Original article (short paper)

Profile of infrared thermography in elite soccer players

Alex Souto Maior
Universidade Augusto Motta (UNISUAM), Rio de Janeiro, RJ, Brazil.
Centro de excelência em Performance - Clube de Regatas Flamengo, Rio de Janeiro, RJ, Brazil.

Gustavo Leporace
Instituto Brasil de Tecnologias, Rio de Janeiro, RJ, Brazil
Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

Marcio Tannure
Centro de excelência em Performance - Clube de Regatas Flamengo, Rio de Janeiro, RJ, Brazil.

Moacir Marocolo
Universidade Federal de Juiz de Fora, Juiz de Fora, MG, Brazil

Abstract — Aims: The aim of this study was to establish thermographic profiles of lower limbs and to correlate them with creatine kinase level in professional players. **Method**: Thirty healthy male professional soccer players (25.4 ± 4.7 years; 179.5 ± 6.7 cm; 78.3kg ± 7.5 kg; body fat 10.2 ± 4.2 %) from a club of Brazilian first division soccer league volunteered. Thermal images sequences of lower limbs (thighs and legs) were acquired in an anteroposterior manner (i.e., frontal and dorsal views) by a digital infrared thermo-camera. Blood creatine kinase (CK) concentration was assessed by reflectance photometry. All thermographic images and CK were performed between 8:00 and 9:00 am. **Results**: No significant difference ($p>0.05$) was found between left and right sides from both anterior and posterior measurements of thighs and legs for mean or maximal skin temperature. Low values of correlation (range $r=0.14$ to $r=0.38$) was found between skin temperature and CK levels while contralateral thermal symmetry in the lower limbs (regions of interest < 0.2°C) was found. **Conclusion**: It was observed contralateral thermal symmetry in the lower limbs and low correlation between CK and temperature values in elite soccer players.

Keywords: thermal image, creatine kinase, athletes.

Introduction

Soccer is the most popular sport worldwide, with 275 million participants of either sex and of all ages[1]. Either in amateur competitions, professional tournaments or leisure activities, as a form of physical activity, these numbers make this sport probably the biggest phenomenon of all time and one of the most widely played sports in the world[1, 2]. On the other hand, soccer players need technical, tactical and physical skills to succeed. However, many specific conditioning drills vary considerably in the number of players involved, and the specific tactical roles performed by players. Thus, the stress associated with training and competition often temporarily prevents players' physical performance[3].

The substantial physiological demands, training intensity and the body contact between players account for the generally high injury incidence in this sport and 70% of them occur in the lower limbs, even by the nature of sport that requires movement of this body region[1, 4, 5]. The development of new technologies of the diagnoses applied to soccer has allowed better understanding of the physiological responses and injury prevention associated to training load and match intensity. Plasma creatine kinase (CK) monitoring has been used to determine the magnitude of physical stress on the skeletal muscle system[6, 7]. This analysis is correlated with larger the number of muscle micro traumas that lead to the secretion of this enzyme into the extracellular medium and provides information about the physical condition of athletes[7, 8].

In this way, the biochemical analysis and images assessments seem to help in a preventive diagnosis. Infrared thermography (IRT) is a non-invasive method used to visualize human body temperature changes in response to physiological processes or pathological reactions related to the control of the temperature of the skin noninvasively, without exposing the patient to any type of radiation[9-11]. This technique has been used increasingly in medical and sports area and already has applications for the diagnosis of musculoskeletal disorders in the evaluation of muscle recovery after training or football match[11-13].

Thermal symmetry of the human body is similar between the sides of the body which are identical in shape and size, being taken at the same angle. On the other hand, acute injuries lead to vasodilatation and increase of inflammatory mediators in the area, which result in an increase of the metabolism and blood flow in the region, consequently, increase local body temperature and disturb this normal symmetric pattern[14-16]. Thus, differences greater than 0.7°C between contralateral limbs or body areas have been associated with structural or physiological abnormalities in athletes[12, 13]. This way, IRT is now seen as a helpful technology that may help athletes, coaches, physicians and physical therapists in cases of injuries for prevention, early detection and therapy assessment. Thus,

the aim of this study was to provide thermographic profiles of the lower limbs and correlate them with level plasma CK in professional soccer players. Our hypothesis is that the temperature will be higher in the dominate limbs due to greater utilization during training.

