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Running Title: Ultra Cycling Case Report

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New Findings:

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Dynamic heart rate response to multi-day unsupported ultra-endurance cycle racing: a case report

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New Findings

What is the main observation in this case?

Ultra-endurance cycle racing is known to lead to suppressed heart rates as a product of time spent racing. This case report identifies a racer who experienced this phenomenon initially, but then uniquely experienced an overall increase in heart rate late in the race.

What insight does it reveal?

In this case, unique chronotropic disturbances to heart rate occurred as a result of the many extreme demands of ultra-endurance racing. Work should now focus on identifying the frequency of this response in other racers and whether the causes are physiological, environmental or genetic in nature.

Abstract

Participation in ultra-endurance cycling events such as the Transcontinental Race is increasing. These extremely demanding races provide a unique opportunity for field observation as to the limits of human endurance physiology and importantly, when these limits might be exceeded, and crossover into pathology. The heart is of special interest in this field and previous data suggest 'reverse drift' of heart rate occurs as a product of time and load in races of 24 - 48 hrs, whilst transient structural abnormalities have been observed upon completion of running ultramarathons. Here, we report a unique case of a male cyclist racing in the Transcontinental Race over an extended period of 14 days characterised by extreme workloads and low quantity and quality of sleep. Heart rate response was dynamic over the course of the race and defined by a U-shaped quadratic relationship. Larger scale study is required to determine the relevance of this information to the ultra-endurance cycling community.

Introduction

The body of evidence investigating combined environmental and physiological stressors is limited (Tipton, 2016). Participation in ultra-endurance sporting events are rapidly growing in popularity and provide a unique opportunity for field study into the physiological outcomes of combined environmental stressors on a background of excessive fatigue. Moreover, There is a body of evidence emerging which has identified that acute exposure to ultra-endurance exercise can result in transient adverse effects to cardiac function (La Gerche & Heidbuchel, 2014), with specific focus on the right ventricle (Oxborough *et al.*, 2011; La Gerche *et al.*, 2012). Much of this information comes from studies of ultra-distance running, which typically cover 100-160 km and last 24-36 hrs. On the other hand, studies of ultra-endurance cyclists have reported transient effects on the presence of blood biomarkers for cardiac damage but no structural deficiencies (Williams *et al.*, 2011). Information on the chronotropic response of the heart to endurance cycling is limited, but previous studies have reported 'reverse drift' in average heart rates of subjects over time in races of 25-35 hrs in duration (Neumayr *et al.*, 2003; Neumayr *et al.*, 2004). What is not known is the effect on heart rate of multiple days of exposure to excessive workloads with little rest. The emergence of long unsupported races, such as the Transcontinental Race, which occur over 4000 km or more provide an opportunity to investigate this in the field. He we present a retrospective report of race, environmental and physiological data from a Transcontinental Race No5 (TCRNo5) competitor in who, we observed a dynamic heart rate response over 14 days of ultra-distance cycling covering 4000 km across Europe in changeable conditions, in which extreme heat and poor sleep quality were a prominent feature.

Case report

Ethical consent

This report is a post-race analysis of data that are in the public the domain, therefore ethical approval for the report was not required. As the subject is also one of the authors (DB), informed consent is hereby given for their data to be used in the context of this case report. This report conforms to the Declaration of Helsinki with the exception of clause 35 as prior registration on a database was not completed. The authors clarified with their institution that IRB clearance was not required.

Data availability

After racing the data were uploaded to online training software suites for analysis (Garmin, Germany; Strava, USA) and are publicly available at https://connect.garmin.com/modern/profile/djbrayso. Further analysis was also performed on Strava (https://www.strava.com/athletes/daniel_brayson).

The Subject

At the time of racing, he was a 32 year-old well-trained recreational male competitor, 182 cm tall and with a body mass and body mass index of 73.3 kg and 22.1 kg/m^2, respectively. His pre-race training amounted to approximately 5000 km of cycling from January to July 2017. 281 competitors started TCRNo5. The subject placed 54th out of 94 competitors who completed the race inside the cut-off time for race classification (https://www.transcontinental.cc/race-records/). Prior to the race he underwent screening to ensure he was in adequate health to compete. His clinical records showed that his ECG characteristics were unremarkable other than a possibility of electrical indication for left ventricle hypertrophy, though that fact he was very lean may account for this observation. Moreover, he had no prior history of cardiovascular health issues. His resting heart rate before the race was 50 beats per minute (bpm). Distance, cumulative elevation gain, velocity, environmental temperature and heart rate were measured by an Edge 1000 head unit, coupled wirelessly to a heart rate monitor chest strap (Garmin, Germany). Measurements of power and calorie expenditure were derived (https://support.strava.com/hc/en-us/articles/216917107-How-Strava-Calculates-Power).

