease in the upper limb's Tsk and trunk and an increase in Tsk of the lower limbs. Running increases the repetitive demand in lower limbs together with an increase in physical stress and production of metabolic heat, which explains the temperature elevation in the lower limbs, mainly in the knees and ankles (Merla et al., 2009; Côrte & Hernandez, 2016). Also, increased blood flow in the overloaded muscles increases tissue oxygenation, and therefore a greater variation in skin surface temperature occurs in these areas (Sillero-Quintana et al., 2017).

Another theory that may explain our findings is the physiological process of compensatory vasoregulation, which provides, at the beginning of the exercise, peripheral vasoconstriction of areas with lower physical requirement level and vasodilation for the areas with greater activation (Merla et al., 2009; Johnson, 1992; Neves et al., 2016; Fernandes Amorim, Brito, Sillero-Quintana, & Marins 2016). A significant increase in the Tsk of the lower limbs (especially in the ankles, in the anterior and posterior views) was also verified in the study by Chico, Lozada, and Moralez (2015), who analyzed 25 subjects after a moderate run of 12 minutes.

Regarding the Tsk of the upper limbs and trunk, our results corroborate the study by Merla et al. (2009), who observed a general tendency of Tsk decrease in the upper limbs of athletes after running with a gradual load on a treadmill. It is noteworthy that Merla et al. (2009) evaluated the temperature up to eight minutes post-run; while in our study, the Tsk was taken 15 minutes after finishing the Cooper's run test. This decrease in Tsk may be related to the redirection of blood flow that occurs by the compensatory vasoregulation process (Akimov & Son'Kin, 2011; Sawka, Leon, Montain & Sonna, 2011; Chudecka & Lubkowska, 2012).

In addition, the influence of wind speed, relative air humidity, and temperature during the outdoor run test in our study may have influenced the convection process of the Tsk of the upper limbs, increasing the body's heat exchange with the environment (Kenefick, Cheuvront, & Sawka, 2007). Corroborating with this hypothesis, Tanda (2015) compared running performed in two environments (indoor and outdoor) and verified a greater Tsk decrease when the athletes performed the run in an external environment.

No differences in the thermographic pattern were found between the right and left sides of the body before and after the running test. This may be due to the thermal body homeostasis that controls the temperature variation maintaining the thermal balance between the sides (Charkoudian, 2003).

This study has some limitations, such as the inability to ensure the same ambient temperature during the running test for all volunteers as well as on different days, and the lack of thermographic evaluations after 15 minutes to identify the moment of return to basal temperature. Moreover, the specificity of the test environment to athletes' training and competitions, the control of the thermographic environment, and the padronization of time of day in which the running tests and thermographic evaluations were performed can be considered as strengths of our study.

Conclusion

In conclusion, our data showed that after a short-term maximum effort test, the skin temperature change of runners was symmetrical between sides, decreasing in the upper limbs and trunk and increasing in the lower limbs. Thus, thermographic monitoring was important for perceiving the physiological behavior in relation to temperature after exercise in middle-distance runners.

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