

Responses of Elite Road Motorcyclists to Racing in Tropical Conditions: A Case Study

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Introduction: Anecdotal reports suggest that elite road motorcyclists suffer from high core body temperatures and physiological and perceptual strain when competing in hot conditions. **Methods:** Four male non-heat-acclimatized elite motorcyclists (3 Superbike, 1 Supersport) had their gastrointestinal temperature, heart rate, and respiratory rate measured and recorded throughout practice, qualifying, and race sessions of an Australian Superbike and Supersport Championship round contested in tropical conditions. Physiological strain was calculated during the sessions, and fluid-balance measures were taken during practice and qualifying. Rider thermal sensation was assessed immediately postsession. **Results:** Mean ambient temperature and relative humidity were 29.5–30.2°C and 64.5–68.7%, respectively, across the sessions. Gastrointestinal temperature rose from 37.6°C to 37.7°C pre-session at a median rate of 0.035°C, 0.037°C, and 0.067°C/min during practice, qualifying, and race sessions to reach medians of 38.9°C, 38.8°C, and 39.1°C postsession, respectively. The peak postsession gastrointestinal temperature was 39.8°C. Median heart rates were ~164, 160, and 177 beats/min during the respective practice, qualifying, and race sessions, contributing to median physiological strain of 5.5, 5.6, and 6.2 across the sessions. Sweat rates were 1.01 and 0.90 L/h during practice and qualifying sessions, while rider thermal sensation was very hot after each session. **Conclusions:** This investigation confirms that elite road motorcyclists endure moderate to high physiological strain during practice, qualifying, and race sessions, exhibiting more-rapid rates of body-heat storage, higher core body temperatures, and higher physiological and perceptual strain than their stock-car-racing counterparts when competing in tropical conditions.

Keywords: heat, physiology, motor sport, thermal

Despite anecdotal accounts of motor-sport athletes suffering high physiological strain while competing in hot conditions, there are few reports addressing this phenomenon in the peer-reviewed literature. Brearley and Finn¹ characterized the physiological responses of V8 Supercar drivers during races in tropical conditions, reporting substantial driver heat storage with a peak gastrointestinal temperature of 39.7°C and high physiological strain despite the provision of cooling during races. That report was the most thorough analysis of heat stress during motorcar racing where driver protective attire severely restricts body-heat dissipation, and, when combined with the physical workload of driving within an extremely hot cabin, creates uncompensable conditions, where body-heat storage is inevitable. While elite road motorcyclists do not endure the high cabin temperatures encountered by stock-car racers, the riders' physical workload to maneuver the motorcycle, limited permeability of their protective attire, inability to use active cooling, and hot ambient conditions could manifest in physiological responses that detrimentally influence performance, safety, and ultimately rider health when competing in the heat. There is, however, an unfortunate lack of physiological data for elite road motorcyclists, despite the popularity and breadth of road motorcycling championships. Such categories include the Australian Superbike and Supersport Cham-

pionships that use modified commercially available road-going motorcycles, with the Supersport category permitting engines of 600 cc, while Superbike engines are 1000 cc. These championships were recently expanded to incorporate a round in the tropics of Northern Australia. The championship round was contested during the late wet season, when high ambient temperatures combine with elevated environmental moisture, thus providing an opportunity to report the physiological and perceptual responses of elite road motorcyclists to competition in tropical conditions.

Methodology

Participants

Four male partially heat-acclimatized elite motorcyclists competing in the Australian Superbike (3) and Supersport Championship (1) volunteered and provided written informed consent for this study, which was approved by a local human research ethics committee and the race organizers. The participants had a median (range) age of 24.5 (21.0–28.0) years, height 1.75 (1.72–1.83) m, mass 73.9 (70.8–74.9) kg, and body-mass index (BMI) of 23.9 (22.2–24.4).

Championship Round

The championship round was conducted at Hidden Valley Motorsports Complex, Darwin, Northern Territory, Australia, consisting of four 30-minute practice sessions over the initial 2 days, two 30-minute qualifying sessions on day 3, and two 17-lap (48.8-km)

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races on the final day. Sessions were at similar times across each day. The formats were identical for Superbike and Supersport categories.

Physiological Measures

Gastrointestinal temperature (T_{gi}) was measured by an ingestible sensor consumed 3 to 4 hours before each session (Jonah, Vital-Sense, Respronics, Pittsburg, PA, USA) and recorded by a wearable sensor that also measured and recorded heart rate according to Brearley et al.² Hydration status was estimated from pre-session urine specific gravity determined by a refractometer (UG- α , Atago, Tokyo, Japan). Riders had pre- and post-session body mass determined as per Brearley et al.² Physiological strain was calculated according to Moran et al.³ with T_{gi} substituted for rectal temperature. Where T_{gi} exceeded 39.5°C, the peak value replaced 39.5°C in the equation. Maximal observed rider heart rate was substituted into the equation if it exceeded 180 beats/min.