The complete dataset for the race is given in Table 1. Average daily power was recorded as 109 {plus minus} 12 watts. Analyses of average heart rate data appeared to show a decrease in heart rate over time followed by an increase towards the end of the race. To assess this complex relationship a second-order polynomial regression analyses was fitted to daily average heart rates and showed a U-shaped quadratic relationship of heart rate response. To establish the turning point- the point at which heart rate ceased to decrease and began to increase, inferential statistics were deployed. To gain reliable confidence intervals (CI), bootstrap resampling was performed using an open source statistical programme (Hopkins, 2012). For the quadratic relationship the R^2 was 0.63 with a standard error of the estimate (typical prediction error) of plus or minus 9 bpm. The turning point was calculated as 6.7 (7 days) with a bootstrap-derived 95% CI of 5.5 - 7.5 days. The corresponding mean heart rate from the model was returned as 122 bpm. Additionally maximal heart rates appeared to undergo a progressive increase during the race overall (Fig. 1B), and on the morning of Day 7 the subject experienced a resting tachycardia (HR of >170) before commencing cycling that day, which decreased to a relatively normal value after commencing cycling (Fig. 1C).

Environmental temperature was warm leading up to Day 4 at which point a dramatic increase in daily average and maximum temperatures was observed. Temperature remained high throughout the remainder of the race (Table 1). At the end of Day 12 the subject reported feeling extremely fatigued and irritable, and suggested that overexertion in the heat was responsible. Subsequently, day 13 was marked by substantial decrease in performance and overall workload (see Table 1). Linear regression performed on average daily power versus average daily temperature showed a strong negative relationship (R^2=0.34, Fig. 2A).

Sleep was recorded by a wristwatch activity device (Garmin, Germany), which measured an average of 247 min/day during the race, which was significantly different to a typical 'out of race' week of sleep recorded as an average of 533 min/day (Fig. 2D). Moreover, the coefficient of variance for sleep obtained during the race was greater than out of race, suggesting less consistent sleep quantity occurred during the race (Fig. 2E). Regression analysis average power versus sleep preceding and after daily cycling indicated that sleep was not directly correlated with performance (Fig. 2D,E).

Resting heart rates were measured daily for 9 days after the race. These were initially very high and decreased over this time, but did not fully return to pre-race resting values in this time (Table 2).

According to derived calculations based on heart rate (https://www.firstbeat.com/en/energy-expenditure-estimation-firstbeat-white-paper/) the subject expended a total of 75,929 calories during the race. The subject's body mass was measured 24 hours after race completion. He weighed 70.1 kg meaning a loss of at least 3.2 kg had occurred during the race. This represents a point at which fluid replacement had occurred and indicates the unmet energy demands in this individual of this demanding race. This is supported by the slow post-race recovery of body mass, despite the insatiable eating regimen employed after the race as subjectively reported by the subject (Table 2).

Apart from overall fatigue and tiredness, the subject reported no subsequent adverse health effects and returned to his non-physically demanding vocation as a research scientist 48 hrs after completing the race. 8 months after the race the subject underwent another ECG screen, which was comparable to the initial ECG.

Discussion

Though participation in these events is increasing substantially, this is the first report on the physiological consequences of unsupported racing in which nutritional and rest/sleep needs are approached in a less structured manner compared to supported elite racing. Though undoubtedly doing so at slower moving speeds, racers of these events cover similar distances as cyclists completing the Tour de France in much less overall time, the deficit in speed being compensated for by substantially less rest and sleep.

