

Participating In The Race Across AMerica In A Team Of Eight Cyclists: Do Not Neglect Crew Preparation

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Background: The Race Across America (RAAM) is considered as one of the longest, and most difficult cycling races in the world. It can be performed in solo or in relay of two, four or eight persons.

Purpose/method: The aim of the present study was to investigate several physiological, perceptual and psychological responses before, during and after RAAM in a team of eight amateur cyclists. Because logistics of all team is demanding and complex, crew members have followed the same testing procedure.

Results: The main result is that parameters were globally not altered to a greater extent in cyclists than in crew members over the course of the RAAM, and that all variables returned to pre-race levels 1 week after the end of the race in both groups. In crew, body fat was decreased ($p < 0.05$) at mid-race (Mid) vs 1 week before the RAAM (Pre) (-1.5%) and total body water was increased ($p < 0.05$) at Mid vs Pre (+2.5%). In pre-relay quadriceps strength in cyclists was significantly lower ($p < 0.05$) at Mid vs Pre (41.6 ± 9.1 vs 45.0 ± 11.2 N, $d = 0.36$). Therefore, performing the race with eight well-prepared amateur cyclists seems to decrease potential risks on health. In crew, quadriceps strength remained stable at each assessment time but general fatigue increased all along the race. Anger was increased ($p < 0.05$) at Mid vs Pre in crew.

Conclusion: The most important message of this study is that crew members for a team of eight require adequate and sufficient preparation and training. Roles and responsibilities need to be thoroughly defined; individuals need to know each other beforehand and they must be prepared for sleep deprivation. The results of this study show the importance of the preparation of two teams: crew members, as well as cyclists.

Keywords: ultra-endurance exercise, strength, mood, sleep, body fat, pain

Introduction

Ultra-endurance cycling races (UECR), defined as competitions exceeding 6 hrs of duration, have become very popular in recent years.¹⁻³ The Race Across America (RAAM) is the oldest UECR and is considered as one of the longest, and most difficult in the world.^{4,5} Racers must cycle across the United States of America from West to East in solo or in relay of two, four or eight persons. RAAM represents a unique opportunity to investigate responses of the human body to an extreme load and stress (i.e. distance, elevation, climate).⁶ In the context of a team, it is the occasion to test both the cyclists and crew members. However, to our knowledge, no study has investigated a team of eight competing in this event and its accompanying staff members.

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During multiday UECR, many challenges (e.g. nutrition, hydration, sleep deprivation and environmental conditions) could affect physiological, perceptual, psychological, and performance variables.⁷⁻¹¹ Previous studies on RAAM demonstrated that a negative energetic balance occurred due to a mean daily energy deficit of about 8500 kcal in solo and ~1500 kcal in a team of four.^{8,9} In solo, the latter led to a 5 kg body weight loss, for example. However, a decrease of body weight could also be influenced by changes in hydration status,^{8,12} since it was demonstrated that effective body water changes were correlated to the body mass change in an UECR of 164 km.¹² The impact on other physiological parameters, like blood measurement, power output, strength and aerobic capacity have also been studied in UECR.^{3,6,13} While neuromuscular fatigue and strength parameters were well described in ultra-endurance running races,^{14,15} it is not the case in UECR, where only one study showed no significant loss of knee extension strength 5 days after a race of 1700 km.³

Besides, perceptual parameters were explored in non-elite cyclists during an UECR of 164 km.¹ An increase of pain, thirst, perceived exertion associated with muscle cramps from the 97 km was observed. Regarding the amount of sleep, about ~2 hrs of sleep per day were found in both solo and team of four cyclists during RAAM.^{8,9} To our knowledge, no other study reported perceptual parameters during RAAM.

Perturbations in psychological parameters (e.g. emotions and mood) are also present in UECR.^{10,11,16} For example, during RAAM, cyclists reported that they experienced an optimal emotional state for less than 50% of the total competition.¹¹ This emotional disturbance was associated with poor sleep duration and quality combined with energy deficit.¹¹ Dehydration status could also negatively affect the mood with a decreased in vigor.¹⁰ Consequently, maintaining an optimal emotional state, which is associated to functional performance, represents a challenge for athletes and crew members.^{11,17}

The aim of the present study was to investigate several physiological, perceptual and psychological responses before, during and after RAAM in a team of eight amateur cyclists. Because logistics of all team is demanding and complex, and because no previous study has investigated this population, crew members have followed the same testing procedure. It was hypothesised that physiological, perceptual and psychological parameters would be altered to a greater extent in cyclists than in crew members over the course of the RAAM. Moreover, it was hypothesised

that all measured variables would return to pre-race levels 1 week after the end of the RAAM.