Methods

Subjects and anthropometric measurements

The study included 30 healthy male professional soccer players (25.4 ± 4.7 years; 179.5 ± 6.7 cm; 78.3kg ± 7.5 kg; body fat 10.2 ± 4.2 %) from a club of the Brazilian first division soccer league that participates in national and international competitions organized by the Brazilian Soccer Confederation (CBF) and South American Soccer Confederation (CSF). The current training frequency was 6.3 ± 0.7 days/week and the training programs consisted of jumps, ball fights, sprints, accelerations and decelerations. Exclusion criteria included: 1) smoking history during the previous 3 months, 2) presence of any cardiovascular or metabolic disease, 3) systemic hypertension (≥ 140/90 mmHg or use of antihypertensive medication)[17], 4) use of anabolic steroids, drugs or medication with potential impact in physical performance (self-reported), or 5) recent presence of musculoskeletal injury, 6) pain symptoms in any region of the body. The study was approved by the local institutional Ethical Committee for Human Experiments, and was performed in accordance with ethical standards in sport and exercise science research[18]. All data collection was carried out in the beginning of the training season.

Body weight was measured using a calibrated physician's beam scale (model 31, Filizola, São Paulo, Brazil), with the men dressed in shorts. Height was determined without shoes using a stadiometer (model 31, Filizola, São Paulo, Brazil) after a voluntary deep inspiration. Body fat percentage (%) was estimated using the seven-site skinfold procedures[19], and performed twice, in circuit. The mean technical error of measurement for skinfold value was 0.31. All biometric measurements were carried out in a climatized room (22±1 ° C). No clinical problems occurred during the study.

Procedures

Blood CK concentration

Blood creatine kinase (CK) concentration was assessed by reflectance photometry at 37°C using the Reflotron Analyser Plus (Reflotron Plus; Roche, Germany), previously calibrated. After the finger asepsis, by using 70% ethyl alcohol, a lancet device with an automatic trigger was used for puncturing finger and the blood was drained into a strips for specific analysis (heparinized capillary strips). Blood sample (32 µl) was immediately pipetted into a CK test strip which was inserted into the instrument. Absolute values of CK were used for analysis.

Acquisition of the thermographic images

All thermographic images were performed between 8:00 and 9:00 A.M. with an acclimatized room with temperature of 21ºC with a relative humidity of 65%. The acclimation period to evaluate skin temperature was set at 15 minutes. Thermal images sequences of lower limbs (thighs and legs) were acquired in an anteroposterior manner (i.e., frontal and dorsal views) by a digital infrared thermo-camera (Flir Systems Inc®, model T-420, USA) with a measurement range of-20°C to 650°C (accuracy of ± 2°C or 2 %; sensitivity of ≤ 0.05°C), an infrared spectral band from 7.5 to 14 microns, a refresh rate of 60 Hz and an FPA (Focal Plane Array) of 320 x 240 pixels. The distance between the subject and the camera was standardized at 4 m and the index of human skin emissivity was set to 0.95. Analyze of the body regions of interest (ROI) were selected by a drawing rectangular areas by the software (Smartview 3.1 - Fluke®, Everett, USA), which provided us with the average and maximum temperatures from each analyzed ROI[13, 20, 21]. Selection of the ROI utilized 5 cm above the upper border of the patella and groin line for the thigh, and for the leg, 5 cm below the lower border of the patella and 10 cm above the malleolus[13]. Figure 1 shows representative anterior and posterior thermal images from thighs and legs.

Coffee, tea and alcohol intake was prohibited for 4 hours and subjects avoided formal and strenuous exercise for 48 hours before testing. The subject not use physiotherapy before the test (e.g. massage, electrotherapy, ultrasound, heat treatment, cryotherapy, hydrotherapy) and without cosmetics products before the measurements to obtain thermal images most meaningful of skin temperature. All subjects reported the absence of any type of sports injury according to these criteria.

Statistical analysis

The Shapiro-Wilk test was applied to verify the normality of the data. The average and maximum temperature of skin were expressed as median and confidence interval. A histogram of frequency distribution was carried out and grouped into skin temperature range (29.10°C - 33.70°C) from thighs and legs. Wilcoxon test was applied to verify the difference between temperature maximum and means of thighs and legs. The intraclass correlation coefficient (ICC) was used to verify the reliability of skin temperature measures between right and left thighs and legs and the correlation between CK and skin temperature was assessed by Spearman's correlation coefficient. The significance level was set at 0.05 and the software used for data analysis was GraphPad® (Prism 6.0, San Diego, CA, USA).

