Core temperature up to 41.5°C during the UCI Road Cycling World Championships in the heat

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ABSTRACT

Objective To characterise the core temperature response and power output profile of elite male and female cyclists during the 2016 UCI Road World Championships. This may contribute to formulating environmental heat stress policies.

Methods Core temperature was recorded via an ingestible capsule in 10, 15 and 15 cyclists during the team time trial (TTT), individual time trial (ITT) and road race (RR), respectively. Power output and heart rate were extracted from individual cycling computers. Ambient conditions in direct sunlight were hot (37°C±3°C) but dry (25%±16% relative humidity), corresponding to a wet-bulb globe temperature of 27°C±2°C.

Results Core temperature increased during all races (p<0.001), reaching higher peak values in TTT (39.8°C±0.9°C) and ITT (39.8°C±0.4°C), relative to RR (39.2°C±0.4°C, p<0.001). The highest temperature recorded was 41.5°C (TTT). Power output was significantly higher during TTT (4.7±0.3W/kg) and ITT (4.9±0.5W/kg) than RR (2.7±0.4W/kg, p<0.001). Heart rate increased during the TTs (p<0.001) while power output decreased (p<0.001).

Conclusion 85% of the cyclists participating in the study (ie, 34 of 40) reached a core temperature of at least 39°C with 25% (ie, 10 of 40) exceeding 40°C. Higher core temperatures were reached during the time trials than the RR.

What are the findings?

- Thirty-four of 40 participants in the study at the UCI Road Cycling World Championships in the heat reached a core temperature of 39°C and 10 of those exceeded 40°C.
- Higher core temperatures were reached during the time trials than the road race; the highest temperature recorded was 41.5°C.

How might it impact on clinical practice in the future?

- Cyclists (including world championship medallists) can reach a core temperature >40.5°C in the heat without ill-effects.
- In a given thermal environment, exercise Intensity, specifically heat production, is a more potent determinant of body temperature than exercise duration.

INTRODUCTION

Beyond the difference in training status, several factors differ between elite cyclists competing in hot environments and most laboratory studies conducted under heat stress. This includes a potentially large radiative solar load, and enhanced evaporative and convective cooling supported by the high speeds sustained during racing.[1 2] There is also no ethical cut-off for the attainment of a specific core temperature during competitions. Only one study, to our knowledge, reported core temperature responses during competitive cycling (National Series Road Race), although in temperate conditions.[3] Despite the relatively low environmental temperatures (13°C–16°C), most cyclists reached a core temperature >39°C.[3] In the absence of field data on the core temperature responses of elite athletes competing in the heat, the International Olympic Committee has called for a characterisation of the thermal strain experienced by international competitors during major competitions.[4]

The innovation of data loggers that are embedded in ingestible thermometers, has made it possible to non-invasively monitor elite athletes in competition. Therefore, we characterised the core temperature response and power output production of elite male and female cyclists participating in the team time trial (TTT), individual time trial (ITT) and road race (RR) of the 2016 UCI Road World Championships that were held in hot ambient conditions. Contextualising the level of thermal strain elite athletes can reach and tolerate will provide insight that may help in understanding adjustments in performance and formulating environmental heat stress policies to protect the health of this specific population.

METHODS

Project design

This cross-sectional study was designed to evaluate the core temperature, along with the physiological (ie, heart rate) and performance (ie, power output) responses of elite cyclists participating in the 2016 Union Cycliste Internationale (UCI) Road World Championships (Doha, Qatar, 9 October–16 October). The environmental conditions during the championships were hot (average temperature under direct sunlight 36.9°C±2.8°C), but dry (average relative humidity 24.6%±15.6%), corresponding to an outdoor wet-bulb globe temperature of 27.1°C±2.4°C. TTT was 40 km for both men and women, ITT was 28.9 km for women and 40 km for men, and RR was 134.5 km for women and 257.5 km for men. All courses were

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Table 1 Number of observations and average values during the 2016 UCI Road World Championships

