Physiology, Power Output, and Racing Strategy of a Race Across America Finisher

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ABSTRACT

SCHUMACHER, Y. O., C. AHLGRIM, S. PRETTIN, and T. POTTGIESSER. Physiology, Power Output, and Racing Strategy of a Race Across America Finisher. *Med. Sci. Sports Exerc.*, Vol. 43, No. 5, pp. 885–889, 2011. The Race Across America, a 4800-km nonstop cycle race, is one of the most demanding endurance sports events. We display the racing strategy, power output, HR, hormonal levels, and inflammatory markers of an athlete before and during the race, which he completed in 10 d 23 h. The athlete showed physiological characteristics of a well-trained (nonelite) cyclist ($\dot{V}O_{2peak}$ = 63 mL·min^{-1}·kg^{-1}, heart volume = 11.3 mL·kg^{-1}). The race was mainly performed at low intensities (mean ± SD: power output = 141 ±76 W, HR = 117 ±14 bpm). During the race, testosterone levels dropped initially by 30–40% and returned to baseline toward the end. Cortisol remained elevated throughout (+75%–90% compared with baseline). Markers of inflammation (C-reactive protein), dehydration, and protein catabolism (albumin) were not affected. The athlete used a race strategy with regular sleeping breaks (total rest = 91 h, 45 h of sleep). Contrasting conventional racing strategies for the Race Across America, which aim at minimizing sleep and maximizing ride time, our case demonstrates that by emphasizing regular recovery and sleep, such alternative strategy might lead an equally successful race result. **Key Words:** PERFORMANCE, CYCLING, FATIGUE, PACING, ULTRA ENDURANCE

The cycling Race Across America (RAAM) is unarguably one of the hardest individual endurance sport events (16). Four thousand eight hundred kilometers has to be covered in 12 d in an individual effort, which is much more than during the Tour de France, where approximately 3800 km is covered in 21 d. The winner of the RAAM usually performs the task in 8–9 d. In contrast to other endurance sport disciplines, the determination of performance in the RAAM is much more complex and involves a multitude of physiological and psychological factors (17,21). In general, it is believed that the rider who is able to sustain the longest effort without sleeping will be the most successful. Therefore, most participants only sleep 2–3 h per night, riding 20 h every day, thus jeopardizing their recovery and their physical performance. The line between this strategy and fatigue causing withdrawal from the race is thin and slims further with ongoing race duration, as illustrated by several fatal traffic accidents that have occurred during the event because of sleep deprivation. Furthermore, it is known that the capacity of the organism to cope with sleep deprivation cannot be trained, making all training for this part of the effort difficult. Several reports have described different aspects of the RAAM, mostly focusing on energy intake, metabolic issues, or medical aspects (4,8,9,12,14). Little is known about the maximal sustainable intensity that can be produced over this extreme volume of cycling. In addition, the wake–sleep cycle and hematological and biochemical indicators of stress have not been well described in this unique high-volume event.

The purpose of this case study was therefore to document the race strategy, race intensity, and physiological response in a successful finisher (top 10) of the RAAM.

CASE REPORT

A 45-yr-old male athlete was followed in the lead up and during his first participation in the RAAM 2008 using conventional physiological measurements methods. The athlete finished the race in seventh place after 10 d, 22 h, and 53 min and an average speed of 18.34 km·h^{-1}. He gave informed consent for the publication of his case. His physiological and anthropometrical data are displayed in Table 1.

A complete medical and physiological check with echocardiography, determination of hemoglobin mass (20), and an incremental cycling test (SRM Ergometer; protocol: start at 100 W, increment of 20 W every 3 min until volitional exhaustion; SRM Rad-Messtechnik, Jülich, Germany) was performed 2 months before the race. $\dot{V}O_{2peak}$, lactate threshold (LT), and individual anaerobic threshold (IAT) (on the basis of the lactate and HR recordings during the test) were

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Submitted for publication June 2010.
Accepted for publication September 2010.

0195-9131/11/4305-0885/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0b013e3181fec009

TABLE 1. Anthropometrical and physiological data of a RAAM participant obtained 8 wk before the race.

Age (yr)	45
Training (yr)	8
Kilometers per year (2008)	29,924
Height (m)	1.80
Weight (kg)	77
Hb mass (g·kg^{-1})	12.54
Heart volume (mL·kg^{-1})	11.3
Power output at LT (W·kg^{-1})	2.37
Power output at IAT (W·kg^{-1})	3.72
Maximal power output (W·kg^{-1})	4.69
$\dot{V}O_{2peak}$ (mL·min^{-1}·kg^{-1})	63.2
Maximal HR (bpm)	174

determined as measures of aerobic performance (18). Basic exercise test data are displayed in Table 1.

