HIGH AMBIENT TEMPERATURE IMPAIRS 1-HOUR CYCLE TIME TRIAL PERFORMANCE

K. Backx, K.A. van Someren, G.S. Palmer

School of Life Sciences, Kingston University, Kingston upon Thames, UK

ABSTRACT

Exposure to thermal stress has been shown to limit performance of athletes who compete and train in hot environments. The majority of literature however, relates to low-intensity exercise (<70% of peak oxygen uptake [$\dot{V}O_{2peak}$]) of long duration (>2hr). Little consideration has been given to high-intensity exercise (>80% $\dot{V}O_{2peak}$) of moderate duration (30-90 min). Hence, the aim of this investigation was to determine the influence of ambient temperature on self-paced, one-hour cycle time trial performance.

Twelve well-trained male cyclists (mean ±SD), age 32 ±7 yrs, mass 74.6 ±10.5 kg, height 177.5 ±6.6 cm, $\dot{V}O_{2peak}$ 64.0 ±6.8 ml•kg^{-1}•min^{-1}, peak power output (PPO) 393 ±50 W, acted as subjects in this investigation. Prior to experimental trials, PPO and HR_{peak} were measured during a maximal incremental test to exhaustion. Subjects then undertook three to eight 1-hour time trials (TT) on a cycle ergometer (Kingcycle, High Wycombe, Bucks, UK). These trials were preceded by 24 hrs rest and standardised diet, and were performed in a climatic chamber, under a range of ambient temperatures (T_a) 10-14, 14-18, 18-22, 22-26, 26-30, and 30-34˚C. Ten min prior to each TT subjects were provided with a bolus feeding (6ml•kg^{-1}•BM, 6% carbohydrate solution), during the rides subjects were allowed to consume water *ad libitum*.

Whilst distance covered and power output were monitored continuously and averaged every 60-s of the trial, the only feedback given to the subjects was elapsed time. The performance data of each subject were then converted from actual distance to a percentage of their best TT performance (%BP) and a percentage of their %PPO. Heart rate measured during the trials was converted to a percentage of peak heart rate (%HR_{peak}). Thermistors for the measurement and calculation of mean skin temperature (T_{MST}), were attached to the chest, upper arm, thigh and calf. Core temperature (T_{REC}) was measured by means of a rectal probe, mean body temperature (T_{MBT}) was calculated from the measured skin and rectal temperatures.

Results indicated subjects performance significantly deteriorated in the 30-34˚C zone (98.2 ±1.1, 98.7 ±1.4, 98.9 ±1.6, 97.8 ±2.9, 97.0 ±2.1, vs. 94.1 ±2.2 %BP for 10-14, 14-18, 18-22, 22-26, 26-30, and 30-34˚C respectively, P<0.05). There were no significant differences in %PPO, %HR or T_{REC} between any of the zones. Mean skin temperature was significantly lower at 10-14˚C, T_{MBT} was significantly lower at 10-14˚C when compared to ambient temperature above 18˚C. Mean skin temperature at 30-34˚C was significantly higher than at temperatures below 22˚C.

This study demonstrated that ambient temperatures in excess of 30˚C impaired 1-hour cycle time trial performance in well-trained hydrated cyclists.

INTRODUCTION

- It is well documented that exercise time to exhaustion is reduced in high compared to low ambient temperature, however subjects in these investigations were moderately active, or endurance trained males, none were specifically trained cyclists.
- The time taken for the athlete to fatigue was used as a measurement of performance; several studies have however shown great variability in this measure.
- The majority of literature relates to low-intensity exercise (<70% $\dot{V}O_{2peak}$) of long duration (>2hr). Little consideration has been given to high-intensity exercise (>80% $\dot{V}O_{2peak}$) of moderate duration (30-90 min).
- The underlying mechanisms responsible for the premature development of fatigue in the heat have yet to be clearly identified. However, the suggested mechanisms include metabolic, cardiovascular and central nervous system perturbations, together with an elevated core temperature.
- Whilst cycling time-trial (TT) performance is considered the ultimate test of the cyclist's physiology, there has been no experimental investigation into the influence of ambient temperature on such performance.