This dataset, though anecdotal, is the first to report on the cardiovascular responses to unsupported ultra-endurance cycle racing and provides new insight to the potential consequences of an extreme set of demands; repeated daily exposure to excessive physiological fatigue, environmental stress and poor sleep. The finding in this report that average heart rates increased substantially towards the end of the race after having become depressed in the middle of the race is interesting and unique. One of the significant correlative findings was that increased temperatures were associated with decreased power. This suggests that high environmental temperatures had the most profound effect on cycling performance. The race in question took place on the backdrop of a heat wave in southern Europe during August of 2017 (https://www.worldweatherattribution.org/euro-mediterranean-heat-summer-2017/). During physical activity heat provides a stimulus to accelerate heart rate increases as a compensatory mechanism for increased demand brought about by a vasodilatory response to re-direct blood flow from the muscles and core organs to the skin, in order to facilitate heat loss to the environment (Gonzalez-Alonso *et al.*, 2008).This division of resources results in lower oxygen delivery to the muscles and a consequently, accelerated fatigue (Gonzalez-Alonso & Calbet, 2003). Similarly, inadequate blood flow may lead to ischaemia and associated cytotoxicity in crucial organs including the heart, with implications for health (Mora *et al.*, 2017). However, heat was not directly correlated with heart rate in this case therefore other factors must also be contributing. Indeed, dehydration can also contribute to increase in heart rate because of reduced blood volume and consequently stroke volume (Gonzalez-Alonso *et al.*, 2000; Cheuvront *et al.*, 2003; Cheuvront *et al.*, 2010).

Poor and erratic sleep was another prominent feature of the subjects' race experience. Evidence suggests that disrupted sleep can result in higher levels of sympathetic activation overall, with resultant increases in heart rate and blood pressure (Meerlo *et al.*, 2008; Slomko *et al.*, 2018). Although sleep time preceding or after cycling was not directly correlated with performance or heart rate measurements the cumulative effect may be important to consider. Because of the confounding nature of data gathered from the field, it is not possible to conclude a mechanism for the observed heart rate response. Moreover, the observation that this excessive workload may have induced a resting tachyarrhythmia in this individual may be symptomatic of such stressful physiological demands, but there is also the question as to whether these demands are causing a genuine physiological phenomenon as a result of extreme exertion, or whether they might reveal an underlying genetic or pathologic abnormality.

Further study on the effects of these multi-day races is required to fully characterise cardiovascular responses to extreme and continued workloads with poor rest and sleep. Data mining of competition and physiological data would provide an observational strategy with high power. Mechanisms however, will require more logistically challenging prospective studies utilising measuring devices with the capability of accurately and robustly resolving the full electrical cardiac cycle. This would help to determine the nature of any disturbances, especially since the usefulness of standard commercial heart rate monitors in identifying potential tachy-arrhythmias has recently been questioned (Gajda *et al.*, 2017). Functional assessment of the myocardium by echocardiography as well as analysis of sensitive blood biomarkers for cardiac damage would enable a comprehensive characterisation of the cardiac response to this scenario (Marjot *et al.*, 2017). To answer the question as to whether extreme endurance activity can cause a genuine over-exertion or 'pheidippedes' cardiomyopathy response, or whether this reveals underlying genetic abnormalities, would also require genetic screening of candidates known to cause heart disease (Pua *et al.*, 2016).

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Competing Interests

None to declare

Table 1. Daily breakdown of data collected during Transcontinental Race No5

Day	Distance (km)	Cumulative Elevation (m)	Average speed (km/h)	Average power* (watts)	Energy expenditure* (kcal)	Heart rate (bpm)		Ambient Temperature (^oC)		Sleep (min)
						Mean	Maximum	Mean	Maximum	
1	308.3	3657	22.9	118	6373	142	171	17	33	0
2	354.9	3644	22.3	107	6833	143	184	22	39	354
3	288.9	3962	23.0	129	6494	134	186	18	35	206
4	268.3	3228	21.9	115	5664	135	178	23	42	389
5	240.7	1328	23.3	103	4270	111	168	30	42	149
6	399.7	2128	25.6	111	6942	116	188	25	38	195
7	289.9	3961	20.4	111	6349	126	202	24	39	404
8	239.2	1587	25.7	105	3911	119	205	25	37	NA
9	265.4	1176	24.5	102	4436	126	206	26	50	340
10	235.3	3184	21.1	116	5203	151	207	18	33	185
11	228.2	996	26.2	102	3561	132	200	23	33	231
12	310.5	1998	26.0	125	6004	130	197	27	43	302
13	139.8	1181	20.4	85	2332	154	200	27	41	451
14	409.6	4117	19.9	91	7557	158	205	27	46	0
Total	**3978.7**	**36147**			**75929**					**3206**
Mean	**284.2**	**2582**	**23.1**	**109**	**4864**	**134**	**193**	**24**	**39**	**247**
SD	**71.4**	**1202**	**2.2**	**12**	**1358**	**14**	**13**	**4**	**5**	**144**