During the RAAM, the athlete wore am HR monitor (Polar Oy, Kempele Finland) and used an SRM Powermeter (SRM Rad-Messtechnik) on his bicycle; thereby, HR and power output during the entire race were registered every 5 s. The power meter was zeroed at the start of each riding segment. The times and distances for every cycled segment were recorded, and the sleeping/recovery times were noted. Sleep quality was not assessed.

Figure 1 displays the timeline of the RAAM together with HR, power output, cadence, and speed. The main findings are a very constant power output throughout the race, resulting in a relatively steady speed despite a constantly changing topography during the race. HR showed a decrease over race duration.

At the start and at the finish and on five mornings during the race at 8:00 a.m. local time, a venous blood sample was obtained from a forearm vein. Blood sampling was performed after a period of 10 min to allow the vascular volumes to stabilize with the athlete in a seated position (3). The blood was centrifuged and stored at −4°C. After the race, all the samples were analyzed in batch for albumin (as a measure of protein metabolism and hydration), testosterone (as a measure of the hormonal/metabolic state), C-reactive protein (CRP, as a measure of inflammation), cortisol (as a measure of stress or sympathetic activation), and pro–brain natriuretic peptide (pro-BNP, as a measure of cardiovascular stress and an indicator of left ventricular dysfunction). All measures were performed according to current laboratory standards on equipment in a certified laboratory that was submitted to regular internal and external quality controls. The laboratory values are displayed in Table 2. The main results were an initial rise in pro-BNP and a drop in testosterone, and both variables gradually returned to baseline with ongoing race duration. Cortisol increased from the start of the race and remained elevated beyond the normal range throughout the race.

DISCUSSION

The data obtained from the HR and the power output recordings during the race identify the RAAM as a continuous, low-intensity effort. Compared with other cycling race types, virtually no time is spent at higher intensities, and there is little variation of power output. Power output throughout the race averages 1.8 W·kg^{-1}, which is lower than data reported for flat stages of major cycling

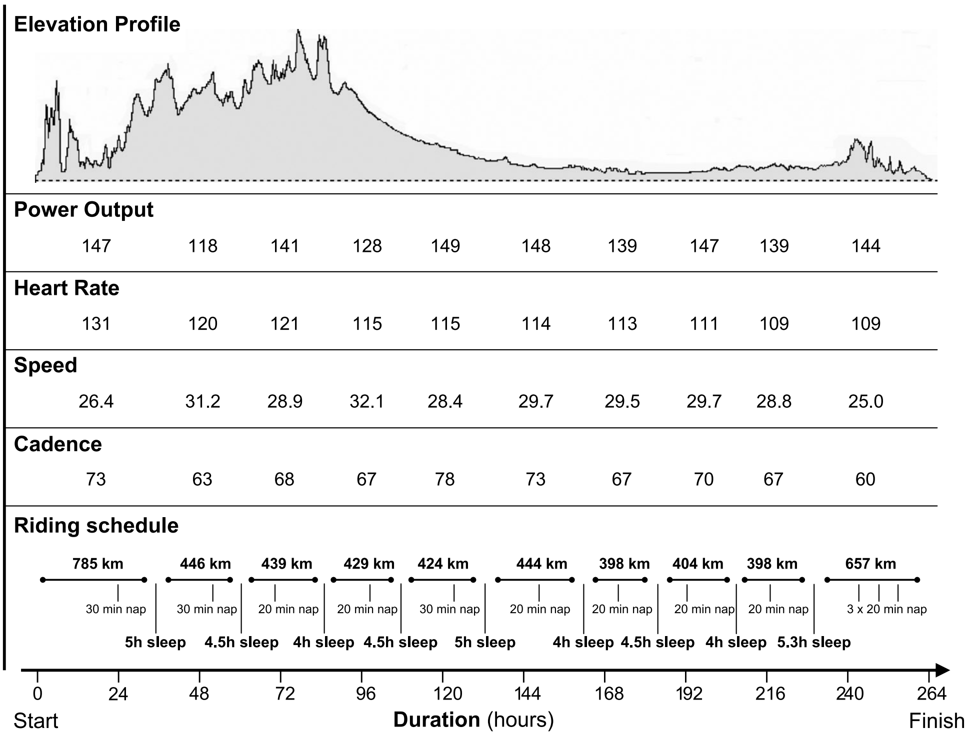

FIGURE 1—Elevation profile of the RAAM 2008, power output (W), HR (bpm), speed (km·h^{-1}), cadence (rpm), and the riding schedule of the studied athlete.