		Nb observations			Values		
		TTT	ITT	RR	TTT	ITT	RR
Core temperature (°C)	Men	6	10	3	39.2±0.2	39.8±0.4	39.6±0.2
	Women	4	5	12	40.8±0.7	39.9±0.5	39.1±0.4
	Combined	10	15	15	39.8±0.9	39.8±0.4	39.2±0.4
Power output (W)	Men	7	6	3	333±33	379±35	221±10
	Women	4	4	3	257±10	258±25	139±16
	Combined	11	10	6	305±47	331±69	180±47
Relative power output (W/kg)	Men	7	6	3	4.8±0.2	5.3±0.2	2.9±0.0
	Women	4	4	3	4.5±0.2	4.5±0.4	2.5±0.5
	Combined	11	10	6	4.7±0.3	4.9±0.5	2.7±0.4
Heart rate (bpm)	Men	5	3	1	175±3	174±6	134
	Women	1	2	4	195	181±17	158±17
	Combined	6	5	5	179±8	177±10	153±18

Values are average ±SD.
Numerous riders used power metres without heart rate.
ITT, individual time trial; RR, road race; TTT, team time trial.

flat. TTs lasted for ~45 min whereas RR lasted for ~3hours 11 min and 5 hours 43 min for women and men, respectively.

Participants

Forty data sets from elite male and female cyclists (ie, no junior or under 23 years) were analysed (table 1). Average (±SD) age, body mass and height were 28.6±3.4 years, 74±5 kg and 184±6 cm for men, and 27.2±4.0 years, 58±6 kg and 169±5 cm for women. Written informed consent was obtained prior to racing. All procedures complied with the Declaration of Helsinki regarding human experimentation.

Data collection

Core temperature was recorded using e-Celsius ingestible capsules and e-Viewer receivers (BodyCap, Caen, France). The capsule was provided to the cyclist the day before the race with instructions to swallow it immediately on waking. Data (precision 0.1°C, 1 recording every 30 s) were stored within the capsule and downloaded immediately after the race. Power output and heart rate were extracted from individual cycling computers after the events.

Data analyses

Data were coded in Wizard (V.1.9.13, Evan Miller) for non-parametrical analyses. Average absolute power output and heart rate, as well as peak core temperature were extracted from each file. The effect of sex (two groups) was analysed with a Mann-Whitney test. The effect of race type (three groups) was analysed with a Kruskal-Wallis test. In addition, data were averaged for each 10% of the race and the effect of time (ie, 10 segments) was analysed with a Friedman test. Sidak adjustments for multiple comparisons were applied for post hoc analyses. Statistical significance was set to $p<0.05$. Data are reported as mean±SD in text, tables and figures. Effect sizes are reported as Cohen's d and interpreted as small ($d\leq0.5$), medium ($d\leq0.8$) or large ($d>0.8$).

RESULTS

Individual peak core temperatures are represented in figure 1. Peak core temperature was significantly higher during TTs