Methods

Participants

Sixteen participants, all cyclists or crew members of a team of eight cyclists participating in the RAAM, took part in the present study. Four females and four males (34.1 ± 12.6 years, 175.7 ± 9.2 cm, 69.5 ± 10.7 kg) composed the cyclist group (Cyclists), while one female and seven males (38.9 ± 15.9 years, 178.9 ± 6.8 cm, 71.4 ± 10.2 kg) composed the crew members group (Crew). Cyclists included amateur athletes, who followed a supervised and individualised training program in the year before the RAAM with a mean cycling load of 4260 ± 1420 km. Crew included a crew chief, a physician, a physical therapist, a camera operator, a cycling coach, a bicycle mechanic and two drivers. The entire crew met one time before the race for a 1 day team building event, during which roles and responsibilities of each person, as well as global organisation of the crew were addressed. Prior to the beginning of the study, participants signed an informed consent after explanation of the study protocol, data collection procedures and significance of the study objectives. Ethical approval for the project was obtained from the competent committee on human research (Commission cantonale d'éthique de la recherche sur l'être humain, CER-VD, Agreement 2017-00027, Lausanne, Switzerland) and the protocol was run in accordance with the principles of the Declaration of Helsinki.

Experimental Design

The race supporting this study was the RAAM, which consists of cycling in one continual stage ~4900 km from Oceanside, CA to Annapolis, MD with a total positive elevation change of ~50,000 m. Team racers have a maximum of 216 hrs to complete the race. The present study investigated physiological, perceptual and psychological responses in Cyclists and Crew. During the race, the cyclists were split in four duos, each assisted by two crew members. During the race, each duo covered ~1240 km in eight relays of ~6 hrs (relay 1: duo 1 – duo 2 – duo 3 – duo 4; relay 2: duo 1 – duo 2 - ...). The pacing strategy and repartition of the efforts during each relay were free, with however a trend for each cyclist to cycle three times ~1 hr with ~1 hr rest period between each cycling bout.

Participants were tested four times (Figure 1): 1 week before the RAAM (Pre); at about mid-race (Mid) between

Test period	Pre	Mid				End				Post	
When	Post-sleep	Pre-relay	Post-relay	Pre-sleep	Post-sleep	Pre-relay	Post-relay	Pre-sleep	Post-sleep	Post-sleep	
Where	Home	RAAM								Home	
Physiological parameters											
Anthropometric parameters	Cyclists + Crew					Cyclists + Crew					Cyclists + Crew
Quadriceps strength	Cyclists + Crew	Cyclists	Cyclists		Crew	Cyclists	Cyclists		Crew		
Perceptual parameters											
General fatigue	Cyclists + Crew				Cyclists + Crew	Cyclists + Crew			Cyclists + Crew	Cyclists + Crew	
Subjective pain	Cyclists + Crew					Cyclists + Crew				Cyclists + Crew	
Amount and quality of sleep	Cyclists + Crew					Cyclists + Crew				Cyclists + Crew	
Psychological parameters											
Mood states	Cyclists + Crew					Cyclists + Crew					Cyclists + Crew
Cohesion of group	Cyclists + Crew					Cyclists + Crew					Cyclists + Crew

Figure 1 Summary of all the measures that were performed in cyclists and crew groups during the study.

Trinidad, CO (km 1930; ~23,000 m cumulated positive elevation) and Maize, KS (km 2610; ~25,000 m cumulated positive elevation), during the last part of the race (End) between Chillicothe, OH (km 4110; ~39,000 m cumulated positive elevation) and Rouzerville, PA (km 4730; ~50,000 m cumulated positive elevation); and 1 week after the end of the RAAM (Post). At each assessment time, physiological, perceptual and psychological parameters were tested following the main period of sleep as described below. Moreover, at Mid and End, quadriceps strength was also tested following the last relay (post-relay) of each group of two athletes in Cyclists, while in both groups, general fatigue was also tested before the main period of sleep (pre-sleep).