Perceptual Measures

The modified scales of Gagge et al.⁴ were used to assess pre-session and post-session thermal sensation and thermal discomfort. Rating of perceived exertion was assessed for each driving bout according to Borg.⁵ The perceptual strain index was calculated according to Tikuisis et al.⁶

Athlete Cooling

Participants were free to undertake precooling during the investigation, with all riders using cooling before race sessions. Water immersion (5–12 min at 22°C) and crushed-ice ingestion (150–300

mL) were their methods of choice. Towels soaked in ice water were draped over the posterior neck of riders while they were stationary on the grid prerace for approximately 5 minutes.

Environmental Conditions

Ambient temperature, relative humidity, and apparent temperature data were acquired every 30 minutes from the Bureau of Meteorology Darwin Airport weather station, located 4.4 km from the race track.

Statistical Analysis

Due to the limited sample size, descriptive measures were used to report dependent variables from the practice, qualifying, and race sessions.

Results

Mean ambient temperature (29.5–30.2°C), apparent temperature (30.9–31.3°C), and relative humidity (64.5–68.7%) were similar between practice, qualifying, and race sessions.

The T_{gi} response was similar during practice and qualifying sessions, with median T_{gi} increase of 0.035 and 0.037°C/min, respectively. Racing produced a more rapid T_{gi} increase of 0.067°C/min, resulting in median T_{gi} of 39.1°C at cessation of races (Table 1). The peak end race T_{gi} was 39.8°C, which rose 0.102°C/min.

The fluid-balance data are summarized by Table 1, and the physiological strain index, perceptual strain index, and thermal-sensation data are summarized by Table 2.

Table 1 Responses of Gastrointestinal Temperature, Heart Rate, and Fluid Balance During the Respective Sessions, Median (Range)

Physiological variable	Session		
	Practice	Qualifying	Race
Pre-session gastrointestinal temperature (°C)	37.6 (37.3–37.8)	37.7 (37.5–37.8)	37.6 (37.5–37.9)
Post-session gastrointestinal temperature (°C)	38.9 (38.3–39.4)	38.8 (38.5–39.0)	39.1 (38.9–39.8)
Median heart rate (beats/min)	163.9 (148.0–173.6)	160.1 (148.0–173.6)	176.6 (171.1–182.5)
Maximum heart rate (beats/min)	188.6 (179.8–198.0)	189.1 (188.3–195.7)	191.7 (182.8–196.9)
Sweat rate (L/h)	1.01 (0.61–1.28)	0.90 (0.83–0.96)	—
Fluid consumption (L/h)	0.23 (0.00–0.80)	0.55 (0.40–1.00)	—
Urine specific gravity	1.014 (1.007–1.018)	1.015 (1.006–1.023)	1.012 (1.007–1.016)
Body-mass loss (%)	1.3 (0.9–1.6)	1.1 (0.5–1.3)	—

Table 2 Responses of the Physiological Strain Index, Perceptual Strain Index, and Thermal Sensation, Median (Range)

Session	Physiological Strain Index, 0–10		Overall Perceptual Strain Index, 0–10	Thermal Sensation, 0–13	
	Median	Peak		Pre-session	Post-session
Practice	5.5 (4.2–6.3)	7.4 (5.8–8.4)	7.3 (6.5–9.0)	8.0 (8.0–8.5)	11.0 (10.0–13.0)
Qualifying	5.6 (5.0–6.3)	8.0 (6.9–8.2)	7.6 (6.9–8.6)	7.5 (7.0–8.0)	11.3 (10.5–12.5)
Race	6.2 (5.7–7.1)	8.3 (7.5–9.7)	8.3 (7.0–8.7)	6.0 (5.0–9.0)	11.5 (10.0–12.0)