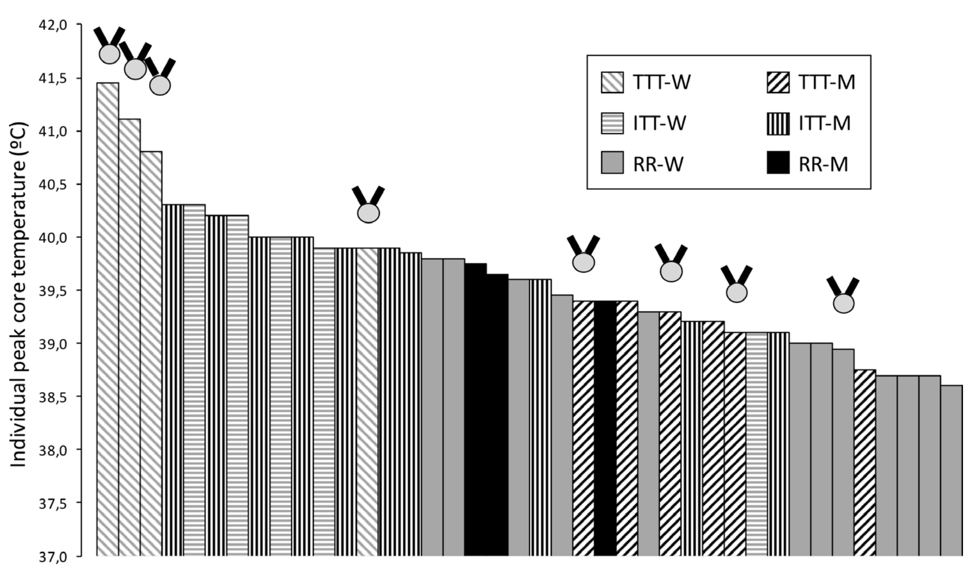

Figure 1 Peak core temperature reached during the team time trial (TTT), individual time trial (ITT) and road race (RR) of the 2016 UCI Road World Championship. Each column represents an individual value from an elite male (M) or female (F) cyclist. The medals symbolise data points of medallists in the corresponding event. W, watts.

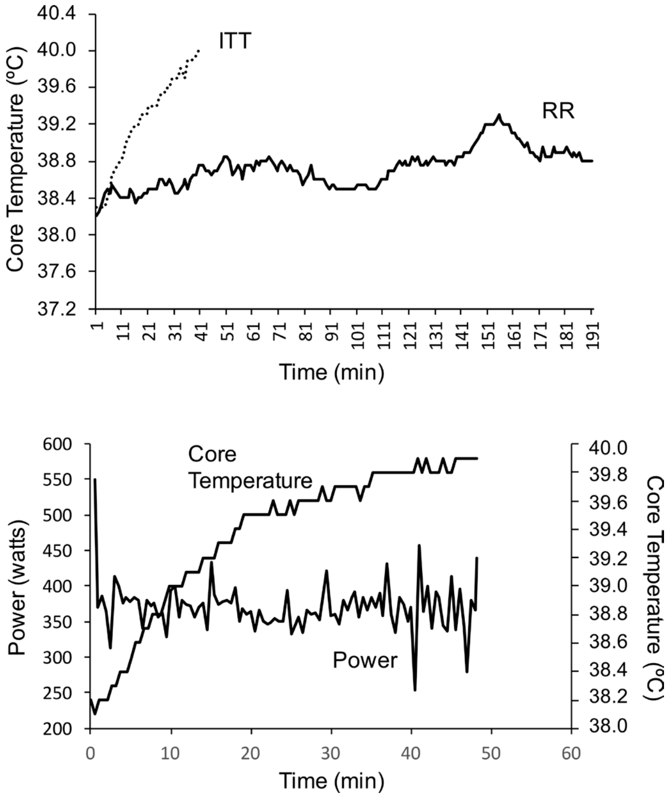

Figure 2 Individual examples of (1) the evolution of core temperature in an elite woman participating in both the individual time trial (ITT) and road race (RR) (upper panel), and (2) the concomitant evolution of core temperature and power of an elite man during ITT (lower panel).