*Derived Values

NA = Not available

Table 2. Pre- and post-race data

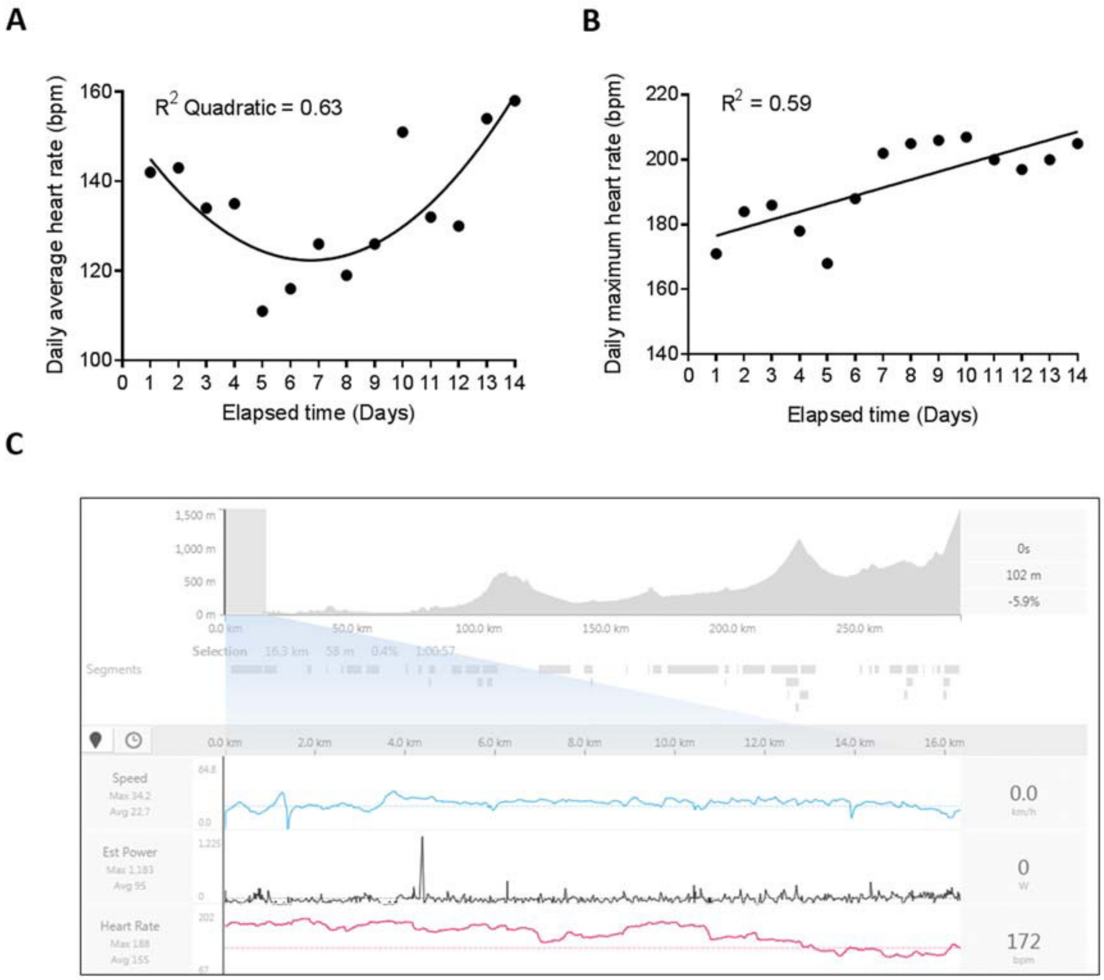
	Day	Heart rate (bpm)	Body Mass (kg)
Pre-Race	-1	58	73.3
	0	52	73.5
Post-Race	15	91	70.1
	16	61	70.1
	17	65	70.3
	18	90	70.6
	19	68	70.0
	20	68	NA
	21	68	71.6
	22	58	71.3
	23	64	70.9

