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ABSTRACT

Purpose:
The application of infrared thermography (IRT) to assess the effects of athletic training is increasing. It is not known if changes in skin temperature (Tsk) as assessed by IRT are affected by the training load or muscle soreness experienced by the athlete. The aim of the present case study was to describe the variations in Tsk in body areas affected by running training and examine any relationships with subjective ratings of muscle soreness. A secondary aim was to assess the feasibility of using IRT for assessing training load in 2 junior middle-distance athletes.

Methods:
Data were collected over a 42-d period with Tsk of the quadriceps, knees, shins, lateral hamstrings, biceps femoris' and Achilles tendons and subjective ratings of muscle soreness taken each morning prior to any training. All training load was quantified via heart rate, running speed and distance. Changes in Tsk outside the typical error (TE) were identified. Relationships between Tsk and subjective ratings of muscle soreness were also examined.

Results
Over the 42-d observational period mean Tsk of the regions of interest were reported outside the TE on 31-d and 22-d for athletes 1 and 2 respectively. These changes in Tsk did not follow similar trends to training loadings. No significant relationships were observed between Tsk of any regions of interest and muscle soreness

Conclusions:
Whilst Tsk changed outside the TE throughout the 42-d observational period these changes were not reflective of training load quantified via cardiovascular strain nor subjective ratings of muscle soreness.

KEY WORDS

Thermography, training monitoring, thermal, screening, injury, infrared

INTRODUCTION

Infrared thermography (IRT) detects infrared light emitted by the body to visualize changes in body heat due to abnormalities in the surface blood flow. Human skin, with an emissivity of 0.98, is almost equal to a black body radiator [1] and therefore, thermal images can be used to assess thermal properties of the body. IRT is a tool that visualizes physiological changes in the underlining tissues. Historically, IRT has been utilized in the field of veterinary medicine to detect locomotion injuries in racehorses and to monitor their health status [2].

Due to the development of portable cameras IRT could be used to assess the effects of training and identify soft tissue and tendon injuries in athletes [3]. IRT has been shown to be valid for assessing skin temperature (Tsk) [4], and has been recommended for clinical use [3]. Previous work has suggested that IRT can be used to assess acute responses to exercise paradigms [5–7]. IRT can be used to describe the temporal characteristics of delayed onset of muscle soreness (DOMS) [8]. Recent work has investigated the acute responses and short term recovery time course of Tsk to exercise [8] and abnormal thermal patterns have been used to identify inflammatory responses in muscles and ligaments [9]. It is logical that Tsk may be reflective of physical responses which contribute to training induced muscle soreness. It is may be suggested that IRT could be applied to monitoring training stress in athletes. However, it is presently unknown if the Tsk of the regions of interest (ROIs) involved during exercise relates to the imposed training load.

The aim of the present case study was to describe the variations in Tsk in target body areas affected by running training and examine any relationships with subjective ratings of muscle soreness.

METHODS

Data collection was conducted over 42-d in 2 junior male middle distance athletes (Athlete 1. 18 years, stature 178.4 cm, body mass 71.8 kg, ∑7 skinfolds 43.7 mm, $\dot{V}O_{2max}$ 67.3 $ml·kg·min^{-1}$, 800 m personal best (PB) 01:53.01 mm:ss.0, 1500 m PB 04:00.03; Athlete 2. 16 years, stature 176.4 cm, body mass 63.2 kg, ∑7 skinfolds 36.8 mm, $\dot{V}O_{2max}$ 63.7 $ml·kg·min^{-1}$, 800 m PB 01:56.21 mm:ss.0, 1500 m PB 04:02.18). All data were collected as a part of routine sport science support provided to the athlete group, which all athletes/parents had consented to. The study was part of a larger study on the effects of training on young athletes approved by the local ethics committee.

Each morning between 0630 h and 0830 h prior to any physical activity participants were acclimated for 5 min in a temperature-controlled environment in order to achieve thermal balance with their surroundings wearing only shorts. Mean temperature of the controlled environment across the 42-d experimental period was 24.3 ± 1.2 °C and 43.4 ± 2.7 % relative humidity, environmental conditions were measured and quantified using a Kestrel 4400 Heat Stress Monitor (Kestrel Meters, MN, USA). During this time participants also gave a subjective rating of general muscle soreness as part of a holistic well-being questionnaire administered via a tablet. Muscle soreness was rated on a visual analogue scale of 1 – 10, 10 being the worst muscle soreness they had ever experienced and 1 being no soreness whatsoever.

Following the acclimation period an image or “thermogram” was taken of participant’s front and rear legs (Figure 1) using a FLIR T600 infrared camera (FLIR Systems, Oregon, USA). Mean Tsk of the right and left quadriceps, knees, shins, lateral hamstrings, biceps femoris’, calves and Achilles tendons were subsequent quantified. On all occasions the camera was positioned 1.5 m from the participant at the same height each day. When temperature readings were stable 1 image was taken and used for analysis, pilot testing indicated 1 stable reading displayed levels good reliability (ICC = 0.94, $r = 0.91$).

Figure 1 about here.