Results

All correlation values are showed in Table 1. Although significant values were found, r values between CK and lower limb temperature were low (range= 0.14-0.38).

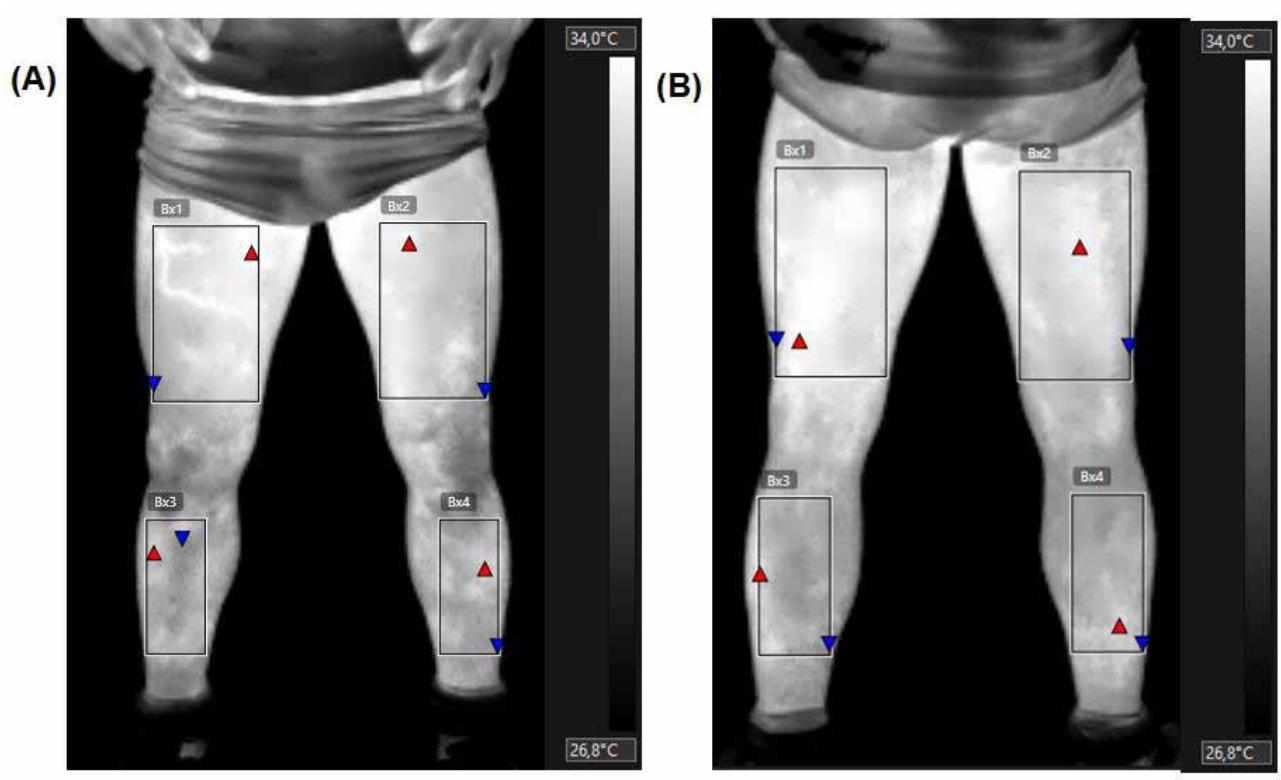

Figure 1. Thermal images anterior (A) and posterior (B) views from thighs and legs.

Table 1. Results of correlations among the variables: skin temperature

Temperature (°C)	CK (U/L-1)	P value
Anterior thigh left	0.19	0.03
Anterior thigh right	0.18	0.03
Posterior thigh left	0.32	0.10
Posterior thigh right	0.26	0.06
Anterior leg left	0.38	0.15
Anterior leg right	0.26	0.06
Posterior leg left	0.24	0.06
Posterior leg right	0.14	0.01

Figure 2 shown histogram of frequency distribution of the averaged skin temperatures in the thigh and leg in anterior and posterior views with temperature range values about 29.0 – 33.0 ° C.

No significance difference was found between left and right sides from both anterior and posterior measurements of thighs and legs for mean (table 2) or maximal (table 3) skin temperature.

