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Thermographic analysis of physiological conditions and after exercise in classic equestrian horses

Análise termográfica das condições fisiológicas e pós-exercício em cavalos de hipismo clássico

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Highlights

Training changes physiological variables and surface temperatures in horses.
Baths similarly reduce physiological variables and surface temperatures.
Rectal temperature remains elevated for longer, even after bathing.

Abstract

Few studies have associated horse skin temperature with the thermal environment, physiology and exercise. This study aimed to use infrared thermography to analyze thermoregulation in horses during training and the efficiency of bathing time in restoring normal physiological conditions. A completely randomized design was used, with 2 treatments and 6 replications. The treatments were different bathing times, after exercise: BE – Before exercise (Control – resting animal); T2 – 2-minute shower, after exercise; T5 – 5-minute shower, after exercise. Six Brazilian Sport (BH) and six Thoroughbred (TB) horses were studied, with average age and weight of 8.5 years and 415 kg respectively, ridden over a classic showjumping course for 50 minutes. The variables were collected from 13h00 to 15h00 over 3 nonconsecutive days, before jump training, prior to bathing (post-training) and after bathing. The environmental variables (wet bulb temperature, black globe temperature, relative air humidity and dry bulb temperature) were determined in the external (track) and internal (bathroom) environments. Thermal comfort indexes were calculated: Temperature and Humidity Index (THI), Black Globe Temperature and Humidity Index (BGHI). Were collected the rectal temperature, respiratory rate and body surface temperature. A significant effect was observed for the rectal temperature, respiratory rate and surface temperature ($P<0.05$) between the pre- and post-training and before and after bathing. Training for around 50 minutes increased respiratory rate as well as rectal and skin temperatures. Bathing times of 2 or 5 minutes promote equivalent reductions in the animals' respiratory rate and skin temperatures, reaching values below those observed before training. The rectal temperature of the animals remained high even after bathing, indicating delayed recovery in relation to the other variables.

Key words: Equine. Physiology. Sport. Thermal imaging. Thermoregulation.

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Resumo

Poucos estudos associaram a temperatura da pele de cavalos ao ambiente térmico, à fisiologia e ao exercício. Este estudo objetivou utilizar a termografia infravermelha para analisar a termorregulação em cavalos durante o treinamento e a eficiência do tempo de banho na restauração das condições fisiológicas normais. Foi utilizado um delineamento inteiramente casualizado, com 2 tratamentos e 6 repetições. Os tratamentos foram diferentes tempos de banho, após o exercício físico: BE – Antes do exercício (Controle – animal em repouso); T2 – 2 minutos de banho, após exercício; T5 – 5 minutos de banho, após exercício. Foram estudados seis cavalos das raças Brasileiro de Hipismo (BH) e seis Puro-sangue inglês (PSI), com idade e peso médios de 8,5 anos e 415 kg respectivamente, montados em um percurso clássico de hipismo com duração de 50 minutos. As variáveis foram coletadas das 13h00 às 15h00 durante 3 dias não consecutivos, antes do treino de salto, antes do banho (pós-treino) e após o banho. As variáveis ambientais (temperatura de bulbo úmido, temperatura de globo negro, umidade relativa do ar e temperatura de bulbo seco) foram determinadas nos ambientes externo (pista) e interno (sala de banho). Foram calculados os índices de conforto térmico: Índice de Temperatura e Umidade (ITU) e Índice de Temperatura de Globo Negro e Umidade (ITGU). Foram coletadas a temperatura retal, frequência respiratória e temperatura da superfície corporal. Foi observado efeito significativo para temperatura retal, frequência respiratória e temperatura superficial (P<0,05) entre os períodos pré e pós-treino e, antes e após o banho. O treinamento por cerca de 50 minutos aumentou as frequências respiratórias, bem como as temperaturas retal e da pele. Tempos de banho de 2 ou 5 minutos promoveram reduções equivalentes na frequência respiratória e na temperatura da pele dos animais, atingindo valores abaixo dos observados antes do treino. A temperatura retal dos animais permaneceu elevada mesmo após o banho, indicando atraso na sua recuperação em relação às demais variáveis.
Palavras-chave: Equinos. Esporte. Fisiologia. Imagens termográficas. Termorregulação.

Introduction

A major aspect of sport horse training and equestrian events is the influence of the thermal environment on the animals' performance, since these outdoor activities involve direct exposure to environmental variables, causing physiological changes and heat stress (McCutcheon & Geor, 2008). In Brazil, with extremely hot and humid climate conditions have detrimental effects on the equine industry by reducing athletic and reproductive performance, increasing the risk of infectious and heat stress–related diseases and injury, and affects equestrian event management (Kang et al., 2023).

