THERMOREGULATORY EFFECTS OF EXERCISE IN A HYPERCONVECTIVE ENVIRONMENT

M.J. Buono and J.G. Wilson

San Diego State University, San Diego, **CA, USA**

INTRODUCTION

It is well known that airflow across the human body increases convective and evaporative heat loss. For example, previous studies (1,2,3,4) have shown that fan-driven air circulation around the body during stationary cycling in a warm environment significantly enhanced thermoregulation and deterred potential heat illness. Interestingly, the air velocity used in the studies cited above has ranged between 1-18 kilometers per hour **($km \cdot h^{-1}$)**. Yet, most competitive and some recreational cyclists can attain speeds of 32 $km \cdot h^{-1}$ or more. Therefore, the purpose of this study was to examine the whole body sweat rate **(WBSR)**, rectal temperature **(T_{re})**, mean **skin** temperature ($\overline{T}_{sk}$), and heart rate (HR) during stationary cycling in a normoconvective (NC) (air velocity < 1 $km \cdot h^{-1}$) and hyperconvective (HC) (air velocity = **32** $km \cdot h^{-1}$) environment.

MATERIALS AND METHODS

The subjects for the study were 10 (4 female, **6** male) active, healthy volunteers. The mean (± SD) age, height, weight, percent body fat and maximum *oxygen* uptake for the group was **26** ± 5 years, 175 ± **9** cm, 70 ± **9** kg, 15 ± **6%** and 55 ± 11 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively.

Each subject participated in 3 separate testing days. On the initial laboratory visit, body composition was measured using a 7-site skinfold method (5). Additionally, each subject performed a graded exercise test on *a* cycle ergometer to volitional exhaustion. Expired gases were collected during each minute of the test into meteorological balloons to determine $\dot{V}O_{2max}$. Fractional O_2 and CO_2 concentrations were measured on Applied Electrochemistry analyzers. Expired gas volume was measured with a *dry* gas meter.

The second and third test days, which occurred in random order approximately 1 week apart, involved the NC and HC treatments. Each subject performed 60 min of continuous cycling at 60% of their $\dot{V}O_{2max}$ on an electronically braked cycle ergometer. The air temperature and relative humidity on both days was 22°C and 60%, respectively. During the HC trial, airflow was delivered to the subject's frontal aspect by 2 large industrial fans. Wind speed was measured with a hand-held anemometer. The mean (SD) air velocity for the HC trials was 32 1 $km \cdot h^{-1}$.

During both exercise bouts T_{re}, $\overline{T}_{sk}$ and HR were measured at rest and every 15 min. HR was measured using a 3-lead ECG system. T_{re} was measured using a YSI (series 400) temperature probe inserted 10 cm beyond the anal sphincter. $\overline{T}_{sk}$ was determined from **3 skin** sites (chest, triceps, calf) according to the equation developed by Burton **(6)** using **YSI** surface temperature probes. In addition, **WBSR** was determined using the difference in *dry* body weight taken before and after the exercise bout. Lastly, $\dot{V}O_2$ was measured at the 20th min of exercise using a meteorological balloon.

Data collected in the **NC** and **HC** trials were compared using a paired t-test. Significance was set at the $P < 0.05$ level.

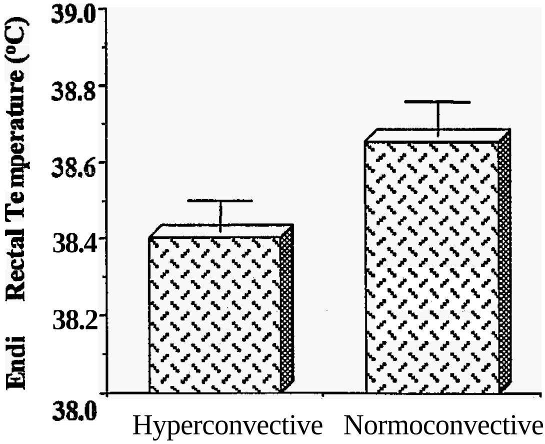

Figure **1.** Mean (±SE) Ending Rectal Temperature in Two Environments

RESULTS

Mean ending **(60** min value) T_{re} was significantly decreased in the HC **(38.40°C)** vs. the NC **(38.65°C)** trial. Likewise, mean **ending** HR **was** also significantly reduced **fiom 160 bpm** to **146** bpm. Mean core temperature and HR **data** is presented in Fig. 1 and Fig. 2, respectively. Furthermore, mean **WBSR** was **significantly** reduced from 1.1 **L·h⁻¹** in the NC **trial** to **0.67 L·h⁻¹ in the** HC trial. Lastly, mean ending $\bar{T}_{sk}$ **was** significantly decreased from **35.05°C** in the **NC** trial to 31.15°C in the HC condition.