Physiological Parameters

Anthropometric parameters (body weight, fat mass and total body water) were acquired when barefoot in underwear using a tetrapolar bioelectrical impedance analysis instrument (Tanita Model BC-601, Tanita Corporation, Tokyo, Japan).

Maximal isometric voluntary quadriceps strength on the right side was tested at 90° of knee flexion seated using a dynamometer (Baseline Electronic push/pull Dynamometer Model 12–0343, Fabrication Enterprise Inc., NY, USA) mounted on a frame attached to a stable metallic chair. Participants of both groups were asked to push as hard as possible two times 3 with a 10 s rest

period between both repetitions, while the examiner ensured proper dynamometer positioning on the lower front tibial part.¹⁸ The best value was kept for calculation. All measures were conducted by the same examiner.

Perceptual Parameters

Participants of both groups were requested to quantify the level of general fatigue by using a visual analog scale (VAS) with a 10 cm horizontal line from 0 cm = no fatigue to 10 cm = extremely fatigued.

They were asked to quantify the level of subjective pain in four anatomical areas (ankle-leg; knee-thigh; hip-low back; cervical) and digestive feeling by using the VAS from 0 cm = no pain to 10 cm = extremely painful.

The amount of sleep in the past 24 hrs was recorded and the quality of sleep was quantified using the VAS from 0 cm = very bad to 10 cm = very good.

Psychological Parameters

To investigate alterations and fluctuations in mood states within Cyclists and Crew, the French version of Profile of Mood State (POMS) questionnaire was used. The POMS comprises 65 single-word mood descriptors, each with a 5-point Likert scale anchored by not at all and extremely, assessing one positive mood states (vigor, 8 items), five negative mood states (tension, 9 items; depression, 15 items; anger, 12 items; fatigue, 7 items; confusion, 7 items) and the state of interpersonal relationships (7

items). An overall global measure of mood (total mood disturbance) was calculated by subtracting vigor from the sum of the five negative mood states.¹⁹

The cohesion of Cyclists and Crew has been investigated using the Questionnaire sur l'Ambiance du Groupe (QAG), which is a French-language instrument for measuring group cohesion. Cohesion is considered as a multi-dimensional, dynamic construct composed of the member's perception of the group as a totality and their perceptions of the personal attractiveness of the group. The first dimension is called individual attractions to group (AG) and the second group integration (GI). Each dimension is focused on task (T) and social (S) aspects of the group. The QAG comprises 18 items (AG-T, 4 items; AG-S, 5 items; GI-T, 5 items; GI-S, 4 items), each with a 9-point Likert scale anchored by strongly disagree and strongly agree. Higher scores represented stronger perceptions of cohesiveness.²⁰

Statistical Analysis

Data are expressed as mean \pm standard deviation (SD) in the text and tables, and as mean \pm standard error (SE) in figures. They were screened for normality of distribution and homogeneity of variance using a Shapiro–Wilk normality test and a Barlett's test, respectively. Since normal distribution was not met, Friedman repeated measures analyses of variance on ranks were used to test differences across each assessment time for both groups. Tukey post-hoc tests were used to localise the differences between means. The importance of the differences found between each assessment time was assessed through the effect size and Cohen's *d* coefficient,²¹ interpreted as follows: small difference: $0.20 \leq d < 0.50$, medium difference: $0.50 \leq d < 0.80$, large difference: $0.80 \leq d < 1.30$, and very large difference: $d \geq 1.30$. To examine Cyclists vs Crew differences, Mann–Whitney rank sum test was used. For all statistical analyses, significance was set at $p < 0.05$. Statistical analyses were performed with SigmaPlot 12.5 (Systat Software Inc., San Jose, CA).