How animals respond to thermal discomfort can be understood based on three main factors: recognizing the threat to homeostasis or well-being, the stress response and its consequences (Almeida, 2009). Body heat is produced by metabolism and environmental conditions. In homeotherms, internal temperature is generally maintained within a narrow range (37 to 40ºC) via integrated neurophysiological mechanisms that balance heat production and loss (McCutcheon & Geor, 2008). According to Braz (2005), thermoregulation is performed by a physiological control system consisting of central and peripheral thermoreceptors, afferent pathways, central nerve impulse control and efferent responses, triggering compensatory responses.

Infrared thermography (IRT) is recommended as a useful method in animal welfare research because the temperature of the body or different body parts can be measured quickly, precisely and noninvasively without containing the animal (Paim et al., 2013; Stewart et al., 2005). Figueiredo et al. (2012) used infrared thermography as a complementary diagnostic technique for lameness in horses. The technique is used to assess skin temperature and can check for injuries based on changes in blood flow and temperature, thereby identifying the anatomical region affected (Head & Dyson, 2001; Tunley & Henson, 2004).

According to Stewart et al. (2005), infrared thermography can detect changes in peripheral blood flow, making it a useful tool for assessing thermal discomfort in animals. Thermographic cameras can accurately monitor minute temperature variations (Knížková et al., 2007). As such, this study aimed to apply infrared thermography to analyze thermoregulation in horses during training and the efficiency of bathing time in restoring normal physiological conditions.

Material and Methods

The experiment was conducted at the Equus Ville Equestrian Center, in the city of Anápolis - GO, in May 2018. According to Koppen-Geiger, the region has a climate classification of type Aw - tropical savannah, characterized by two distinct seasons, rainy season (summer) and dry (winter), with an average annual temperature of 22.1°C, average wind speed of 3.7 km h^{-1} and average relative humidity of 66%.

The present study was approved by the Animal Ethics Committee/AEC of the State University of Goiás, under Protocol number 002/2018 on April 23, 2018, and deemed to be in accordance with current ethical principles.

A completely randomized design was used, with 2 treatments and 6 repetitions. The treatments applied were different bathing times, after physical exercise: BE – Before exercise (Control – resting animal); T2 – 2-minute shower, after exercise; T5 – 5-minute shower, after exercise.

Six Brazilian Sport or Showjumper (BH - *Brasileiro de Hipismo* in Portuguese) and six Thoroughbred (TB or PSI) horses, with average age and weight of 8.53 (±0.37) years and 415.5 (±14.02) kg, respectively, were studied, ridden over a classic showjumping course for 50 minutes. The animals had simple and uniform brown or reddish-brown coats, with no white spots. Coat classification was in accordance with Oliveira (2012).

The variables were collected from 13h00 to 15h00 over 3 nonconsecutive days, before jump training, prior to bathing (post-training) and after bathing. The animals were washed at the equestrian center, using a hose and wetting their entire body.

Two micro station data loggers (HOBO ONSET® H21-002), one installed indoors (next to the bathing place) and the other outdoors (on the training arena) measured environmental variables. The device was equipped with three sensors for temperature and humidity, wet bulb temperature and black globe temperature (S-TMB-M002), with accuracy of ± 0.2°C and ±2.5% for temperature and relative humidity (RH), respectively. The micro station was programmed to measure the environmental variables every 15 minutes on the established dates and times.

Heat stress indexes were calculated during the data collection period to characterize the thermal environment, using the following Eq. (1) and (2):

THI – Temperature-humidity index (Thom, 1958):

(1) $$THI = DBT + 0.36.DPT + 41.5$$

Where: DBT = dry bulb temperature (°C); DPT = dew point temperature (°C).

BGHI – Black globe-humidity index (Buffington et al., 1981):

(2) $$BGHI = BGT + 0.36.DPT + 41.5$$

Where: BGT = black globe temperature (°C); DPT = dew point temperature (°C).

Respiratory rate (RR, breaths min^{-1}) was measured by counting the number breaths for 15 seconds, based on air expelled from the nostrils, and multiplying this by 4 to obtain the breaths per minutes. Rectal temperature (RT, °C) was determined using a veterinary thermometer inserted directly into the rectum for approximately one minute. An infrared camera (FLIR-T62101) was used to measure skin temperature (ST). Thermal images (thermograms) were recorded on both sides of the animals at different distances, in accordance with the areas of the body.