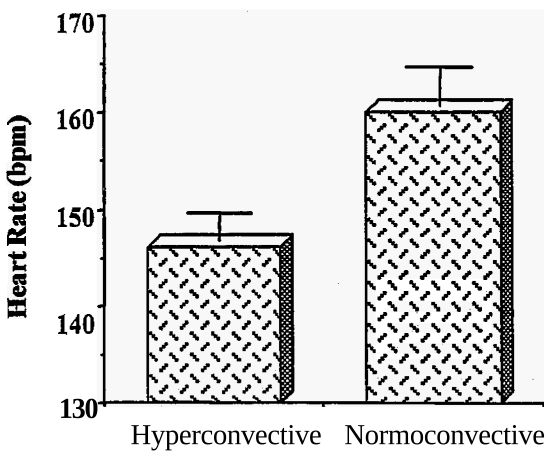

Figure **2.** Mean **(±SE)** Heart Rate in Two **Environments**

DISCUSSION

The results of this study show that a **32-km·h⁻¹** airflow across the frontal aspect of **a** stationary cyclist can profoundly affect many thermoregulatory variables. Specifically, HR is dramatically reduced in a HC environment. The **14** bpm reduction seen in the current study is similar in magnitude to the changes reported by Adams et al. (1) and Shaffrath and Adams **(4) who** reported **18** bpm and **15** bpm differences respectively, between HC and NC. However, it should be noted that in both (1,4) of these studies, significant results only occurred at elevated environmental temperatures (> 35°C). HR **was** not significantly affected by air velocity of **<16 km·h⁻¹** in more temperate environments (24°C). Thus, the current study suggests that higher air velocities can also influence HR in temperate conditions. The decreased HR seen in HC trials is probably the result of a decreased skin blood flow, thus reducing "cardiovascular drift."

The 0.25°C reduction in T_{re} in the HC trial is consistent with the findings of Shaffrath and Adams (4). They reported a 0.3°C decrease in T_{re} during 70 min of exercise at 60% $\dot{V}O_{2max}$ in a HC environment. Other studies (1,2) have reported larger decreases in T_{re} in HC environments. It should be noted, however, that these studies had some combination of longer duration, higher intensity or hotter ambient conditions.

The reduced T_{re} can either be the result of reduced heat production or increased heat loss. The 20th min $\dot{V}O_2$ values in the current study were identical (2.5 $L \cdot min^{-1}$) for the HC and NC trials. This **finding** is in agreement with others (4) and suggests that HC does not alter heat production. Therefore, the reduced T_{re} seen in the HC trial is probably the result of increased sensible **(i.e.,** *dry)* heat **loss.**

This is supported by the fact that WBSR was significantly reduced in the HC trial. Other studies (1,3) corroborate these findings and support the hypothesis that if convective cooling is increased during an exercise bout, evaporative cooling will decrease, and vice versa.

CONCLUSION

In conclusion, the current study supports the hypothesis that stationary cycling in a NC environment requires more reliance on sweat evaporation resulting in significantly greater HR and T_{re} values compared to similar intensity exercise in a HC environment. Furthermore, the current data suggests that the previously reported changes in HR and T_{re} that occurred in high ambient temperature conditions can also be seen in temperate conditions if the air velocity is increased to match the speeds actually produced during competitive cycling.

REFERENCES

1. Adams, W.C., Mack, G.W., Langhans, G.W. and Nadel, E.R. 1992, Effects **of** varied **air** velocity on sweating and evaporative rates during exercise, ***Journal of Applied Physiology, 73,*** 2668-2674.
2. Graetzer, D.G., Johnson, S.C., Shultz, B.B., Leutkemeier and Chen, C. 1992, Thermoregulatory dynamics during prolonged cycling in normoconvective and hyperconvective environments, ***Medicine and Science in Sports and Exercise,* 24,** 156.
3. Wyndham, C.H., Bouwer, W.M. Devine, M.G. and Paterson, H.E. 1952, Physiological responses of African laborers at various saturated air temperatures, wind velocities and rates **of** energy expenditure, ***Journal of Applied Physiology,*** 5,290-298.

4. Shaffrath, J.D. and Adams, W.C. 1984, Effects of airflow and workload on cardiovascular drift and skin blood flow, *Journal of Applied Physiology*, 56, 1411-1417.
5. Jackson, A.S. and Pollock, M.L. 1985, Practical assessment of body composition, *Physician and Sportsmedicine*, 13, 76-90.
6. Burton, A.C. 1934, New technique for the measurement of average skin temperature over the surfaces of the body and the changes of skin temperature during exercise, *Journal of Nutrition*, 7, 481-496.