Results

The team of eight cyclists finished the RAAM in 7 days 12 hrs and 46 mins (25.8 km/h), in 13th position out of 15 teams. Each cyclist individually rode between 300 and 840 km, with a total positive elevation change between 2310 and 11,530 m. Figure 2 presents positive elevation change (m) and temperature evolution by section. These data were maximal values of the day for all sections. There was a significant difference of

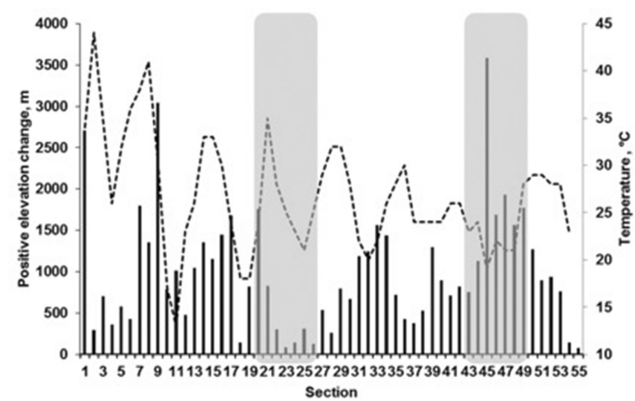


Figure 2 Evolution of positive elevation change (m) (represented by black bar histogram) and maximal temperature ($^{\circ}\text{C}$) (represented by dashed curve) by section during the race. Left axis represents bar and right grey zones represent the two assessment times during the RAAM.

temperature between the first and the last part of the race (28.6 ± 7.9 vs $24.9 \pm 3.6^{\circ}\text{C}$, $p < 0.05$) but not in elevation change. Due to inadequate participation in physiological, perceptual and psychological measurements, one female in Cyclists and one male in Crew were excluded from the data analysis.

Physiological Parameters

Body weight, body fat and total body water remained stable at each assessment time in Cyclists. In Crew, body fat was decreased ($p < 0.05$) at Mid vs Pre (-1.5%) and total body water was increased ($p < 0.05$) at Mid vs Pre ($+2.5\%$). No significant difference was observed between groups. Anthropometric parameters in Cyclists and Crew groups are presented in Table 1.

In Cyclists, pre-relay quadriceps strength was lower ($p < 0.05$) at Mid vs Pre (41.6 ± 9.1 vs 45.0 ± 11.2 N, $d = 0.36$). At Mid, post- vs pre-relay quadriceps strength was decreased ($p < 0.05$) by 11% (37.0 ± 8.0 vs 41.6 ± 9.1 N, $d = 0.58$). In Crew, quadriceps strength remained stable at each assessment time (Pre, 40.6 ± 6.1 N; Mid, 39.3 ± 5.5 N; End 40.0 ± 4.4 N). No significant difference was observed between groups. For technical reasons, no data were collected at Post. Maximal isometric voluntary quadriceps strength values are shown in Figure 3.

Perceptual Parameters

In Cyclists, general fatigue was increased ($p < 0.05$) on VAS at Mid pre-sleep vs Pre (6.0 ± 1.3 vs 1.5 ± 1.3 cm, $d = 3.74$) and post (6.0 ± 1.3 vs 1.2 ± 0.6 cm, $d = 5.12$), at Mid post-sleep vs. Pre (4.2 ± 0.3 vs 1.5 ± 1.3 cm, $d = 3.09$), and at End pre-sleep vs Pre (5.3 ± 2.2 vs 1.5 ± 1.3 cm, $d = 2.27$). In Crew,

Table 1 Anthropometric Parameters

	Pre	Mid	End	Post	Effect Size Pre-Mid	Effect Size Mid-End	Effect Size End-Post	Effect Size Pre-Post
Body weight, kg								
Cyclists	69.5 ± 10.7	70.0 ± 11.8	70.6 ± 11.9	69.4 ± 10.8	0.05	0.06	0.11	0.01
Crew	73.4 ± 9.5	72.9 ± 9.0	72.7 ± 9.1	72.5 ± 9.4	0.06	0.02	0.02	0.10
Body fat, %								
Cyclists	14.0 ± 6.1	13.7 ± 5.3	12.9 ± 6.4	14.0 ± 6.6	0.06	0.15	0.18	0.00
Crew	10.5 ± 3.2	8.0 ± 3.0* [§]	8.6 ± 2.8	9.0 ± 3.4	0.88 (large)	0.23 (small)	0.14	0.50 (medium)
Total body water, %								
Cyclists	63.4 ± 4.4	63.5 ± 3.5	65.1 ± 5.9	63.6 ± 4.8	0.03	0.36 (small)	0.30 (small)	0.05
Crew	65.1 ± 3.0	67.6 ± 3.4*	66.9 ± 3.3	66.5 ± 3.9	0.85 (large)	0.23 (small)	0.12	0.44 (small)