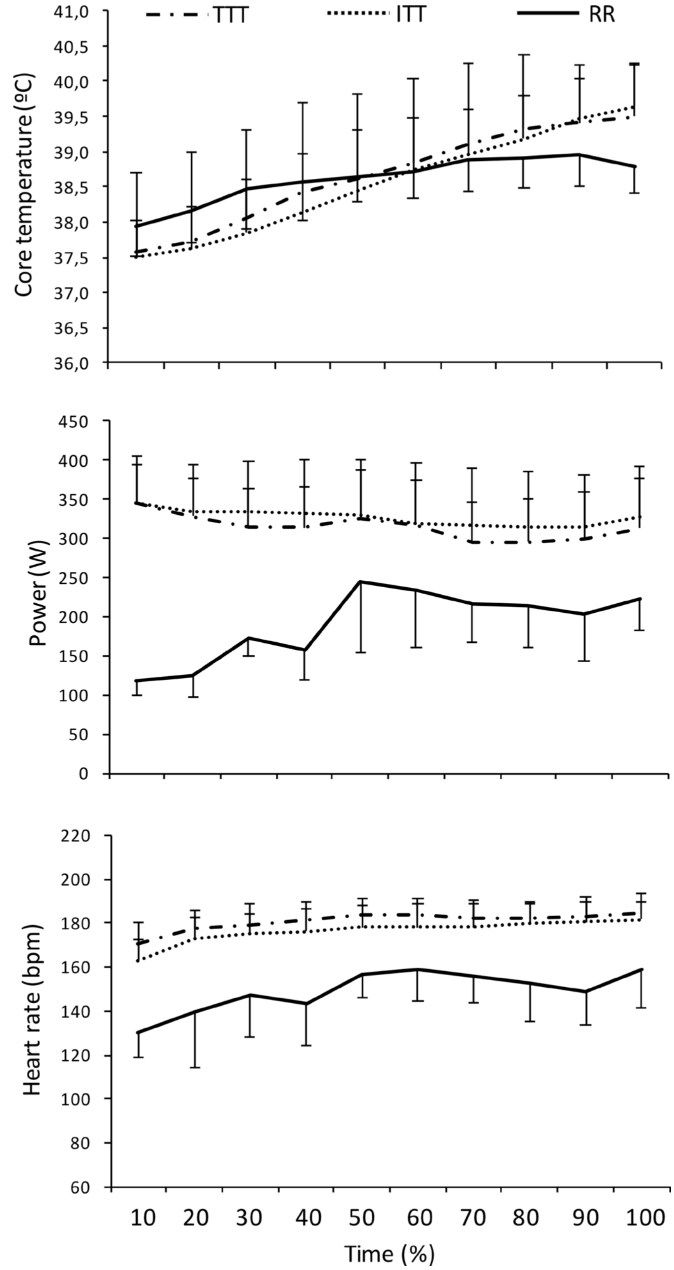

Figure 3 Core temperature, power a heart rate output during the team time trial (TTT), individual time trial (ITT) and road race (RR) of the 2016 UCI Road World Championships.

relative to RR by a medium difference ($d>0.5$, $p<0.05$, table 1). Although not reaching significance ($p<0.10$), heart rate was largely ($d>1.2$) higher during TTs than RR (table 1). Absolute and relative (to body mass) power output were largely ($d>1.5$) and significantly higher during both TTs than RR ($p<0.001$), without differing between TTT and ITT ($d=0.4$, $p>0.05$, table 1).

Examples of continuous core temperature recordings are represented in figure 2. Core temperature significantly increased over time during all races ($p<0.001$, figure 3), as did heart rate ($p<0.018$, figure 3). Power output significantly decreased during the first 90% of both TTT and ITT ($p<0.001$), followed by a small ($d=0.4$) end spurt in the final 10% ($p<0.001$, figure 3).

Seventeen cyclists finished in the top 10 of their event, including eight medallists (figure 1). There was no relationship between core temperature and ranking ($R^2=0.09$) or exercise duration ($R^2=0.14$).

DISCUSSION

The current observations provide a unique insight into the core temperatures attained by elite cyclists during a major competition held under heat stress. Our data showed that both male and female cyclists reached a higher core temperature during TTT and ITT than during RR, with several individuals reaching peak core temperatures >40°C during TTs (figure 1). Although TTT and ITT were shorter than RR, they were performed at a higher average power output (table 1), and as such, a greater metabolic heat production.

The peak core temperature (RR: 39.2°C, TTs: 39.8°C) reached in the current World Championships, with an ambient temperature of 37°C, is between the 38.9°C peak core temperature reported during cycling stage races at an ambient temperature of 13°C–16°C,[3] and the 40.2°C peak core temperature reported in well-trained cyclists performing an ITT in 37°C.[5] Compared with other field studies, this is similar to the average peak core temperature reported in footballers playing at an ambient temperature of 43°C[6] and tennis players in 37°C.[7] Most (85%) of the cyclists participating in the study reached a core temperature of at least 39°C and 25% reached 40°C (figure 1). The highest individual value recorded was 41.5°C. These values align with a previous report of 18 heat-acclimatised male soldiers participating in a 21 km running race in a tropical environment (27°C and 87% relative humidity) and reaching a peak core temperature of 39°C, with 56% reaching 40°C and 11% reaching 41°C.[8]

