Journal of Thermal Biology 69 (2017) 64–68

Contents lists available at ScienceDirect

Journal of Thermal Biology

journal homepage: www.elsevier.com/locate/jtherbio

Monitoring changes in body surface temperature associated with treadmill exercise in dogs by use of infrared methodology

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ARTICLE INFO

Keywords:
Dog
Exercise
Infrared thermography
Infrared thermometry
Body surface temperature

ABSTRACT

The aim of this study was to evaluate the influence of moderate treadmill exercise session on body surface and core temperature in dog measured by means of two infrared instruments. Ten Jack Russell Terrier/Miniature Pinscher mixed-breed dogs were subjected to 15 min of walking, 10 min of trotting and 10 min of gallop. At every step, body surface temperature ($T_{surface}$) was measured on seven regions (neck, shoulder, ribs, flank, back, internal thigh and eye) using two different methods, a digital infrared camera (ThermaCam P25) and a non-contact infrared thermometer (Infrared Thermometer THM010-VT001). Rectal temperature (T_{rectal}) and blood samples were collected before (T0) and after exercise (T3). Blood samples were tested for red blood cell (RBC), hemoglobin concentration (Hb) and hematocrit (Hct). A significant effect of exercise in all body surface regions was found, as measured by both infrared methods. The temperature obtained in the eye and the thigh area were higher with respect to the other studied regions throughout the experimental period ($P < 0.0001$). RBC, Hb, Hct and T_{rectal} values were higher at T3 ($P < 0.05$). Statistically significant higher temperature values measured by infrared thermometer was found in neck, shoulder, ribs, flank, back regions respect to the values obtained by digital infrared camera ($P < 0.0001$). The results obtained in this study showed that both internal and surface temperatures are influenced by physical exercise probably due to muscle activity and changes in blood flow in dogs. Both infrared instruments used in this study have proven to be useful in detecting surface temperature variations of specific body regions, however factors including type and color of animal hair coat must be taken into account in the interpretation of data obtained by thermography methodology.

1. Introduction

The homeothermic animal establishes an equilibrium between heat production and heat loss in order to maintain a constant temperature (Arfuso et al., 2016b). The body produces continuously heat that is dissipated though the surface in several ways (Piccione et al., 2005). It is well established that the body temperature exhibits an endogenous daily cycle (Refinetti and Piccione, 2003). Physical exercise represents stressful stimulation which can lead to homeostasis disruption with direct impact on animal health status and physical performance of the animal (Arfuso et al., 2016a). The evaluation of body temperature represents a valuable tool to monitor the physiologic status, welfare and the stress responses of animals. Exercise induces the conversion of stored chemical energy into mechanical energy and thermal energy; this process is relatively inefficient and about 80% of the energy released from energy stores is lost as heat (Rizzo et al., 2017). The control of heat exchange between body surface and external environment plays a very important role in regulation of body temperature during exercise (Casella et al., 2016). Generally, body surface temperature was estimated by averaging values of the temperature recorded in predetermined regions of interest by means of finite contact temperature probes including resistance thermometers and other types of thermocouples applied to the body surface (Fernandes Ade et al., 2014; Piccione et al., 2013; Matsuo et al., 2006; Eddy et al., 2001). In recent years, infrared thermography has been suggested as useful tool both in the diagnostic field and in physiological assessments (Rossignoli et al., 2015; Redaelli et al., 2014; Ring and Ammer, 2012). In contrast to core temperature measurements through rectal sensors, perceived as invasive and discomfortable for the animals, the infrared methodology represents a non-invasive way of measuring body surface temperature

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http://dx.doi.org/10.1016/j.jtherbio.2017.06.007
Received 30 March 2017; Received in revised form 16 June 2017; Accepted 21 June 2017
Available online 22 June 2017
0306-4565/

changes (Yarnell et al., 2014; Riemer et al., 2016; Salles et al., 2016). Infrared thermography can visualize changes in body surface temperature that result from exercise-induced physiological changes in tissue metabolism and local blood flow (Borba Neves et al., 2016; Yarnell et al., 2014).

In view of such considerations, the present study aimed to evaluate the effect of a moderate treadmill exercise session on body surface and core temperature in dog, and to determine the usefulness of infrared instruments in detecting surface temperature variations of specific body regions in healthy dogs before and after exercise.