A distance of 5 m between the camera and the horse was established for images of the entire body, 0.80 m for the groin and chest, and 0.50 m for the eyes. An emissivity factor of 0.95 was adopted for all the areas analyzed as recommended by (Autio et al., 2006). The thermal images were analyzed using FLIR Tools® software. Skin temperature was calculated considering the average value for three predetermined points of the following body parts: eye, back, croup and groin, as shown in Figure 1.

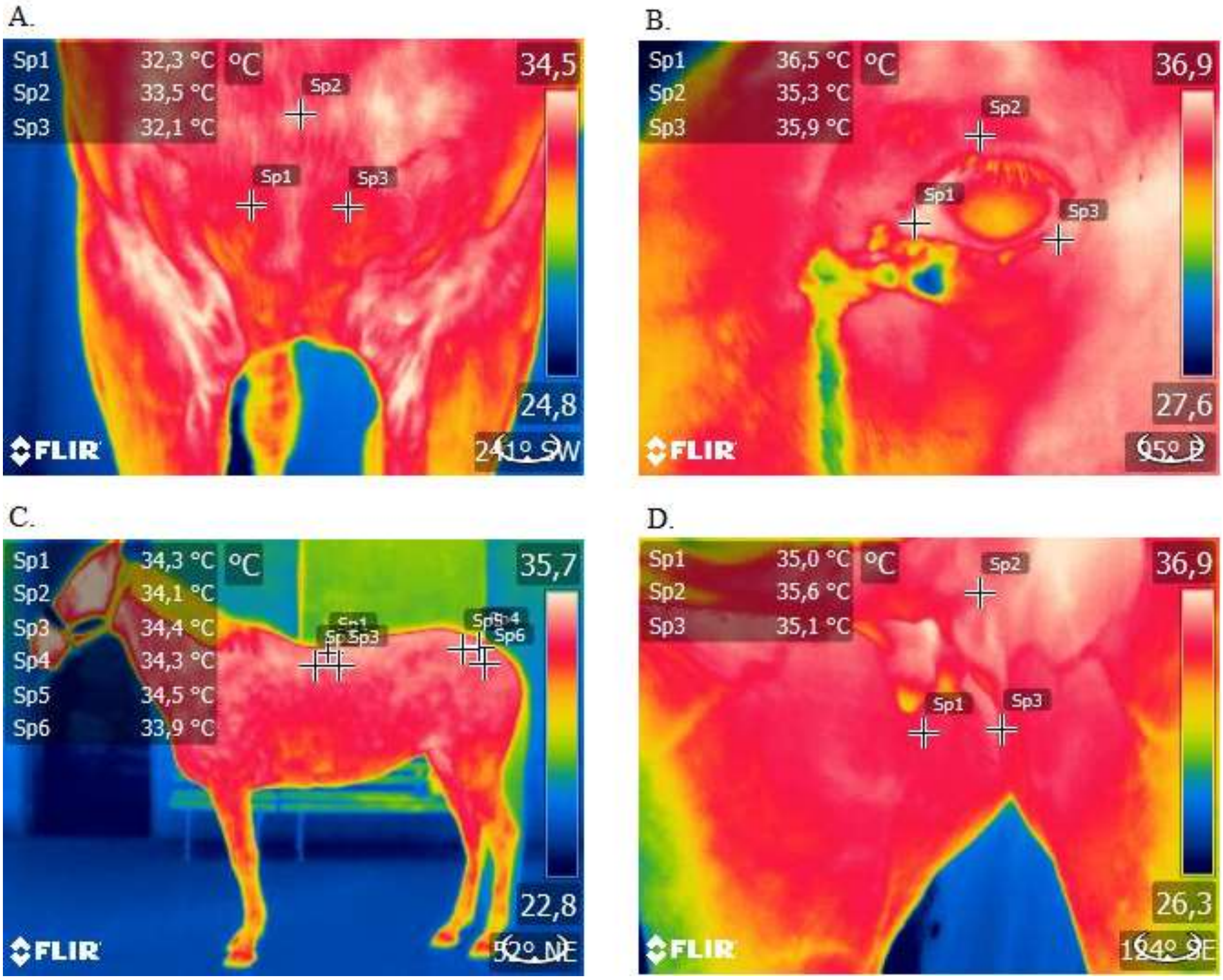

Figure 1. Demonstration of the skin temperature collection points in thermal images of the chest (A), eye (B), back and croup (C), and groin (D).

