

The duration-dependant effect of skin temperature on self-paced cycling exercise

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Introduction

Skin temperature has been suggested as a relevant physiological signal for the anticipatory and feedback control of work rate during self-paced exercise [1, 2]. However, a sudden extreme skin temperature elevation did not affect pacing during a 7.5-km cycling time trial [3]. Possible explanations for the discrepancy in these results are the duration of the self-paced exercise and the length of the skin temperature manipulations. To investigate whether the duration of the manipulation in skin temperature, or the duration of the time trial is more relevant for the influence of an elevated skin temperature on pacing pattern and performance during aerobic exercise, we investigated the effect of two different lengths of radiative heat exposure on pacing pattern during a 15-km cycling time trial. Together with results from our previous study [3], in which an identical intervention was applied during a cycling time trial of 7.5 km, conclusions can be drawn about the relative importance of time trial duration and the duration of the manipulation.

Methods

Nineteen well-trained male cyclists completed three 15-km cycling time trials in 18°C and 50% relative humidity with (H-SHORT and H-LONG) or without (CON) radiative heat stress. The heat stress was applied by a panel consisting of 22 infrared heaters that was quickly positioned in front of the cycle ergometer after 1.5 km. The panel was quickly removed at 6.0 km (H-SHORT) or 10.5 km (H-LONG) resulting in 4.5 or 9.0 km of heat stress, respectively. This intervention was identical to the heat stress intervention in a previous study in our lab [3]. During the time trials, power output (PO), skin (T_{sk}) and rectal (T_{re}) temperature, heart rate (HR), RPE, $\dot{V}O_2$, $\dot{V}CO_2$, thermal sensation, and thermal discomfort were measured. The significance of effects of experimental condition on the dependent variables over time was determined using two-way ANOVA for repeated measurements, with two within subject factors (experimental condition and distance completed). One-way ANOVAs were used to determine the significance of effects of experimental conditions on time to completion and values at the finish. Post-hoc analyses used Bonferroni correction to adjust for multiple comparisons.

Results

The radiative heat exposure resulted in $1100 \text{ W}\cdot\text{m}^{-2}$ radiation on the frontal side of the cyclists leading to higher T_{sk} during the time trial for H-SHORT ($35.0 \pm 0.6 \text{ }^\circ\text{C}$) and H-LONG

(35.3 ± 0.5 °C) than for CON (32.5 ± 1.0 °C; $F=155$, $P_{\text{main effect}} < 0.001$), whereas T_{re} remained similar ($F=0.603$, $P_{\text{main effect}}=0.55$). During the second half of the time trial, T_{sk} was higher for H-LONG than for H-SHORT ($P < 0.05$) resulting in a higher final T_{sk} for H-LONG (35.6 ± 0.5 °C) than for H-SHORT (35.3 ± 0.6 °C; $P=0.011$). Time to completion of the time trials was longer in H-SHORT (1352 ± 65 s) and H-LONG (1357 ± 80 s) than in CON (1326 ± 49 s; $F=5.42$, $P_{\text{main effect}}=0.009$). In line with the longer time to completion, PO was lower for H-SHORT (273 ± 8 W) and H-LONG (271 ± 9 W) than for CON (287 ± 7 W; $F=5.45$, $P_{\text{main effect}}=0.02$), but no difference in pacing pattern was observed ($F=0.944$, $P_{\text{main effect}}=0.55$; Figure 1). No differences in any performance measures were found between H-SHORT and H-LONG. HR was lower in H-SHORT (172 ± 11 b·min⁻¹; $P < 0.001$) and H-LONG (171 ± 11 b·min⁻¹; $P < 0.001$) than in CON (177 ± 9 min⁻¹). No differences were found between the trials in RPE, $\dot{V}O_2$, and $\dot{V}CO_2$, whereas thermal sensation ($P < 0.001$) and thermal discomfort ($P=0.03$) were higher for H-LONG than for H-SHORT during km 6.0-10.5.