Table 2: Maximal values of skin temperature (°C) of thigh and leg soccer players and theirs ICC's

	Right	Left	IC	Right	Left	IC
Anterior	33.14 (0.66)	33.06 (0.65)	0.95	32.56 (0.71)	32.35 (0.65)	0.95
Posterior	32.84 (0.56)	32.92 (0.57)	0.95	32.22 (0.63)	32.23 (0.65)	0.95

Table 3: Mean values of skin temperature (oC) of thigh and leg soccer players and theirs ICC's

	Thigh			Leg		
	Right	**Left**	**IC**	**Right**	**Left**	**IC**
Anterior	31.93 (0.73)	31.82 (0.7)	0.95	31.19 (0.67)	31.02 (0.76)	0.95
Posterior	31.89 (0.73)	31.97 (0.68)	0.95	31.15 (0.68)	31.21 (0.70)	0.98

(regions of interest) and CK.

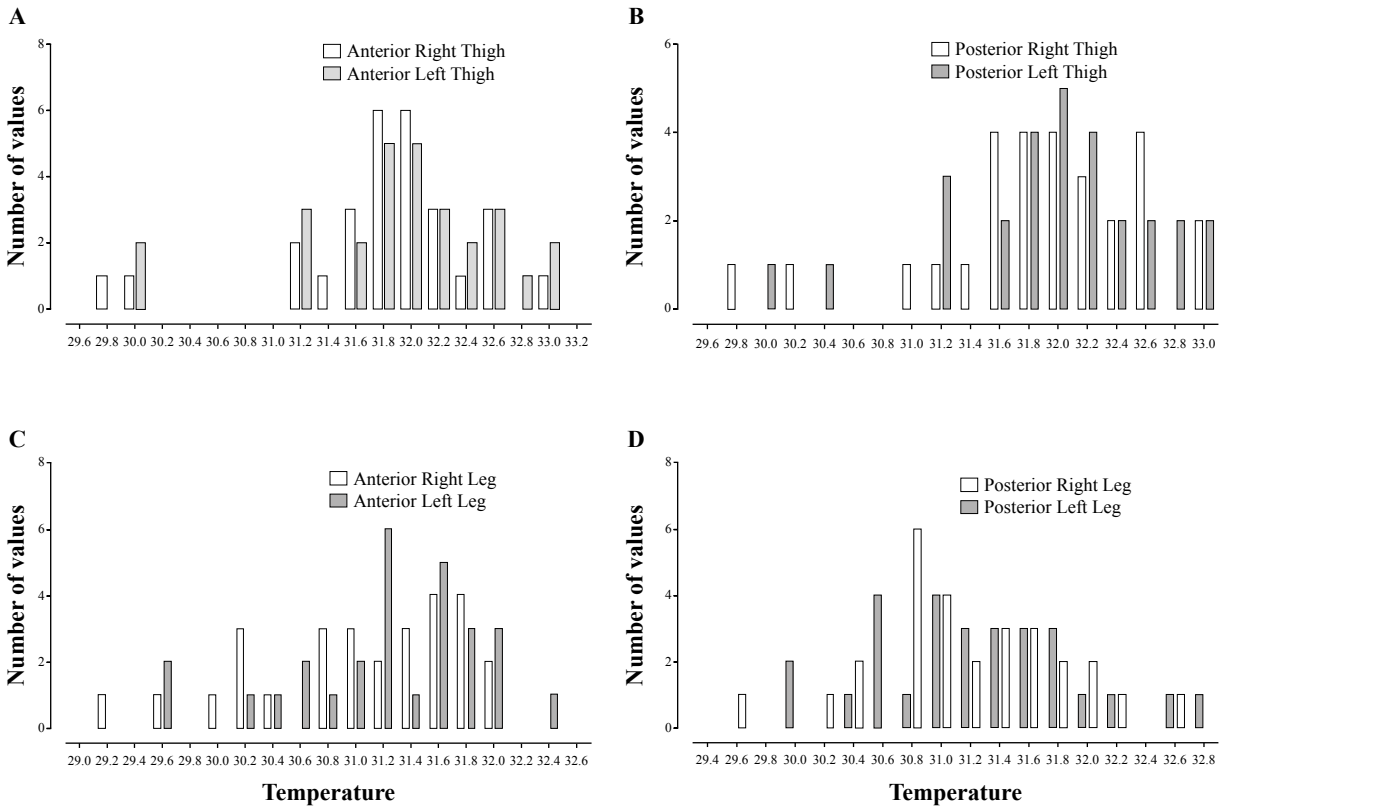

Figure 2. Frequency distribution of the mean values from skin temperature in lower limbs of professional soccer players: A, anterior thigh; B, posterior thigh; C, anterior leg and D, posterior leg.