2. Materials and methods

Ten healthy Jack Russell Terrier / Miniature Pinscher mixed-breed dogs (3 females and 7 males; 1–4 years; mean body weight 8 ± 1.8 kg) with short coat were enrolled in the study with the informed owner consent. All animals were clinically healthy based on a clinical and laboratory exam. All animals were submitted to treadmill exercise session consisting of walking (15 min), trotting (10 min) and gallop (10 min). The room where the treadmill was housed was enclosed with a large front door that allowed natural light but not strong solar radiation to enter the building. No artificial cooling methods were used on the dogs. Each dog was left in the treadmill room one hour before exercise session to allow for acclimatization. Thermal and hygrometric records were carried out inside the treadmill room throughout the study by means of a data logger (Model Tinytag Ultra 2 Temperature/Relative Humidity Logger, Gemini Data Logger, United Kingdom). Minimum and maximum mean temperature were 20 °C and 22 °C, respectively, and mean relative humidity was 65%. Thermal images of subjects were taken before (at rest, T0) and immediately after each exercise stage, walk (T1), trot (T2) and gallop (T3), using a digital infrared camera (ThermaCam P25 Model, Flir Systems, Boston, MA, USA). Seven specific regions of interest were defined (neck, shoulder, ribs, flank, back, internal thigh and eye) (Fig. 1). Each region of interest of a similar area was selected for all animals and for each time measurement. The eye temperature were measured near the caruncula lacrimalis. Absolute mean temperature of each regions of interest was obtained using thermography software (Thermacam Researcher Basic 2.8 software, FLIR, Wilsonville, Oregon, USA). To reduce the effects of environmental factors on thermographic readings, all images were scanned at the same distance (1 m) from the subject. The settings of the camera were as follows: range of temperature 20–40 °C; emissivity of skin: 0.97; reflected air temperature (Trifl): 20 °C; distance between camera and body surface (Dist): 1 m; and field of view (FOV): 23°. The detector consisted of a focal plane array (FPA) uncoiled microbolometer with the following specifications: 320 × 240 pixels resolution, thermal sensitivity of 0.08 °C (at 30 °C), spatial resolution (IFOV) of 1.3 mrad, spectral range between 7.5 and 13 µm accuracy ± 2 °C. Automatic corrections based on user input were conducted for reflected ambient temperature, distance, relative humidity and atmospheric transmission. At the same time point the body surface temperature ($T_{surface}$) of each regions of interest was measured also with a non-contact infrared thermometer (Infrared Thermometer Model THM010-VT001, Mediaid Inc., Cerritos, CA, USA) with the following specifications: accuracy ± 0.3 °C, range of temperature from 0 °C to 60 °C, thermal sensitivity 0.2 °C. Rectal temperature (T_{rectal}) and venous blood samples were collected immediately before starting the treadmill exercise session (T0) and after the end of the exercise session (T3). Rectal temperature (T_{rectal}), taken as representative of core temperature, was measured by a means of a digital thermometer (HI92704, Hanna Instruments Bedfordshire, UK), inserted approximately 1 cm in the rectum. Blood was collected by cephalic venipuncture into vacuum tubes containing ethylenediaminetetraacetic acid (EDTA) (Terumo Co., Tokyo, Japan) and tested for red blood cell (RBC), hemoglobin concentration (Hb) and hematocrit value (Hct) by means of an automated blood cell counter (HeCo Vet C, SEAC, Florence, Italy) within 1 h from the collection. All treatments, housing and animal care were carried out in accordance with the standards recommended by the EU Directive 2010/63/EU for animal experiments and according to Italian Legislation 26/2014.

Data were tested for normality using the Shapiro-Wilk normality test. All data were normally distributed ($P > 0.05$). A general linear model (GLM) for repeated measures was applied to assess significant effects of exercise and infrared instruments on body surface temperature in each region of interest, as well as the statistically significant change in temperature values among the considered body surface regions. When significant differences were found Bonferroni's post hoc comparison was applied. P values < 0.05 were considered statistically significant. Moreover, a paired *t*-test was used to compare rectal temperature and haematological parameters recorded at rest (T0) and immediately after exercise (T3) conditions. The Person test was performed to assess significant correlations between the T_{rectal} and $T_{surface}$ of each region of interest in exercised dogs. A P value < 0.05 was considered statistically significant. Statistical analysis was performed using the STATISTICA software package (STATISTICA 7, Stat Software Inc.,

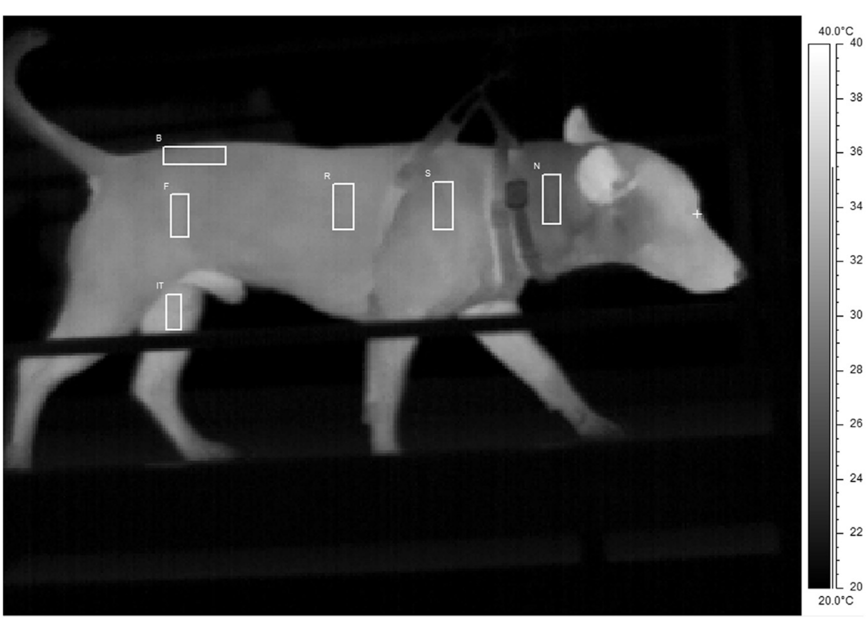

Fig. 1. Representative infrared thermal image with the regions of interest: N, neck; S, shoulder; R, ribs; F, flank; B, back; IT, internal thigh; +, eye (settings at gray-scale for subsequent analysis; brighter colors correspond to higher temperatures as indicated on the bar on the right).