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The relationship between radiant heat, air temperature and thermal comfort at rest and exercise

Julien Guéritée [a,*], Michael J. Tipton [b]

[a] University of Portsmouth, Department of Sport and Exercise Science, Portsmouth, UK
[b] University of Portsmouth, Department of Sport and Exercise Science, Spinnaker Building, Cambridge Rd, Portsmouth, UK

HIGHLIGHTS

• The radiant heat required for thermal comfort correlates with the air velocity.
• Thermal comfort is maintained despite dropping mean skin and body temperatures.
• The allowance to adjust the thermal environment increases cold discomfort tolerance.

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ABSTRACT

The aims of the present work were to investigate the relationships between radiant heat load, air velocity and body temperatures with or without coincidental exercise to determine the physiological mechanisms that drive thermal comfort and thermoregulatory behaviour. Seven male volunteers wearing swimming trunks in 18 °C, 22 °C or 26 °C air were exposed to increasing air velocities up to 3 m s^{-1} and self-adjusted the intensity of the direct radiant heat received on the front of the body to just maintain overall thermal comfort, at rest or when cycling (60 W, 60 rpm). During the 30 min of the experiments, skin and rectal temperatures were continuously recorded. We hypothesized that mean body temperature should be maintained stable and the intensity of the radiant heat and the mean skin temperatures would be lower when cycling. In all conditions, mean body temperature was lower when facing winds of 3 m s^{-1} than during the first 5 min, without wind. When facing winds, in all but the 26 °C air, the radiant heat was statistically higher at rest than when exercising. In 26 °C air mean skin temperature was lower at rest than when exercising. No other significant difference was observed. In all air temperatures, high correlation coefficients were observed between the air velocity and the radiant heat load. Other factors that we did not measure may have contributed to the constant overall thermal comfort status despite dropping mean skin and body temperatures. It is suggested that the allowance to behaviourally adjust the thermal environment increases the tolerance of cold discomfort.

1. Introduction

The thermal environment consists of a combination of air temperature, air velocity, relative humidity and radiation. These parameters influence skin temperature through conductive, convective, evaporative and radiant routes of heat exchange. Under normal circumstances, humans will respond to cutaneous thermal sensations by adjusting their behaviour in order to maintain an overall thermally comfortable state, reflecting satisfaction with the thermal environment [1]. Adding or removing clothing layers, changing body position, or adjusting the heating system in a room conserves the resources (fluid, substrate) used by the autonomic responses when maintaining deep body temperature within its narrow range [2].

The conscious, subjective behavioural responses of humans to the thermal environment have been investigated by allowing volunteers to self-adjust the temperature of a liquid conditioning garment (and hence their skin temperature), at rest or when exercising in cold air [3]. It was shown that such adjustments related to changes in mean body temperature, as the rise in deep body temperature was counteracted by drops in skin temperature such that mean body temperature remained stable. Previous work revealed that thermoregulatory behaviour was driven by both deep body and skin temperatures [4,5]. As skin and deep body temperatures equally contribute to thermal comfort [6], in situations where deep body temperature remains stable, thermal comfort (and thermoregulatory behaviour) should be determined by skin temperatures. In support of this, in a recent study the decision to move between a warm and cool place was initiated before deep body

* Corresponding author at: 43 avenue de Lissardy–Zuhaizti 2–Haritza–Appt 09, 64700 Hendaye, France. Tel.: +33 6 78 67 14 93.
E-mail address: julien.gueritee@gmail.com (J. Guéritée).

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temperature was affected [7]. At rest, the cutaneous thermoreceptors may thus provide the primary input for thermoregulatory behaviour.

Amongst the main parameters defining the thermal environment, wind speed has been reported to be a better predictor of behavioural adjustments to the environment than ambient temperature [8]. However, in this study, skin temperatures were not recorded and therefore their impact on the thermoregulatory behaviour could not be estimated. Other investigations observed a linear relationship between thermal sensations and the intensity of simulated solar radiation [9]. Nevertheless, the authors did not consider air velocity. It is also important to note that in both studies, participants had no control over their thermal environment.

Although their work was conducted without wind or direct radiant heat, and in a very cold air temperature (−20 °C), Flouris and Cheung [3] demonstrated an accurate and objective way of collecting data on behavioural thermoregulation: if people are given some control over the environment in order to maintain their overall thermal comfort, they should provide relevant information regarding the satisfactory thermal profile (absolute and rate of change of body temperatures) required for that particular state of mind.