Notes: * $p < 0.05$ for difference with Pre; [§] $p < 0.05$ for difference with Cyclists. Data are presented as mean ± SD.

general fatigue was increased ($p < 0.05$) at Mid pre-sleep vs Pre (6.4 ± 2.3 vs 1.3 ± 1.4 cm, $d = 2.89$) and post (6.4 ± 2.3 vs 2.1 ± 1.4 cm, $d = 2.44$), at Mid post-sleep vs Post (3.9 ± 2.0 vs 2.1 ± 1.4 cm, $d = 1.13$), and at End pre-sleep vs Pre (5.1 ± 2.0 vs 1.3 ± 1.4 cm, $d = 2.38$) and Post (5.1 ± 2.0 vs 2.1 ± 1.4 cm, $d = 1.88$). No significant difference was observed between groups. Ratings of general fatigue are displayed in Figure 4.

At each assessment time, pain in ankle-leg, knee-thigh, hip-low back, and cervical areas and digestive feeling remained below 2 cm on VAS in both Cyclists and Crew. No significant change between times and groups was observed.

Sleep duration was decreased ($p < 0.05$) at Mid vs Pre in Cyclists (-33%) and Crew (-38%), and at Mid vs. Post in Cyclists (-31%) and Crew (-44%). Quality of sleep was decreased ($p < 0.05$) on VAS at Mid vs Pre (-3.5 cm) and at Mid vs Post (-4.2 cm) in Cyclists, while it remained

stable in Crew. There was no significant sleep duration difference between groups. Quality of sleep was worse ($p < 0.05$) in Cyclists vs Crew at Mid. Sleep parameters in Cyclists and Crew are presented in Table 2.

Psychological Parameters

Tension was decreased ($p < 0.05$) at Post vs Pre in Cyclists. Anger was increased ($p < 0.05$) at Mid vs Pre in Crew. In both groups, vigor was decreased ($p < 0.05$) and fatigue was increased ($p < 0.05$) at Mid vs Pre and at Mid vs Post. Total mood disturbance was increased ($p < 0.05$) at Mid vs End and at Mid vs Post in Cyclists and at Mid vs Pre and at Mid vs Post in Crew. Interpersonal relations were decreased ($p < 0.05$) at Mid vs Post in Crew. No significant difference was observed between groups for the mood aspects, excepted

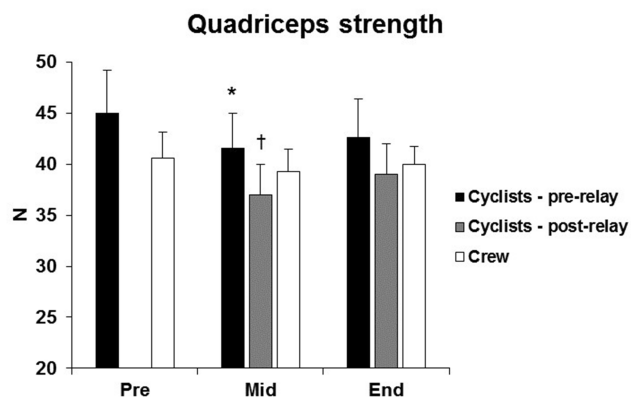


Figure 3 Maximal isometric voluntary quadriceps strength at pre, mid and end in cyclists and crew groups. * $p < 0.05$ for difference with Pre; [†] $p < 0.05$ for difference with cyclists pre-relay. Data are presented as mean ± SE.