None of the athletes in that study or in the current study were treated for heat illness. Thus, despite the different requirements between sports and athlete characteristics, these observations confirm that well-trained and elite-level athletes commonly reach core temperatures of 40°C and above without heat illness. It should be recognised however, that the development of hyperthermia impairs performance,[9] and that this level of heat strain may be deleterious to the health of individuals unacclimatised to heat or immunocompromised when starting an event.[10]

The highest core temperatures were observed in women during TTT with two cyclists exceeding 41°C. These same cyclists also reached a core temperature between 40°C and 41°C 2 days later, during ITT. Interestingly, these two cyclists had followed a comprehensive 9-day heat acclimatisation programme in Qatar before their first race, the TTT. It has been reported that heat acclimatisation does not modify the maximum temperature reached at the end of a time trial,[5] as the increases in heat dissipation (eg, sweat rate) and heat storage (eg, decreased resting temperature) capacity afforded by heat acclimatisation are likely accompanied by an increase in heat production (ie, power output).[5]

Anecdotally, while we did not observe temperatures above 41°C in the male cyclists during TTT on the same course, we note that the two male professional teams that participated consumed an ice slurry beverage during the warm-up. This could have decreased their core temperature and/or interfered with the gastrointestinal recording.

As displayed in figure 2, core temperature and heart rate both increased during TTs despite a progressive decrease in power output, indicating a progressive increase in thermal and cardiovascular strain. The average heart rate during the last 10% of TTs was 185 bpm. These physiological responses are in line with previous field[5] and laboratory[11] studies and suggest that relative exercise intensity was likely near maximal.[9] Thus the average heart rates reported in the current study are similar or slightly above those previously reported during an ITT (174 bpm)[12] and TTT (165 bpm)[13] in temperate environmental conditions.

Limitations

The ingestible pills used in the current study had been reported to underestimate core temperature during cycling by 0.34°C when compared with a rectal probe.[14] However, subsequent to that report and prior to the current study, the manufacturer implemented modifications to their calibration procedure to account for this systematic error.[15] Notwithstanding, it is impossible to control the location of the ingestible pill during a race—and its was likely located in slightly different places among cyclists based on individual transit times.

The cyclists had been instructed to take the pill at breakfast, with the TTT and ITT starting between 13:22 hours and 15:52 hours, and the women and men RR starting at 12:45 hours and 10:30 hours, respectively. Of the 70 pills we distributed, 40 data sets could be analysed. This was due to pills having been passed before download, incoherent values from pills remaining in the stomach and affected by cold water ingestion, and cyclists not complying with study requirements. Moreover, given the nature of the event it was not possible to control for team tactics or the hydration level of the cyclists.

Conclusion and applicability of our results

A core temperature of at least 39°C was reached in 85% (ie, 34 of 40) of the elite male and female cyclists participating in the study during the 2016 UCI Road World Championships under hot conditions. Of the athletes, 25% (ie, 10 of 40) reached a core temperature of 40°C, with the highest individual value recorded being 41.5°C. Despite the elevated core temperature, none of the athletes were admitted to the medical facilities for heat-related issues. Thus, while a core temperature above 40°C is a primary diagnostic criterion for exertional heat stroke, this temperature is often reached by several elite athletes while competing in the heat. As such, the severity of heat stroke should be defined by the severity of central nervous system dysfunction at the time of collapse, along with rectal temperature.[10,16] In addition, core temperatures were higher during TTT and ITT than RR, despite being shorter events. This reinforces the notion that exercise intensity is a more potent parameter than duration for increasing body temperature. Accordingly, while reducing event duration in extreme environmental conditions is a viable option for limiting exposure time, it may not be sufficient for events where a high intensity is maintained.

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Competing interests None declared.

Patient consent Not required.

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