TABLE 2. Laboratory data before and during the RAAM (normal ranges as indicated by our laboratory).

	Albumin ($g \cdot dL^{-1}$)	HS-CRP ($mg \cdot dL^{-1}$)	pro-BNP ($pg \cdot dL^{-1}$)	Testosterone ($nmol \cdot L^{-1}$)	Change from Baseline (%)	Cortisol ($nmol \cdot L^{-1}$)	Change from Baseline (%)
Normal range	3.4–4.8	<5	<125	9.9–27.8		171–536	
Baseline	4.4	0.04	40	11.79		429	
Day 2	4.5	0.9	614	8.36	71	809	189
Day 4	4.3	0.5	713	7.27	61	757	177
Day 5	4.3	0.42	476	9.22	78	784	183
Day 7	4.2	0.2	469	10.56	90	615	143
Day 9	4.3	0.0	246	14.8	126	737	172
Day 10	4.1	0.07	245	16.73	142	705	164
Finish	4.1	0.12	99	17.68	167	646	105

Changes from baseline (%) are indicated for testosterone and cortisol.

tours (2.5–3.5 $W \cdot kg^{-1}$) (22). This difference is certainly due to the different duration and average speeds of the events.

The athlete kept a constant speed throughout the race with no drop in velocity toward the end, suggesting an appropriate pacing strategy (Fig. 1). It has to be noted that the official, overall speed average of 18.34 $km \cdot h^{-1}$ comprises all resting periods. The average speed calculated for actual cycling time (not including recovery periods) was 28.04 $km \cdot h^{-1}$.

From a physiological point of view, the exercise testing data of the studied athlete obtained before the race are comparable with those reported for well-trained (nonelite) cyclists. The aerobic performance (described as power output at LT or IAT) is substantially lower than that in professional cyclists competing in conventional road races. Similarly, other measures that have been used to predict or describe aerobic performance such as $\dot{V}O_{2peak}$, hemoglobin mass, and cardiac volume were noticeably lower than that in professional cyclists (5,6). These data suggest that maximum aerobic capacity and other physiological characteristics known to support high-intensity aerobic exercise are not required for success in the RAAM. When relating the power output during the race to the results of the laboratory test conducted before the race, it appears that the athlete performed virtually the entire race at intensities around or below the LT, irrespective of the topographic characteristics of the course.

During the race, a significant drop of the average HR for each segment is visible with power output remaining stable. This is in line with findings from multiday events in professional road cycling and ultraendurance cycling competition (2,15). According to the literature, this observation is most likely to be attributed to a reduced sensitivity of the heart to sympathetic stimulation, exercise-related plasma volume expansion, or a fatigue-associated sympathetic activity of the nervous system with ongoing racing. However, in view of the laboratory (cortisol) measures described in the following sections, the latter mechanism seems unlikely in our data. The fact that power output did not change accordingly but remained stable over the entire race might allow speculation on other explications; in fact, it might be possible that the phenomenon indicates some kind of "training adaptation" in reducing the HR necessary for a given exercise intensity. However, no information on the respective development of maximal HR and power output throughout the race or other measures that might help to differentiate between these two explanations is available.

BLOOD MEASUREMENT

At baseline, all measured variables were in the normal range. HS-CRP and albumin remained stable throughout the period of the study and indicate an absence of significant systemic inflammation or important protein catabolism. In contrast, pro-BNP increased in the first few days of racing to gradually return to normal levels until the end of the race. Pro-BNP and BNP are markers of cardiovascular stress and have been shown to be elevated after different types of endurance exercise to levels well beyond what is measured in our subject (10,19). Interestingly, pro-BNP dropped back to baseline in our athlete after several days despite an unchanged exercise load. No other data are available on cardiac markers during multiday endurance events until present; however, our results suggest that the organism seems to adapt to the "new" cardiac workload, either by a down-regulation of receptors (thus modulating the same signal through a lower concentration of BNP) or by accomplishing the adaptive processes induced by the initially elevated BNP. Furthermore, it seems that the cardiovascular system is not negatively affected by 10 d of continuous, low-intensity exercise.