The training content was prescribed by the group's Head Coach. Throughout training sessions participant's heart rate (HR) was recorded using Polar RS800CX monitors (Polar Electro, Kempele, Finland) for the purposes of quantifying training load using the Edwards approach [10]. Briefly, the TRIMP score was calculated by multiplying the accumulated training duration spent in each intensity domain by an intensity-weighted multiplier. One-minute in the first intensity domain (50 – 59% max heart rate (HRmax)) is given a score of 1, 1-minute in the second intensity domain (60 – 69% HRmax) is given a score of 2, 1 minute in the third intensity domain (70 – 79% HRmax) is given a score of 3, 1 minute in the fourth intensity domain (80 – 89% HRmax) is given a score of 4 and 1 minute in the fifth intensity domain (≥90 HRmax) is given a score of 5. Distances and velocities were also quantified via Polar RS800CX global positioning satellite (GPS) systems (Polar Electro, Kempele, Finland), all training took place outdoors and time of training differed depending on the coach's plan or environmental conditions. Mean environmental conditions at the times of day the athletes trained over the 42-d period were 28.2 ± 2.8 °C and 43.0 ± 11.4 %.

Statistical analysis

The alpha level of 0.05 was set prior to data analysis. Statistical analyses were conducted using SPSS Statistics version 20 (IBM, Chicago, IL). Pearson's correlation (r) analysis evaluated relationships between the Tsk and ratings of muscle soreness. Typical error (TE) for the measurement of the Tsk of all ROIs were calculated using pilot data collected over 7 d prior to the observational period (mean TE of all regions for both athletes = 0.5ºC). Student's *t*-tests for paired samples assessed any asymmetries between the right and left legs.

RESULTS

Details of training performed over the 42-d observational period are presented in Table 1. No asymmetries between right and left limbs were observed for any ROIs. It was deemed appropriate to use mean data (right and left limb) for further analysis.

Table 1 about here

Tsk of all ROIs changed outside the TE over the 42-d observational period. Mean Tsk of all ROIs were reported outside the TE on 31-d and 22-d for athletes 1 and 2 respectively. These changes in Tsk did not follow similar trends to training loadings nor correlate with subjective rating of muscle soreness (Figure 2).

Figure 2 about here

DISCUSSION

This case study presented changes in Tsk of the lower limbs in response to longitudinal training in 2 junior middle-distance athletes. Mean Tsk of the regions of interest were reported outside the TE on numerous occasions, this indicates that Tsk of the trained musculature appears to be affected by the training stimulus, although these changes did not follow a similar trend to training load quantified by the Edwards approach. Furthermore, no significant relationships were observed between subjective ratings of muscle soreness and Tsk of any ROIs.

It is possible that the lack of relationships between muscle soreness and Tsk are attributable to the manner in which soreness data were collected. Soreness data were collected as part of holistic well-being questionnaire with the single soreness metric incorporating all muscle groups. The soreness measure employed provided a measure of general muscle soreness rather than a specific descriptor of which muscle groups were experiencing soreness. It is likely that this measure was not sensitive enough to detect subtle changes in soreness of the individual trained musculature. Previous work has reported relationships between Tsk and DOMS [8]. Unlike the present study participants were asked about muscle soreness in the muscle group trained (this being the biceps brachii), this was also the muscle from which Tsk was recorded. It is advisable to assess perceived soreness in the same ROIs as the IRT measurements to assess how specific body parts are affected by training. Additionally, here training load was quantified via cardiovascular rather than mechanical strain. It is reasonable to suggest that if training load was reflective of muscular or mechanical strain relationships between Tsk and load may have been observed.

Athletes trained in the AM, PM or both. As recordings were conducted each morning prior to any training (0630 h - 0830 h) if on the previous day only an AM session was performed there was a ˜21.5 h period between the cessation of training and the thermogram being taken. If a PM session was performed there was a ˜15.5 h between the cessation of training and the thermogram being recorded. Much of the previous work pertaining to IRT in exercise paradigms has investigated the acute effects of various exercise modalities on the Tsk response. Furthermore, this is the only study to track changes in Tsk in response to training over a longitudinal period.

PRACTICAL APPLICATIONS

Data presented here do not support the application of IRT as a monitoring tool in junior middle distance athletes.

CONCLUSIONS

This case study analysed Tsk assessed via IRT in response to longitudinal and real world training that is conducted in athletic populations. It is possible that in laboratories IRT can provide a useable measure to quantify the effects of training loads on Tsk and muscle loading. Further, and larger scale work is needed to analyse the application of IRT in athletic paradigms.

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CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

FIGURE LEGENDS

Figure 1. Thermogram and regions of interest.

Figure 2. Edwards training load (Athlete 1 Panel A; Athlete 2 Panel B), muscle soreness (Athlete 1 Panel C; Athlete 2 Panel D) and mean skin temperature of all regions of interest. Shaded grey area represents the mean typical error of the skin temperature measurements.

TABLES

Table 1. Summary of middle-distance training performed over the 42-d observational period. Data are reported as athlete total and mean ± SD per athlete.

	Sum		**Average per session**	
	Athlete 1	Athlete 2	Athlete 1	Athlete 2
Training time (h:mm:ss)	36:33:48	32:42:49	0:52:14 ± 0:24:14	0:45:18 ± 0:35:08
Distance covered (km)	382.2	351.5	10.2 ± 2.3	8.3 ± 2.5
Edwards TRIMP (AU)	6532	5901	165 ± 41	139 ± 48

AU = arbitrary units, Edwards TRIMP = Edwards training impulse, Training time = time in session spent above 50% max heart ra