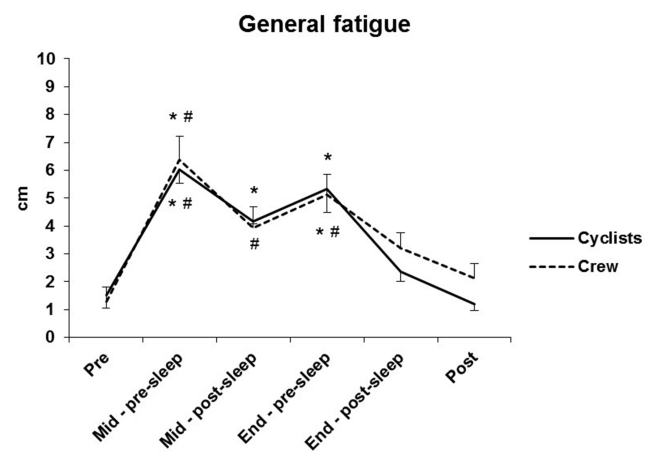


Figure 4 General fatigue at each assessment time in cyclists and crew groups. * $p < 0.05$ for difference with pre; [#] $p < 0.05$ for difference with post. Data are presented as mean ± SE.

Table 2 Sleep Parameters

	Pre	Mid	End	Post	Effect Size Pre-Mid	Effect Size Mid-End	Effect Size End-Post	Effect Size Pre-Post
Sleep duration per day, h								
Cyclists	7.2 ± 1.0	4.8 ± 1.6*	5.6 ± 1.5	7.0 ± 1.5 [#]	1.94 (very large)	0.56 (medium)	1.01 (large)	0.17
Crew	7.3 ± 0.8	4.5 ± 1.2*	5.7 ± 0.9	8.0 ± 1.2 [#]	2.97 (very large)	1.22 (large)	2.34 (very large)	0.74 (medium)
Quality of sleep, cm								
Cyclists	7.6 ± 2.7	4.1 ± 2.5*	7.3 ± 2.9	8.3 ± 2.0 [#]	1.45 (very large)	1.28 (large)	0.43 (small)	0.32 (small)
Crew	7.9 ± 1.2	6.6 ± 2.4 [§]	7.3 ± 1.8	8.6 ± 1.3	0.74 (medium)	0.36 (small)	0.89 (large)	0.60 (medium)

Notes: *p < 0.05 for difference with Pre; [#]p < 0.05 for difference with Mid; [§]p < 0.05 for difference with Cyclists. Data are presented as mean ± SD.

for the interpersonal relationships at Mid, which were lower (p < 0.05) in Crew vs Cyclists. Mood state values in Cyclists and Crew are presented in Table 3.

The four dimensions of group cohesion (social and task aspects of individual attractions to group, and social and task aspects of group integration) remained stable at each

Table 3 Profile Of Mood State

	Pre	Mid	End	Post	Effect Size Pre-Mid	Effect Size Mid-End	Effect Size End-Post	Effect Size Pre-Post
Tension								
Cyclists	7.4 ± 3.7	4.3 ± 2.9	3.6 ± 1.7	3.6 ± 1.5*	1.01 (large)	0.32 (small)	0.00	1.45 (very large)
Crew	6.4 ± 4.0	4.9 ± 3.2	6.3 ± 3.4	4.7 ± 2.1	0.45 (small)	0.46 (small)	0.61 (medium)	0.58 (medium)
Depression								
Cyclists	2.4 ± 2.4	2.7 ± 4.4	1.0 ± 2.2	2.0 ± 3.2	0.09	0.53 (medium)	0.39 (small)	0.15
Crew	1.0 ± 2.2	1.4 ± 2.8	1.7 ± 1.7	0.9 ± 1.6	0.17	0.14	0.52 (medium)	0.06
Anger								
Cyclists	5.9 ± 4.0	6.9 ± 5.5	4.7 ± 1.7	5.9 ± 4.2	0.23 (small)	0.58 (medium)	0.41 (small)	0.00
Crew	3.4 ± 3.7	8.3 ± 6.3*	6.4 ± 3.9	4.9 ± 4.9	1.02 (large)	0.39 (small)	0.37 (small)	0.37 (small)
Vigor								
Cyclists	24.4 ± 3.7	17.7 ± 6.2*	22.7 ± 4.2	24.3 ± 2.9 [#]	1.42 (very large)	1.02 (large)	0.48 (small)	0.03
Crew	23.1 ± 5.7	17.3 ± 5.6*	18.4 ± 7.0	21.6 ± 8.0	1.11 (large)	0.19	0.46 (small)	0.23 (small)
Fatigue								
Cyclists	4.1 ± 1.6	7.6 ± 1.3*	5.0 ± 2.8	3.4 ± 2.1 [#]	2.59 (very large)	1.29 (large)	0.70 (medium)	0.41 (small)
Crew	3.6 ± 1.9	7.3 ± 2.7*	7.3 ± 3.5	3.3 ± 2.2 [#]	1.71 (very large)	0.00	1.48 (very large)	0.16
Confusion								
Cyclists	6.4 ± 5.2	6.9 ± 5.2	4.4 ± 1.0	4.9 ± 1.2	0.10	0.72 (medium)	0.49 (small)	0.42 (small)
Crew	4.7 ± 2.4	5.4 ± 2.6	4.3 ± 3.4	5.0 ± 2.9	0.30 (small)	0.39 (small)	0.24 (small)	0.12
Total mood disturbance								
Cyclists	1.9 ± 14.9	10.6 ± 22.1	-4.0 ± 5.9 [#]	-4.6 ± 11.5 [#]	0.50 (medium)	0.98 (large)	0.07	0.53 (medium)
Crew	-4.0 ± 14.3	10.3 ± 16.2*	7.6 ± 16.4	-2.9 ± 13.3 [#]	1.01 (large)	0.18	0.76 (medium)	0.09
Interpersonal relationships								
Cyclists	23.3 ± 4.1	23.3 ± 4.6	25.1 ± 2.8	25.4 ± 2.6	0.00	0.51 (medium)	0.12	0.66 (medium)
Crew	21.6 ± 5.5	17.1 ± 5.0 [§]	20.7 ± 4.4	22.4 ± 4.3 [#]	0.93 (large)	0.83 (large)	0.42 (small)	0.18

