Topic A7: Thermal comfort

SUBJECTIVE PERCEPTION AND THEROREGULATION IN RESPONSE TO SOLAR RADIATION AND THERMAL TRANSIENT DEVELOPED FROM LOSS OF SOLAR RADIANT HEAT

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INTRODUCTION

The solar radiant heat (SRH) presents an increasing risk of thermal stress to people who remain outdoors daily for routines or job functions, as the metabolic heat accumulating in the body due to excess solar exposure poses a threat of overwhelming the thermoregulation. Among the affected populations, those who live and/or work in the urban areas are of a particular concern—the thermal transient developed between the entrance of an air-conditioned building and the ambient environment often increases the potential thermal stress imposed on human body when people enter or leave the building (Chen et al., 2011). The risk from exposure to SRH is exacerbated in the thermal transient, because people may experience thermoregulatory shocks if the instantaneous change in the metabolic heat load in response to the loss of SRH exceeds the body's capacity to compensate and acclimatize.

Through a series of experiments conducted in dual microclimatic chambers simulating different combinations of solar radiation and environmental temperature (temp), this study investigated the physiological responses of human body in metabolic heat dissipation when the body was confronted with a thermal environment of either a steady state or a transient state developed from a drop in environmental temp following the loss of SRH. The goal was to facilitate a better understanding on the thermal stress that people might sustain as a result of experiencing the SRH and then a thermal transient that immediately followed.

METHODOLOGIES

In the study, the experiments were conducted in twin climatic chambers that each could be individually controlled for environmental variables, including the air temp, relative humidity (RH), air velocity (V_{air}), and radiant heat. The chambers allowed for adjustment of the air temp, RH, and V_{air} in the range of 18-40^{o}C (±0.5^{o}C), 40-90% (±5%), and 0-1m/s, respectively. The twin chambers were used to create two distinct zones of thermal status, one representing the ambient environment with SRH (hereafter referred to as the "outdoor chamber") and the other the thermal transient developed inside an air-conditioned building due to loss of SRH ("indoor chamber"). In the outdoor chamber the SRH varied and was measured as the globe temp (T_g), whereas in the indoor chamber the air temp and RH were kept constant (T_g and RH were set at 24^{o}C and 60%, respectively). The outdoor chamber has a dimension of 4.1 m (length) × 3.6 m (width) × 2.6 m (height) and the indoor chamber a dimension of 4.1 m (length) × 2.6 m (width) × 2.6 m (height). A total of 20 subjects were recruited to participate in the study, including 10 males and 10 females. The subjects were all undergraduate or graduate students of an age between 18 to 22 years old. The effect of SRH exposure was monitored in the outdoor chamber, while that of a temp step due to the loss of SRH was evaluated in the indoor chamber after the participants entered from the outdoor chamber. The SRH simulated in the outdoor chamber was equivalent to an increase in T_g of 4^{o}C (adding to an initial dry-bulb temp of 24 and 28^{o}C). At pre-determined intervals, the participants were assessed for change in their thermal sensation and physiological quantities. The physiological indicators monitored in the study were those of core metabolism and of skin physiology involved in the dissipation of metabolic heat. The core indicators consisted of metabolic rate and core (ear) temp, while the dermal indicators included skin capillary blood flow (SCBF), skin moisture, transepidermal water loss (TEWL), and skin temp. The metabolic rate was measured using the Bodymedia SenseWear® body monitoring system (Bodymedia, Pittsburgh, PA, USA). The skin moisture, TEWL, and skin temp were measured using the Cortex® DermaLab System (Cortex Technology, Hadsund, Denmark) equipped with a TEWL probe (for TEWL measurement) and a flat-head moisture probe (skin moisture). The Moor VMS-LDF tissue blood flow monitor (Moor Instruments, Devon, UK) was used in measuring the SCBF. The subjective thermal sensation and thermal comfort were ranked on a 5- and 7-point voting scale, respectively, using a standardized questionnaire. The results were analyzed for the effect of SRH exposure to metabolic heat load/thermoregulation and the course of acclimation in the thermal transient.

RESULTS AND DISCUSSION

As the results show, the metabolic load and thermoregulation occurring among the participants in response to SRH exposure were greater and required a longer period to acclimatize compared to those resulting from exposure to an environment of the same air temp but without the SRH. This finding suggested that under the same level of heat challenge the SRH likely elicited a greater response in thermoregulation than the air temp-based heat did. However further investigations would be necessary to explore the cause(s) contributing to the difference observed in thermoregulation between the group challenged by SRH vs. the group not challenged.