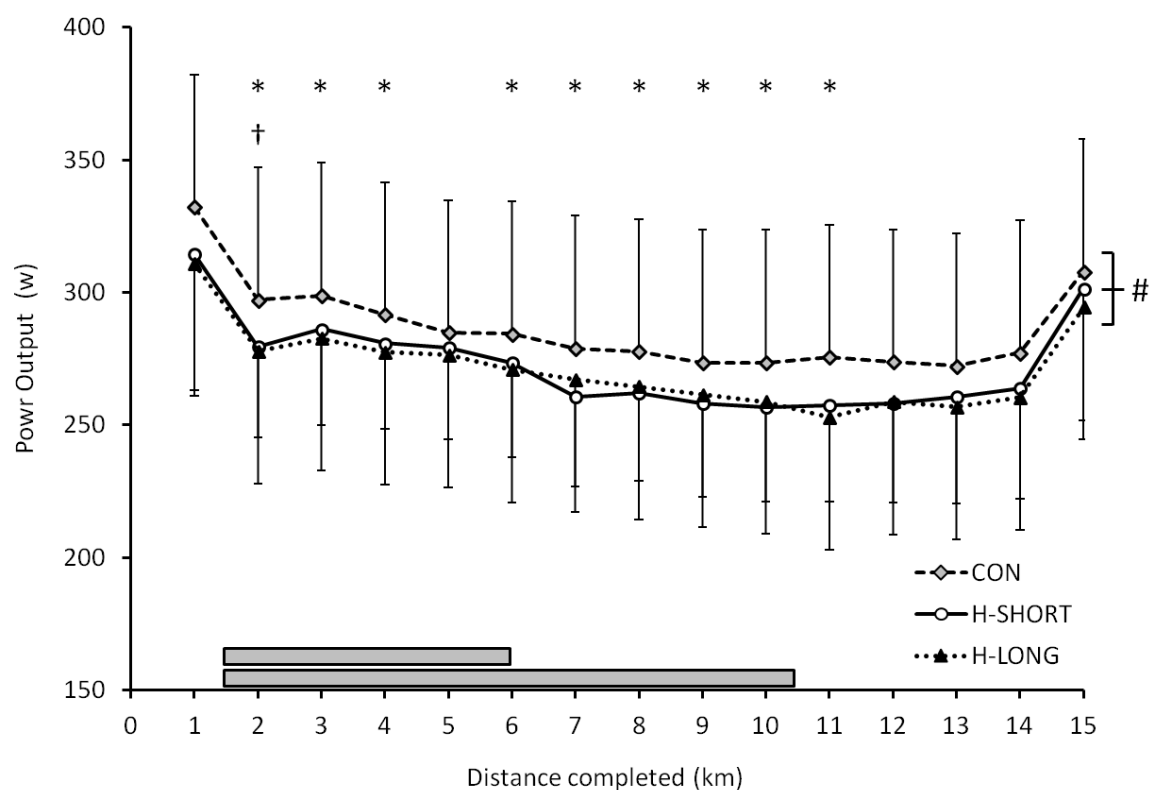


Figure 1 Pacing pattern during the 15-km cycling time trial. Grey bars indicate the appliance of radiative heat stress during H-SHORT (upper bar) and H-LONG (lower bar). * Significant difference between CON and H-SHORT ($P < 0.05$). † Significant difference between CON and H-LONG ($P < 0.05$). # Significant main effect between conditions ($P=0.02$).

Discussion

This study shows that a sudden radiative heat exposure substantially increases skin temperature, prolongs time to completion, and reduces mean power output during a 15-km cycling time trial. Interestingly, pacing pattern (expressed as the development of power output over the distance of the trial) was similar. This indicates that the difference in time to completion is caused by a lower power output that is maintained from the start

until the end of the time trial. Apparently, the knowledge of the upcoming thermal challenge influences the anticipatory selection of power output, which has been documented before [4]. Importantly, we found decreased performance in both H-SHORT and H-LONG, indicating that in a 15-km time trial, the length of heat exposure (and the resulting elevated skin temperature) is relatively unimportant for pacing and performance, as were the associated differences in thermal sensation and thermal discomfort appear to be relatively irrelevant.

Since we observed no differences in pacing and performance after a similar intervention during a 7.5 km cycling time trial [3], the length of the time trial, rather than the length of the manipulation appears to be relevant for the self-selected work rate during aerobic cycling exercise. Since there appears to be a dose-response relationship between the duration of self-paced exercise and the effect of a manipulation on pacing and performance, the duration of exercise should always be taken into account when analyzing the effect of skin temperature manipulations on exercise performance. We speculate that this relationship exists not only for skin temperature, but for all physiological and environmental signals that have an effect on exercise performance.

Conclusion

A sudden radiative heat exposure during a 15-km cycling time trial decreases power output during the time trial and prolongs time to completion. The duration of the radiative heat stress does not modulate this effect. Since radiative heat exposure did not affect performance during a 7.5-km cycling time trial, the length of the time trial, rather than the length of the manipulation appears to be relevant for the self-selected work rate during aerobic cycling exercise.

References

1. Schlader ZJ, Simmons SE, Stannard SR, Mundel T: **Skin temperature as a thermal controller of exercise intensity.** *Eur J Appl Physiol* 2011, **111**:1631-1639.
2. Tucker R, Marle T, Lambert EV, Noakes TD: **The rate of heat storage mediates an anticipatory reduction in exercise intensity during cycling at a fixed rating of perceived exertion.** *J Physiol* 2006, **574**:905-915.
3. Levels K, de Koning JJ, Foster C, Daanen HA: **The effect of skin temperature on performance during a 7.5-km cycling time trial.** *Eur J Appl Physiol* 2012, **112**:3387-3395.
4. Castle PC, Maxwell N, Allchorn A, Mauger AR, White DK: **Deception of ambient and body core temperature improves self paced cycling in hot, humid conditions.** *Eur J Appl Physiol* 2011.