AIM

- The aim of this study was to determine the influence of ambient temperature on self-paced, simulated cycle time trial of 1-hr duration.

METHODS

Subjects:
- Twelve trained male cyclists or triathletes participated in this investigation (see Table 1)

Table 1:
Subject Characteristics

	Mass (kg)	Height (cm)	Age (yr)	HR_{peak} (b•min^{-1})	PPO (W)	P/W (W•kg^{-1})	VO_{2peak} (ml•min^{-1}•kg^{-1})
1	76.8	181	48	180	385	5.0	61.3
2	64.0	172	32	177	376	5.9	61.5
3	61.0	163	36	185	345	5.7	71.7
4	69.5	179	30	199	392	5.6	65.7
5	86.5	187	30	196	495	5.7	67.1
6	75.4	183	24	184	436	5.8	68.1
7	70.0	177	28	196	401	5.7	65.9
8	61.2	170	28	206	387	6.3	74.3
9	97.0	183	35	185	367	3.8	50.8
10	70.5	175	40	172	315	4.5	65.4
11	79.4	180	24	189	460	5.8	65.1
12	81.4	181	28	189	367	4.5	56.3
Mean ± SD	74.4 ± 10.7	178 ± 7	32 ± 7	188 ± 10	394 ± 49	5.4 ± 0.7	64.4 ± 6.4

HRpeak: peak heart rate: PPO: peak power output; $\dot{V}O_2$peak: peak oxygen uptake; P/W: power to Body mass ratio.

Preliminary Testing:
- Prior to participation in the experimental trials each subject performed a progressive maximal incremental test on a 'Kingcycle' ergometry system for the determination of peak oxygen uptake ($\dot{V}O_{2peak}$), heart rate (HR_{peak}) and power output (PPO).
- The incremental test was commenced at a workload of 3.3 W per kilogram body mass. This was increased continuously by 1 W every 3-s (20 W•min-1) until the subjects reached volitional fatigue.
- All incremental tests were conducted under thermoneutral conditions (20˚C and 45% RH).

Pre Trial Familiarisation:
- An initial 1-hr TT was used to familiarise subjects with the experimental protocol.

Experimental Trials:
- Athletes completed four to seven 1-h self paced TT on a 'Kingcycle' air-braked ergometer (Kingcycle, High Wycombe, Bucks, UK).
- Trials were performed in an environmental chamber at a number of different temperature zones 10-14, 14-18, 18-22, 22-26, 26-30, and 30-34˚C, RH 63 ±6%.
- A fan, directed away from the subject, circulated air within the chamber at a rate of approximately 0.33 m•s^{-1}.
- The different trial conditions and number of subjects completing each trial are shown in Table 2. To account for small differences in RH the Wet bulb globe temperature (WBGT) is given.

Table 2:
Environmental Conditions and Numbet of Subjects per Experimental Trial

Temperature Zone (˚C)	10 - 14	14 - 18	18 - 22	22 - 26	26 - 30	30 -34
Ambient temperature (˚C) mean	13.2	16.7	21.0	25.1	28.6	32.1
SD	1.0	1.3	1.2	1.1	0.8	0.2
Relative humidity (%) mean	70	65	63	60	58	58
SD	6	6	6	5	2	3
Estimated WBGT (˚C)	11.5	15.0	18.0	21.0	25.4	28.3
Number of subjects	9	13	10	9	10	7

WBGT: wet bulb globe temperature

Time Trial Efforts:
- Each experimental trial was commenced after calibration of the ergometer and a self paced standardised 10-min 'warm up'.
- Subjects were instructed to cover as much distance as possible during a 1-hr period. Distance covered and power output were monitored continuously and averaged every 60-s of the trial, the only feedback given to the subjects was elapsed time.
- During experimental trials rectal temperature (T_{REC}) and four site skin temperature (T_{SK}) was monitored continuously, and recorded every 5-min. Heart rate (HR) was monitored continuously, and averaged every 60-s.
- Cyclists wore only shorts, and were given a bolus of carbohydrates (Maxim, Holland) (6% solution of CHO; 6ml•kg^{-1}•body weight) 10-min prior to each TT and were allowed to consume water *ad libitum* during the TT. Water consumption was recorded at 10-min intervals.
- Each experimental trial was performed three to ten days apart, at the same time of day.
- Prior to the first experimental trial each individual was required to record their physical activity and dietary intake for 24 hours, this was then repeated prior to subsequent trials.