Under the different exposure scenarios investigated, the physiological change in response to heat exposure was particularly pronounced in males, as manifested in the alteration of skin moisture and TEWL, when the participants were thermally challenged at a T_g of 32^{o}C, with or without the SRH exposure (Figure 1). As the skin moisture and TEWL represented the intermediate stages of thermoregulation leading to an ultimate heat exchange between the human body and the environment (Chen et al., 2011), this observation suggested a greater metabolic demand among the males than its counterpart among the females that would require a more aggressive thermoregulation in order to gain thermal balance. When entering the thermal transient developing from the loss of SRH, the SCBF and skin temp took a longer period to re-equilibrate with the ambient environment, compared to those required when the transient arose entirely as a result of a change in the air temp. This observation suggested a potential residual effect of the SRH in prolonging the thermoregulatory activities corresponding to a thermal transient (Figure 2). The thermal comfort of the participants was less correlated with the thermal sensation when the SRH was present than when the SRH was not (Figure 3), suggesting that the perception of thermal comfort was subject to the influence from factors other than those of a meteorological origin, e.g., possibly the subjective aversion of the participants toward sun exposure.

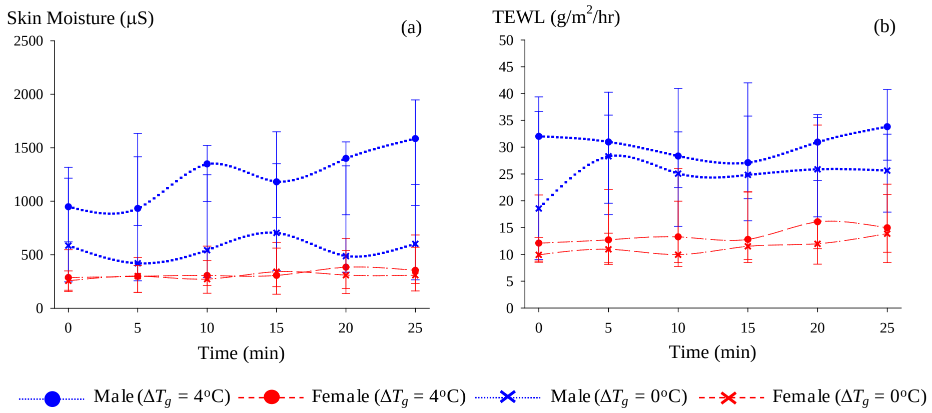

Figure 1. Alteration in (a) skin moisture and (b) transepidermal water loss (TEWL) in male and female study participants in response to heat exposure at a globe temperature (T_g) of 32°C with or without solar radiant heat at a magnitude equivalent to a T_g increase (ΔT_g) of 4°C.

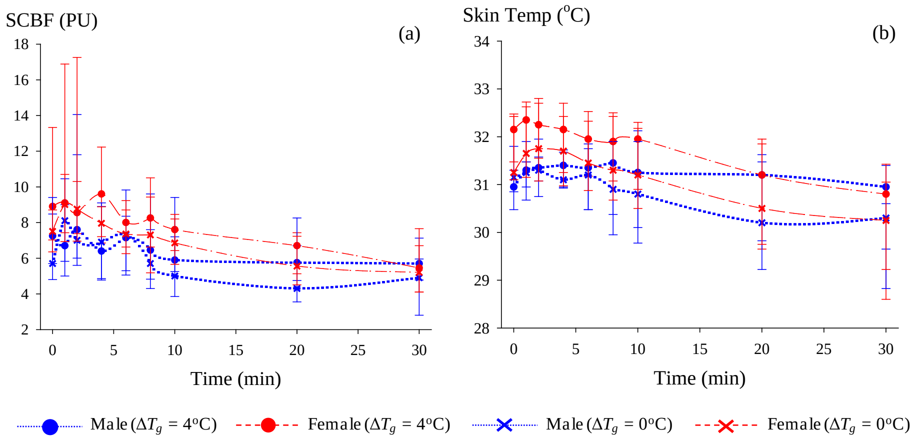

Figure 2. Alteration in (a) skin capillary blood flow (SCBF) and (b) skin temperature in study participants in response to thermal transient developed from loss of solar radiant heat (SRH) when participants moved into indoor chamber from outdoor chamber of a globe temperature (T_g) of 32°C with or without SRH equivalent to a T_g increase (ΔT_g) of 4°C.

CONCLUSIONS

The influence of SRH exposure to thermoregulation required a longer course of adaptation compared to that from the change in air temp. Thus, caution to reduce excess SRH exposure is needed when remaining outdoors in hot summer days to reduce the residual influence of SRH exposure on the thermal balance in a thermal transient, e.g., by use of adequate clothing.

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