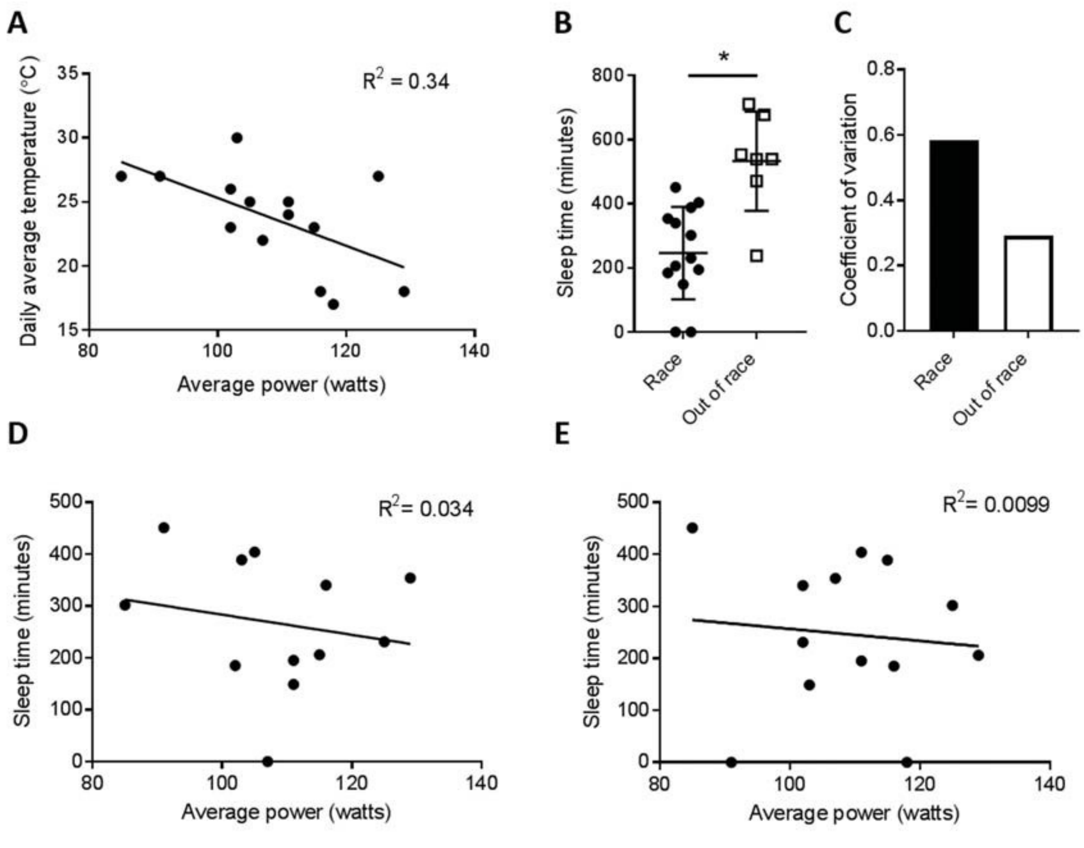
NA = Not Available

Figure legends

Figure 1. The subjects' daily heart rates underwent dynamic changes over the course of Transcontinental Race No5. A. A second order polynomial was plotted for the average daily heart rates versus elapsed time in days to reveal a U-shaped quadratic relationship. **B.** Overall, daily maximum heart rates increased as the race progressed shown by linear regression. **C.** Raw data trace from Strava online software highlighting a substantial resting tachycardia despite being at rest.

Figure 2. Summary of effects of environmental temperature and sleep time during Transcontinental Race No5. A. Average daily power was directly negatively correlated with average daily temperature according to linear regression**. B.** Daily sleep records for the race period were plotted against a typical 'out of race' week (sampled from May 2017) to show a significant reduction in quantity of sleep. A paired T-test was used to compare for differences. $P<0.05$ **C.** The large coefficient of variation also suggests high variation in sleep quantity compared to the subjects' normal value. **D.** There was no direct correlation between average power and sleep obtained preceding the commencement of cycling the following day, and **E.** There was no correlation between average power and sleep obtained after cycling each day.


A
R2 Quadratic = 0.63
Daily average heart rate (bpm)
160
140
120
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Elapsed time (Days)
B
R2 = 0.59
Daily maximum heart rate (bpm)
220
200
180
160
140
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Elapsed time (Days)
C
Speed
Est Power
Heart Rate
0.0
km/h
0
W
172
bpm


A
R^2 = 0.34
Daily average temperature (°C)
Average power (watts)
B
*
Sleep time (minutes)
Race
Out of race
C
Coefficient of variation
Race
Out of race
D
R^2= 0.034
Sleep time (minutes)
Average power (watts)
E
R^2= 0.0099
Sleep time (minutes)
Average power (watts)