A high ICC was found for all skin temperature measures (anterior left and right thigh= 0.97; posterior left and right thigh= 0.98; anterior left and right leg= 0.98; posterior left and right leg= 0.96), which suggest high validity and reliability of the measurement method.

Discussion

Few studies evaluated the profile of infrared thermography in lower limbs of the elite soccer players. The results obtained in the present study related no significant difference between sides in lower limbs, which suggests that volunteers had the same homogeneity status. We also did not find a high correlation between CK levels and infrared thermography in lower limbs. Possibly because this variable shows individual characteristics for each athlete[22]. However, the use of infrared thermography and CK plasma level can together determine muscle damage, because only biochemical markers do not show the anatomic location of the muscle injury.

Considering that CK levels increase after exercise or soccer matches[23], applying two methods for muscle activity are more accurate. CK levels increase up to 24h after matches[7], and thermal images could measure muscle activity immediately after exercise. Since the athletes should recover not only for matches but also for training, the response of thermal images analysis could provide a rapid feedback for coaches during training phases.

The training level and intensity of each training session could promote differences in muscle mass level and skin temperature. Some studies concluded that trained subjects have a higher

cutaneous blood flow than others[24, 25]. This response could be related with several physiological changes (e.g., increased muscle metabolism, anaerobic energy reserve, density of capillaries and nerve conduction rate)[26].. Also, age difference could provoke changes in skin temperature in soccer players. A study conducted in soccer players from the U-19 categories (age: 15.5 ± 1.37 years) observed mean values of skin temperature of 30.2ºC in anterior and posterior thigh and 29.6ºC in legs[13]. Thus, comparing mean values of skin temperature between elite soccer players and U-19 categories, a difference of 1.67ºC and 1.5ºC in thighs and legs, respectively could be noted. These skin temperature changes can be related to higher workout intensity, maturation, increase capillary density and morphological changes in muscle tissue by modifying the cross-sectional area of the muscle[1, 27].

The evaluated elite soccer players showed contralateral thermal symmetry the difference between both sides in most players and all the ROI is not greater than 0.2°C. The symmetry obtained indicates that athletes have a normal thermography pattern which does not suggest the presence of injury. Thermal response between two contralateral body parts is expected to be symmetrical and thermal monitoring comparing bilateral body parts that indicate differences surfaces temperature < 0.5°C are deemed negligible[27-29]. However, difference > 0.5°C is considered asymmetry of temperature distribution which may be related with pathological conditions in tissues in non-athletes[12, 27, 29]. On the other hand, values > 0.7ºC are considered asymmetry between contralateral body parts in athletes[12, 13]. When observed difference > 0.7ºC is important verifying if some external factor influenced the result, observe environmental and training conditions and increase the frequency of monitoring. Moreover, differences contralateral > 0.7ºC can contribute to decrease of quadriceps power in 7.9%[30]. Our results showed no difference significant contralateral in lower limbs to maximal (Thigh: 0.08ºC; leg: 0.1ºC) and mean (Thigh: 0.09ºC; leg: 0.1ºC) values of skin temperature. We propose that a ROI below 27°C may be related to a condition of hypothermia caused by reduced local blood flow, whereas a ROI above 35°C could suggest an inflammatory process[13].

A limitation of this type of investigation could be age range, since this parameter could influence skin temperature measurements. However, our sample was quite homogeneous and the sample size was not large enough to provide separate skin temperature profiles.

Conclusion

It was observed contralateral thermal symmetry in the lower limbs (ROI < 0.2°C) and low correlation between creatine kinase and temperature level in elite soccer players after the training sessions.

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Corresponding author

Alex Souto Maior, PhD.
University Augusto Motta, UNISUAM, Master Program in *Rehabilitation Sciences*. Praça das Nações, 34 – Bonsucesso, Rio de Janeiro, RJ, Brasil
Email: alex.bioengenharia@gmail.com

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