The present study investigated the previously unexplored relationship between radiant heat load and air velocity with and without coincidental exercise to try to determine the physiological mechanisms that drive thermal comfort and, thus, thermoregulatory behaviour in such situations.

If, in agreement with earlier findings [3], mean body temperature is the adjusted parameter in our study, we hypothesized that mean body temperature should be maintained relatively stable and the intensity of the radiant heat and the mean skin temperatures would be lower in the exercising conditions.

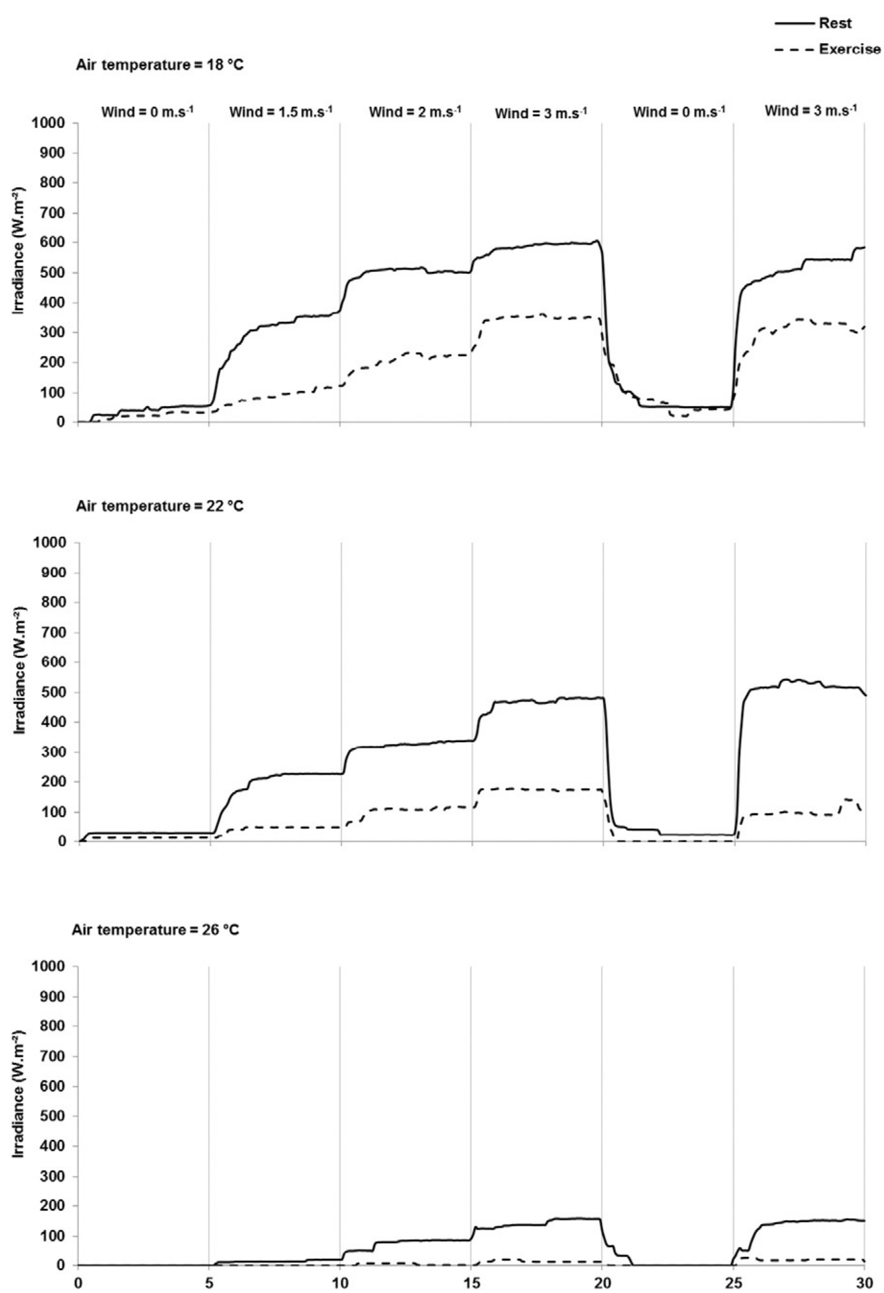

Fig. 1. Mean irradiance required to maintain overall thermal comfort in swimming trunks, at rest or when exercising in three air temperatures when facing different air velocities ($n = 7$).