Testosterone decreased initially by 30%–40% and recovered slowly to reach normal levels toward the end of the race (Table 2). Extensive endurance exercise is known to suppress the hypopituitary–gonadal axis. This phenomenon has been described before for ultraendurance events as being caused by a sympathetic activation (adrenal stress response) (7,11,13). In our study, testosterone returns to normal levels during the race, which points toward the fact that the organism might have adapted to the daily challenge of cycling at this stage. Cortisol as a marker of sympathetic stress is indeed increased after the start of the race and remained elevated throughout (+75%–90% compared with baseline), as expected after several days of intensive exercise (13). This finding indicates that despite the subjective well being of the athlete, his organism was under continuous sympathetic stimulation. Whether this does in fact represent an "abnormal" state or is the normal response of an athlete participating in the RAAM is to be discussed. It has to be pointed out that the results for cortisol need to be interpreted with caution because cortisol levels are rather variable and prone to external confounders, especially considering the altered diurnal rhythm of the athlete.

FATIGUE

There is an ongoing debate on the limits of performance for different types of endurance events (1). The limit is usually a function of energy expenditure defined through the intensity and the duration of an effort. Shorter events can be sustained at a higher intensity and vice versa. Event-adapted anticipatory regulation of exercise intensity is being discussed to play a major role in this context. The RAAM has been characterized as an extremely demanding endurance cycling event (16). However, as demonstrated by our power output and laboratory test data, the intensity at which the RAAM was performed is low. As with many ultraendurance events, it appears that it is the total duration that is challenging and not the exercise intensity, which is relatively mild compared with other competitive cycling events. Athletes usually "pace" their race speed for an event on the basis of information they obtain either consciously (through experience) or subconsciously (through feedback on the state of their organs, energy supplies, etc.). The data collected in this case study suggest that nearly even pacing was adopted over the entire duration of the event. This pacing strategy was likely influenced by planning (race goals), previous training, and feedback during the event. This is compatible with the prediction of the complex regulation model of Noakes et al. (17), which suggests that the pacing strategy is chosen by the subconscious brain to insure that a homeostatic failure does not occur. Interestingly, it seems that during the race, training-like adaptations in several systems occurred, which allowed the athlete to subjectively improve his performance during the race and to avoid significant fatigue. This is illustrated by our hormonal data (pro-BNP and testosterone), the reduction in HR, and the fact that the athlete, at the finish of the RAAM, reported to be able to carry on at the given rhythm without being overly tired. As the performance standard was maintained, it is unlikely that these physiological responses are representative of "excessive stress" or overtraining.

STRATEGY

Contrasting other RAAM riders who have been reported to ride as long as possible to cover as much distance as possible in a given time and face severe sleep deprivation, the studied athlete used a different riding strategy. As pictured in Figure 1, regular breaks were scheduled to allow a certain level of recovery (total break time 91 h with 45 h of sleep). Thereby, the subject was able to cycle faster and to cover the same distance than his opponents despite less time in the saddle. Each riding segment was divided into two "shifts" separated by a short midday break with a 20- to 30-min nap. Between each segment, a longer break of approximately 7 h including an average of 4 h 32 min of sleep was respected. From a scientific point of view, human beings need between 6 and 8 h of sleep per day, with a large interindividual variability. It might therefore be speculated that our study subject was not in severe sleep deprivation during the race because he averaged a total daily sleeping time of approximately 5 h (midday nap + night sleep), which would be in line with the theory on fatigue outlined previously.

In summary, this case report demonstrates that the RAAM is a low-intensity endurance effort. The featured athlete of this case study performed an average of 141 W with a cadence of 69 rpm. Performance at this type of event cannot be assessed by conventional measures of exercise physiology because the physiological systems for energy and oxygen supply do not perform at their limits, highlighting the question which traits differentiate successful athletes in such events from their less successful competitors.

Persistent production of power output over the period of the race was associated with endocrine and biochemical changes, but in context of the perceptions and ability to maintain even pacing, these changes are likely "normal" or at least "tolerable." Contrasting conventional racing strategies for the RAAM, which aim at minimizing sleep and maximizing ride time, our data demonstrate that by emphasizing regular recovery and sleep, such alternative strategy might lead to higher race speeds and an equally successful race. From a health perspective, this approach might be preferential as well because health risks arising from sleep deprivation are minimized. Furthermore, it raises the question of the extent to which sleep deprivation contributes to unnecessary fatigue in this race. However, further research is required to identify the best work–relief cycles, sleep patterns, and nutritional strategies for overall performance in ultraendruance challenges of more than 2–3 wk.

From a more general point of view, our case demonstrates that by challenging conventional pathways and by adopting an innovative strategy, alternative concepts might lead to the successful and easier accomplishment of certain tasks. This might apply to many areas of exercise physiology and training.

No funding was received for this work (from the National Institutes of Health, the Wellcome Trust, The Howard Hughes Medical Institute, or any others).

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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