The homogeneity of the variations was verified by the Cochran test and the normality of the residues by the Shapiro-Wilk test. The data were tabulated and analyzed using SISVAR 5.6 software (Ferreira, 2014), with descriptive analysis and Tukey's test at 5% significance.

Results and Discussion

The environmental characterization carried out during the data collection period is presented in Table 1, referring to the outdoors (on the training arena) and indoors (next to the bathing place) environments. According to Morgan (1998), the air temperature, in the thermoneutrality zone for horses, is between 5 and 25°C, however, this range can be influenced by the relative humidity of the air. In the present study, higher air temperatures (26.8°C) were observed in the track environment, however, the relative humidity values were within those recommended by Silva (2000) as favorable, between 50 and 70%.

Ebisuda et al. (2023), studying Thoroughbred racehorses in exercise, reported that exercise performed at temperatures of 40°C causes an increase in body temperature, decreased running economy and increased cardiac output compared to exercises performed at 20 and 30°C, even at conditions of low relative humidity. In the present study, conditions did not exceed values reported as critical for horses, however differences in rectal temperature and respiratory rate were observed.

Table 1
Averages environmental variables and thermal comfort indexes, on the days and times of data collection, for the outdoors (on the training arena) and indoors (next to the bathing place) environments

Environments	Environmental variables and Indexes					
	Dbt	Wbt	Bgt	RH	THI	BGHI
Indoors	25,95	20,22	26,27	56,58	75,70	74,44
Outdoors	26,84	18,27	28,22	56,54	73,46	74,84

Dbt - Dry bulb temperature (°C), Wbt - Wet bulb temperature (°C), Bgt - Black globe temperature (°C), RH - Relative air humidity (%), THI - Temperature and Humidity Index, BGHI - Black Globe Temperature and Humidity Index.

Statistically significant differences were observed for the rectal temperature and respiratory rate, skin temperatures (ST) of the chest and groin before and after training. There was a significant difference in respiratory rate as well as average skin temperature (AST) and ST in the chest (STC), eye (STE) and groin (STG) areas after training and bathing ($P<0.05$), as show in Table 2. According to McCutcheon and Geor (2008), body heat increases after exercise.

Table 2
Average physiological variable and skin temperature values for the periods assessed, considering a 2-minute bathing time, with the respective coefficients of variation and statistical probabilities at 5% significance

Variable	Pre-training	Post-training	After bathing	CV (%)	F-statistic
RR (breaths min^{-1})	27.11 b	45.78 a	24.89 b	32.51	0.0003
RT (°C)	37.25 b	38.28 a	38.09 a	1.65	0.0025
STB (°C)	33.24 a	33.39 a	30.97 a	6.99	0.0469
STCr (°C)	32.41 a	31.42 a	29.70 a	8.36	0.0922
STC (°C)	33.11 b	35.50 a	31.79 b	4.08	0.0001
STE (°C)	35.11 ab	35.66 a	34.89 b	1.86	0.0477
STG (°C)	35.35 b	36.87 a	33.77 c	2.60	0.0001
AST (°C)	34.41 ab	35.19 a	33.20 b	3.13	0.0012

Means followed by different letters in the rows differ according to Tukey's test at 5% significance. RR: respiratory rate, RT: rectal temperature, STB: skin temperature of the back, STCr: skin temperature of the croup, STC: skin temperature of the chest, STE: skin temperature of the eye, STG: skin temperature of the groin, AST: average skin temperature.

Although the average rectal temperature (RT) recorded after approximately 50 min of training was 1.03ºC higher than that measured before exercising, this is still within the normal range for the species 37.5 to 38.5ºC (Mealey, 2019). None of the horses exceeded 42ºC after training, which is associated with a greater risk of thermal injury and other physiological disturbances.

There was a statistically significant difference in rectal temperature and respiratory rate between pre- and post-training for the 2 min treatment ($P<0.05$) (Table 2), and although RR and RT showed respective declines of 20.89 breaths min^{-1} and 0.2ºC between the post-training and after bathing periods, only respiratory rate was significantly different. However, greater differences in respiratory rate were recorded between these periods, with an increase of 18.7 breaths min^{-1} after training. Ainsworth (2008) reported a normal resting respiratory rate of 12 to 15 breaths per minute, which is lower than the values recorded here, even pre-training. It was reported that a high respiratory rate (>20 breaths min^{-1}) can dissipate 25% of the metabolic heat production of exercising horses (Mejdell et al., 2020).

