

Effectiveness of infrared tympanic thermometry during physical activity in the heat at a solar radiation of 500 W/m² or less

Exposure to high solar radiation in the heat poses a thermoregulatory challenge and increased risks of exertional heat-related illness in workers and exercising individuals. Core temperature monitoring is important during physical activity in the heat to prevent extreme levels of hyperthermia and exertional heat-related illness. In laboratory settings, rectal or esophageal temperatures are generally employed to measure core temperature responses. However, these methods are difficult to use due to safety and convenience concerns in outdoor settings. Although infrared tympanic thermometry is known to be a convenient method that quickly, safely and non-invasively assesses core temperature, the use of this thermometry to determine core temperature has been controversial during physical activity in the heat. This is because previous studies reported that infrared tympanic thermometry is likely to be influenced by environmental conditions in heat stress conditions. Nevertheless, no research has evaluated whether variations in solar radiation affect the effectiveness of core temperature monitoring using infrared tympanic thermometry during physical activity in the heat. Therefore, we examined the effects of various simulated solar radiation levels on infrared tympanic thermometry during exercise-heat stress.

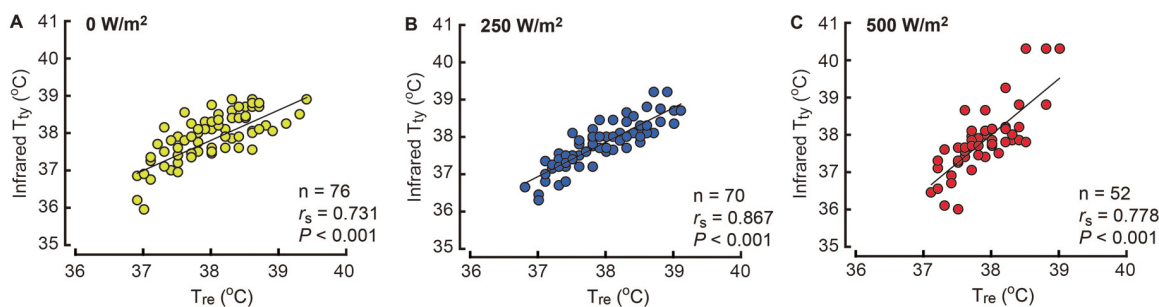


Fig. 1. Linear correlation plot between infrared tympanic temperature (Infrared T_{ty}) and rectal temperature (T_{re}) at each time point in 0 W/m² (A), 250 W/m² (B) and 500 W/m² (C) trials. r_s is Spearman's rank correlation coefficient.

Eight healthy male participants completed three cycle exercise trials at 70% peak oxygen uptake until exhaustion in a climatic chamber maintained at 30°C, 50% relative humidity and <0.3 m/s air velocity. Participants were tested under three solar radiation conditions in randomized order: 0, 250 and 500 W/m². Solar radiation intensity is based on reports that global solar radiation on the Earth's surface is about 250

W/m² under thick clouds and 500 W/m² under thin clouds. Metal halide lamps (67 × 360 Watts) were used as a ceiling-mounted solar simulator, covering a 3 m × 2 m irradiated area.

Infrared tympanic thermometry measurements in all experimental trials were taken by a single operator using an infrared tympanic thermometer. Prior to the measurements, the operator removed participants' earwax and confirmed their tympanic membrane using an otoscope. The positioning of the lens in the infrared tympanic thermometer was made towards the lower anterior quarter of the tympanic membrane. Infrared tympanic temperature was obtained using a standardised technique, including an ear tug on the pinna to straighten the external auditory canal. Two consecutive readings were obtained in each measurement with the mean values used for analysis. Rectal temperature was also measured using a rectal thermistor inserted 10 cm beyond the anal sphincter.

Infrared tympanic and rectal temperatures were similar before and during exercise in each trial ($P > 0.05$). Spearman's rank correlation coefficient (r_s) demonstrated very strong (250 W/m² $r_s = 0.87$) and strong (0 W/m² $r_s = 0.73$; 500 W/m² $r_s = 0.78$) correlations between infrared tympanic and rectal temperatures in all trials ($P < 0.001$) (Fig. 1). A Bland-Altman plot showed that mean differences (standard deviation; 95% limits of agreement; root mean square error) between infrared tympanic and rectal temperatures were -0.11°C (0.46; -1.00°C to 0.78°C ; $0.43 \pm 0.16^\circ\text{C}$) in 0 W/m², -0.13°C (0.32; -0.77°C to 0.50°C ; $0.32 \pm 0.10^\circ\text{C}$) in 250 W/m² and -0.03°C (0.60; -1.21°C to 1.14°C ; $0.46 \pm 0.27^\circ\text{C}$) in 500 W/m² (Fig. 2). A positive correlation was found in 500 W/m² ($r_s = 0.51$; $P < 0.001$) but not in 250 W/m² ($r_s = 0.04$; $P = 0.762$) and 0 W/m² ($r_s = 0.04$; $P = 0.732$), indicating a greater elevation in infrared tympanic temperature than rectal temperature in 500 W/m² (Fig. 2C).

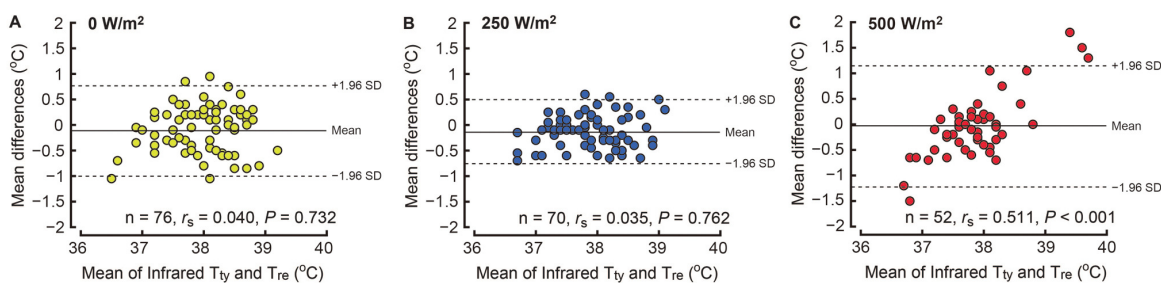


Fig. 2. Bland-Altman plot of difference in temperature (Mean differences; infrared tympanic temperature [Infrared T_{ty}] minus rectal temperature [T_{re}]) against the mean of both temperatures (Mean of Infrared T_{ty} and T_{re}) in 0 W/m² (A), 250 W/m² (B) and 500 W/m² (C) trials. r_s is Spearman's rank correlation coefficient.

In conclusion, we observed a greater elevation in infrared tympanic temperature than rectal temperature during exercise-heat stress under 500 W/m² condition. However, no differences in infrared tympanic and rectal temperatures were shown at any time point of the exercise trials and strong correlations between the temperature responses were observed in all conditions (0, 250 and 500 W/m²). The current study therefore indicates that infrared tympanic thermometry is acceptable for core temperature monitoring in workers and exercising individuals during physical activity in the heat when solar radiation is not greater than 500 W/m².

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