Notes: *p < 0.05 for difference with Pre; [#]p < 0.05 for difference with Mid; [§]p < 0.05 for difference with Cyclists. Data are presented as mean ± SD.

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assessment time in both groups. No significant difference was observed between groups for social and task aspects of individual attractions to group. Social and task aspects of group integration at Pre were lower ($p < 0.05$) in Crew vs Cyclists (11.3 ± 5.8 vs 18.9 ± 4.4 and 27.9 ± 12.0 vs 37.4 ± 2.4 , respectively).

Discussion

The purpose of the present study was to investigate physiological, perceptual and psychological responses before, during and after the RAAM in cyclists and crew members of a team of eight amateur cyclists. The main result, in contrast to our hypothesis, is that physiological, perceptual and psychological parameters were not altered to a greater extent in cyclists than in crew members (excepted for quadriceps strength and quality of sleep) over the course of the RAAM. However, in line with our hypothesis, all variables returned to pre-race levels (excepted tension in Cyclists, which was largely decreased) 1 week after the end of the race in both groups.

Physiological Parameters

Globally, anthropometric parameters remained stable in both groups during the race performed in team of eight, whereas important daily energy deficits were reported in solo and team of four leading to a five kg body weight loss in solo.^{8,9} This result shows that, contrarily to solo and team of four cyclists, it is possible to keep a stable energy balance if participating in a team of eight.

As it could be expected, quadriceps strength was not altered in Crew, but following a relay (usually 3 times ~1 hr with ~1 hr rest period), a loss of 11% and 8% of quadriceps strength was found in Cyclists at Mid and End, respectively. This is in line with the 13% reduction in quadriceps peak torque found after 2 hrs cycling exercise at 65% of VO_{2max} .²² These losses could be attributed to both reduced neural input to the muscles and a failure of peripheral contractile mechanisms, but probably not to a decrease in muscle mass, since this last was found to remain stable following an UECR of 600 km.² In Cyclists, pre-relay quadriceps strength was lower ($p < 0.05$) at Mid vs Pre (41.6 ± 9.1 vs 45.0 ± 11.2 N, $d = 0.36$). This result could be explained by the fact that in a long-distance race (ultramarathon, ultra-trail, ultra cycling race) we observed a specific pacing strategy. Paradoxically, such extreme exercise seems to induce a relative muscle preservation process due likely to a protective anticipatory pacing strategy during the first half of race.¹⁴ For technical reasons, no strength data were

collected at Post. However, one may think that it would not be different from Pre as previously shown after an UECR of 1700 km.³