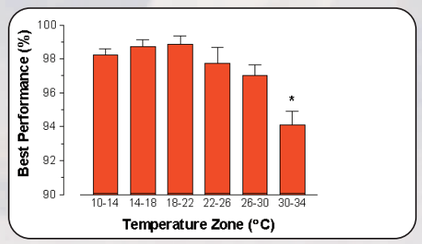
Data Analysis:
- Performance data of each subject were converted from actual distance to a percentage of their best TT performance (%BP), power output and heart rate were converted to a percentage of PPO (%PPO) and peak heart rate (%HR_{peak}). Mean skin temperature (MST) and mean body temperature (MBT) was calculated using the T_{SK} values.

RESULTS

- Figure 1 shows the average subjects' performance, presented as a percentage of their best TT performance (%BP). Subjects' performance significantly deteriorated in the 30-34˚C zone (98.2 ±1.1, 98.7 ±1.4, 98.9 ±1.6, 97.8 ±2.9, 97.0 ±2.1, vs. 94.1 ±2.2 %BP for 10-14, 14-18, 18-22, 22-26, 26-30, and 30-34˚C respectively, P<0.05).

Figure 1.

Distance covered (%BP) during 1-hr TT



***Performance significantly lower**

- There were no significant differences in fluid intake or sweat loss between temperature zones.
- There were no significant differences in %PPO, %HR or T_{REC} between temperature zones. Results of all performance and physiological data are shown in Table 3.

Table 3:
Performance and Physiological Results Shown Per Temperature Zone

Temperature Zone (˚C)	10 - 14	14 - 18	18 - 22	22 - 26	26 - 30	30 -34
% of best performance mean	98.25	98.74	98.87	97.75	97.02	94.09*
SD	1.06	1.37	1.56	2.86	2.05	2.20
% HR_{peak} mean	87	88	84	85	86	88
SD	7	6	6	6	7	6
%PPO mean	65	67	64	64	62	57
SD	7	7	9	6	8	9
T_{REC} (˚C) mean	38.10	38.42	38.33	38.09	38.17	38.37
SD	0.67	0.55	0.56	0.67	1.03	0.78
T_{MST} (˚C) mean	28.34*	30.53	32.14	32.70	34.06	34.53*
SD	1.43	1.21	1.11	1.31	1.25	1.90
T_{MST} (˚C) mean	36.13*	36.84	37.10	37.01	37.31	37.60
SD	0.69	0.53	0.52	0.61	0.95	0.79

***Significant Difference, P<0.05**

- Figure 2 shows that MST was significantly lower at 10-14˚C, MST at 30-34˚C was significantly higher than at temperatures below 22˚C. Mean body temperature was significantly lower at 10-14˚C when compared to temperatures above 18˚C (see Figure 3).
- There was no significant difference in fluid intake between any of the zones.

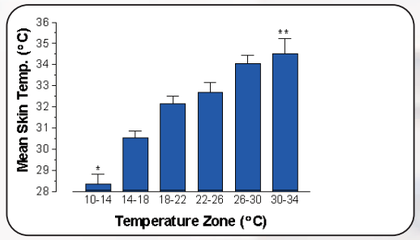


Figure 2.

Mean Skin Temperature

***MST significantly lower than other zones**
****MST significantly higher than zones <22˚C**

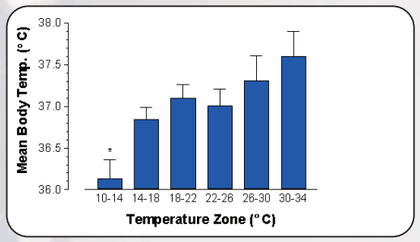


Figure 3.

Mean Body Temperature

***MBT significantly lower than zones >.8˚C**

CONCLUSION

- **This study demonstrated that ambient temperatures in excess of 30˚C impaired 1-hour cycle time trial performance in well-trained hydrated cyclists.**
- **It is not clear which is the underlying mechanism responsible for the decrement in performance at high temperatures.**