Skin temperatures in the chest and groin areas were significantly different after exercise, with respective increases of 2.4 and 1.5°C in relation to resting temperatures. Moura et al. (2011), also described a rise in skin temperatures in the same areas after training (1.1°C for both), albeit less marked than those observed in the present study. Despite the increase in back, eye and average skin temperature from pre- to post-training, the difference was not significant.

Pre and post-training skin temperature measurements for the croup showed no statistically significant differences, corroborating the results obtained by Moura et al. (2011), but the values recorded after training were higher. The same authors suggested that the croup is more closely involved in physical thermoregulation mechanisms such as heat transfer via muscle mass than physiological mechanisms such as peripheral vasodilation, which is more easily measured through skin temperature.

Comparison of the post-training and after bathing periods showed significant reductions in skin temperatures after bathing of 1.9, 3.7, 0.8 and 3.1 for average ST and the chest, eye and groin areas, respectively. However, ST values for the chest and croup were not significantly different between these periods, with decreases of 2.4 and 1.7°C, respectively.

All the variables differed from pre-training to after bathing and returned to the resting values recorded before exercise, except for rectal temperature, which declined after bathing, and skin temperature in the groin area, which was 1.6°C lower than pre-training values.

Statistically significant differences were recorded for the rectal temperature and respiratory rate, STC, STG and AST between pre- and post-training ($P<0.05$), and for respiratory rate, STB, STC, STE, STG and AST in the post-training period and after bathing ($P<0.05$).

Statistically significant differences were observed in the 5 min bath treatment (Table 3) for respiratory rate and rectal temperature from pre- to post-training, with respective increases of 28.44 breaths min^{-1} and 1.2ºC. After a 5 min bath, only respiratory rate exhibited a statistically significant difference in relation to post-training, with a decline of 29.78 breaths min^{-1}, whereas rectal temperature displayed a non-significant 0.25ºC decrease.

Table 3
Average physiological variable and skin temperature values for the periods assessed, considering a 5-minute bathing time, with the respective coefficients of variation and statistical probabilities at 5% significance

Variable	Pre-training	Post-training	After bathing	CV (%)	F-statistic
RR (breaths min^{-1})	25.78 b	54.22 a	24.44 b	32.51	0.0001
RT (°C)	37.11 b	38.49 a	38.24 a	1.65	0.0001
STB (°C)	31.38 ab	33.82 a	30.47 b	6.99	0.0083
STCr (°C)	31.02 a	32.21 a	29.74 a	8.36	0.1416
STC (°C)	32.53 b	35.32 a	31.74 b	4.08	0.0001
STE (°C)	35.60 ab	36.24 a	34.91 b	1.86	0.0004
STG (°C)	34.83 b	37.40 a	33.56 c	2.60	0.0001
AST (°C)	33.75 b	35.58 a	33.11 b	3.13	0.0001

Means followed by different letters in the rows differ according to Tukey's test at 5% significance. RR: respiratory rate, RT: rectal temperature, STB: skin temperature of the back, STCr: skin temperature of the croup, STC: skin temperature of the chest, STE: skin temperature of the eye, STG: skin temperature of the groin, AST: average skin temperature.

Skin temperatures rose from pre- to post-training; however, only the chest, groin and average values were statistically different, at 2.79, 2.57 and 1.83, respectively. Comparison of the average values recorded after bathing and in the post-training period showed a reduction in skin temperatures in all the regions analyzed, with only the croup exhibiting a non-statistically significant difference of 2.47ºC. Rectal temperature differed statistically from pre-training to after bathing (1.13°C) and remained higher than that observed before exercise; however, despite not returning to the resting value, this result is within the normal range for horses reported by (Mealey, 2019). Skin temperature in the groin area was statistically significant, declining by 1.27ºC between the periods assessed. The remaining variables were not statistically different, although the average values declined and returned to resting levels.

According to Mealey (2019), skin temperature increases can be attributed to peripheral vasodilation, which is more evident in highly vascularized areas such as the eyes. In the present study, the eye region exhibited a 0.64ºC temperature rise after training when compared to pre-training since the area is rich in blood vessels innervated by the sympathetic nervous system that respond to changes in blood flow (Vieira et al., 2017).

Conclusion

Show jumping training for approximately 50 min alters breathing rate, rectal and skin temperature in horses. Bathing times of 2 or 5 min promoted equal reductions in equine respiratory rate and skin temperatures, often below those reported during training.

Rectal temperature remained high even after bathing, indicating delayed recovery for this variable in relation to respiratory rate and skin temperature.

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