Perceptual Parameters

General fatigue followed the same pattern in both groups and appears to be higher at Mid than at End. This larger rise following the first part of the race could be attributed to different factors. In cyclists, total positive elevation was about the same between the two parts of the race. However, the mean temperature was significantly higher during the first part of the race (28.6 ± 7.9 vs $24.9 \pm 3.6^\circ\text{C}$) (Figure 2). It was shown that heat stress could induce a significant decrease of 6.5% in cycling performance and increase fatigue perception.²³ Since crew members spent most of their time in cars with conditioned air, other factors must explain their important fatigue at Mid. For example, it was the first RAAM for all participants and crew members did not undergo any specific training before the race. Moreover, roles and responsibilities of each person were not completely clear during the first days of the race. Consequently, a crisis meeting had to be organised at Mid in order to clarify respective tasks and roles of crew members and to improve global organisation. This could probably explain difficulties of the crew at the beginning of the race causing additional fatigue.

No major pain issue was observed during the study. This result shows that performing the RAAM in team of eight well-trained amateur cyclists would seem to decrease the risks of deteriorating health.

In cyclists and crew, sleep duration and quality mostly decreased at Mid. This observation could also explain the general fatigue higher at Mid than at End. However, sleep duration remained higher than the 2 hrs per day found in both solo and team of four cyclists.^{8,9,11} Sleep deprivation is a classical aspect in ultra-distance competitions. In running, for example, sleep deprivation associated with fatigue was shown to induce a decrease of postural control.²⁴ The latter was also shown to be worst during night time,²⁵ increasing the risk of accidents. In crew members, sleep deprivation could induce an altered driving ability. This highlights the importance of being prepared to sleep deprivation in both cyclists and crew members before the race.

Psychological Parameters

Only fatigue and vigor subscales significantly decreased and increased, respectively in both groups at Mid. The pattern of these two parameters appears to be in line

with general fatigue. In Cyclists, the other emotional states remained relatively stable during the race, while in team of four, an optimal emotional state was reported for less than 50% of the race.¹¹ The long recovery between relays (~16 hrs) and the lower sleep deprivation observed in our team could explain this difference. Anger was increased at Mid in Crew, while interpersonal relationships were significantly lower than in cyclists. As previously discussed, the lack of experience and organisation could explain these states. In fact, crew members were not prepared for the conditions of the race, while cyclists were trained for their single cycling task. Initial information and preparation seem to be essential to follow a cyclist group along the RAAM, essentially to ensure logistical aspects. Another set of hypotheses could be related to sharing the same values and goals between individuals (performing or participating?).

This important observation about crew preparation is supported by social and task aspects of group integration and motivation²⁶ that were lower in Crew than in Cyclists at Pre. These results highlight the fact that crew members did not sufficiently know each other before the race and that their respective roles were not enough described. Indeed, while cyclists trained during a whole year, the entire crew team met only one time to train before the RAAM.

Study Limitations

There are some limitations to the present study. The first one is the small sample size. However, other studies about the RAAM have used smaller sample size.^{8,9,11} The second limitation concerns the assessment times during the race. At Mid and End, data were recorded over a window of 600–700 km. Consequently, participants were not tested in the exact same conditions. Thus, results must be considered with caution. Finally, in line with the aim of the study, data analysis was performed on Cyclists and Crew groups, which may have occluded several differences that could have been observed due to gender, different distances covered or climatic factors.

Conclusion

To our knowledge, this is the first study investigating a team of eight cyclists and its crew during the RAAM, leading to two relevant information. First, performing the race with eight well-prepared amateur cyclists does not present any health-related issue, since the demand on cyclists appears to be lower than in solo and in team of

four. Indeed, a single week of recovery was enough for physiological and psychological variables to return to baseline. Second, crew members for a team of eight require adequate and sufficient preparation and training. Role and responsibilities need to be thoroughly defined; individuals need to know each other beforehand and they must be prepared to sleep deprivation. We can argue that in solo, team of two and four a large part of the demand is on the cyclist. In team of eight, with considerable logistical aspects, one may think that it is more fifty-fifty between cyclists and crew members. The results of this study show the importance of the preparation of two teams: crew members, as well as cyclists.

Disclosure

The authors report no conflicts of interest in this work.

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