Discussion

Subsequent to winning the 2013 Catalunya MotoGP, contested in a dry 31°C at Montmeló, Spain, World Champion Jorge Lorenzo commented, "It was very difficult because this was the hottest race, physically it was very tough. Very tough to stay focused and not lose your concentration." Such anecdotes are common from motor-sport athletes after races contested in warm to hot conditions. Yet despite the apparent thermoregulatory challenge, little is known of the physiological impost caused by elite motorcycle racing in the heat, with no reports to our knowledge in the peer-reviewed literature. This investigation is the first to confirm that elite motorcyclists suffer from rapid body-heat storage and substantial elevations in core body temperature during short road races in tropical conditions. Unfortunately, the comparison of data between motor-sport studies of thermal stress is restricted by the lack of publicly available data.⁷ In the sole peer-reviewed analysis of motor-sport heat stress during competition, Brearley and Finn¹ detailed physiological and perceptual responses to V8 Supercar (stock car) racing on the same circuit used by the riders of the current investigation. Both studies examined 4 partially heat-acclimatized motor-sport athletes with similar anthropometric values racing over a comparable duration (~21 min). Notwithstanding the small cohorts, elite motorcyclists demonstrated a more rapid change in T_{gi} during racing than the V8 Supercar drivers (median 0.067 vs 0.042°C/min), with an end race T_{gi} of 39.1°C compared with 38.8°C for the V8 Supercar drivers. The highest T_{gi} observed during the current investigation was 39.8°C, concomitant to a T_{gi} change of 0.10°C/min, which is among the highest rate reported (Figure 1). Similarly high peak T_{gi} (39.7°C) was observed for V8 Supercars, demonstrating that high core body temperatures are attainable by both 2- and 4-wheel motor-sport athletes racing in hot conditions. When combined with the very high physiological strain index and high to very high perceptual strain index observed during the current study, it is intuitive to anticipate deterioration of rider performance as athletes approach their thermal limit. Limiting the rise of core body temperature and the resultant physiological and perceptual strain is likely to curb the impact of the environment on rider performance; however, cooling strategies are limited to prerace.

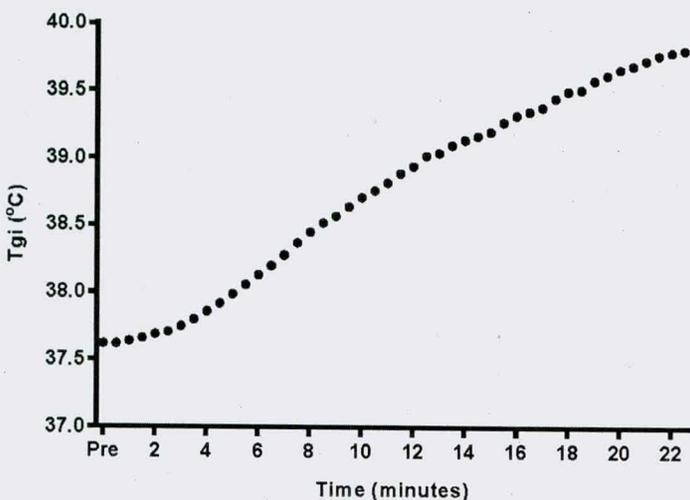


Figure 1 — Example of gastrointestinal-temperature (T_{gi}) response during a race.

The riders in this investigation used temperate-water immersion and/or crushed-ice ingestion to lower prerace T_{gi} by 0.1°C to 0.5°C, notwithstanding the possibility of local cooling overestimating the true effect.⁸ Athletes were free to determine the endpoint of water immersion precooling, resulting in relatively short immersions (5–12 min). A more aggressive approach through use of cooler water or longer immersions is warranted given the end-race T_{gi} values. Similarly, consumption of greater volumes of crushed ice than the 2 to 4 mL/kg by the riders in this investigation would create a larger heat sink to delay T_{gi} rise during sessions.⁹ We recommend ingestion of 5 mL/kg when initially trialing this strategy in the heat,¹⁰ as thermoneutral, lean, ~80-kg athletes can expect to lower T_{gi} by ~0.3°C,⁹ thereby balancing cooling power and convenience during trials. Neck cooling was also implemented on the grid after approval by race organizers and is a worthwhile adjunct to the aforementioned strategies.¹¹

The sweat rates from practice and qualifying are similar to those elicited during V8 Supercar races.¹ Provided that fluids are freely accessible before a race, including while on the grid, the sweat rates reported here should not pose issues for the riders maintaining dehydration within the recommended 2% body-mass threshold¹² during short races.

Practical Applications

Precooling strategies including water immersion, crushed-ice ingestion, and on-grid neck cooling are recommended for elite road motorcyclists racing in hot conditions, with an objective of limiting physical pacing of effort by delaying the onset of high core body temperatures and physiological and perceptual strain. Heat-acclimatization strategies may also be necessary to combat excess heat storage.

Summary

This investigation supports anecdotal evidence of elite road motorcyclists enduring high core body temperatures. Based on available data, elite road motorcyclists experience greater physiological perturbation than do stock-car drivers during short races in tropical conditions. Although there are insufficient data to determine if rider performance was affected, limiting the rise of core body temperature and the resultant physiological and perceptual strain is likely to curb the impact of the environment on rider performance, health, and, ultimately, safety.

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