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Physiological Demands of Cyclists during an Ultra-Endurance Relay Race: A Field Study Report

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Abstract

This study was to describe and compare the physiological demands of ultra-endurance cyclists during a 24 h cycling relay race. Eleven male athletes (means ± SD: 34.8 ± 5.6 years; 71.6 ± 4.9 kg; 174.6 ± 7.3 cm; BMI 23.5 ± 0.5 kg/m^2; VO_{2max}: 66.0 ± 6.4 ml/kg/min) participated in the study; eight in teams with a format of four riders (4C) and three in teams with six riders (6C). To investigate exercise intensity, heart rate (HR) was recorded while cycling using portable telemetric monitors. Three different exercise intensities were defined according to the reference HR values obtained during a pre race laboratory incremental VO_{2max} test: Zone I (< anaerobic threshold [AT]), Zone II (between AT and the respiratory compensation point [RCP]), Zone III (> RCP). Total volume and intensity were integrated as a single variable (training impulse: TRIMP). The score for TRIMP in each zone was computed by multiplying the accumulated duration in this zone by a multiplier for this particular zone of exercise intensity. The average intensity did not differ between cyclists in 4C (means ± SD; 4C: 87 ± 3 HR_{max}) and 6C (87 ± 1% of HR_{max}), despite the higher volume performed by 4C (means ± SD; 4C: 361 ± 65; 6C: 242 ± 25 per min; *P* = 0.012). These differences in total exercise volume significantly affected the values TRIMP accumulated (means ± SD; 4C: 801 ± 98, confidence interval [CI] 95%: 719 – 884; 6C: 513 ± 25, CI 95%: 451 – 575; *P* = 0.012). The ultra-endurance threshold of 4C and 6C athletes lies at about 87% of HR_{max} for both. Although the intensity profile was similar, the TRIMP values differed significantly as a consequence of the higher volume performed by the 4C cyclists.

Key Words: ultra-endurance, cycling, volume, intensity, heart rate, performance

Introduction

Ultra-endurance competitions are defined as an endurance performance of at least 6 h duration (25). Traditionally, they are held as solo events in an attempt to challenge the limits of human endurance. However, the increased popularity of these competitions in recent years has led to different formats of participation, such as 4 and 6 rider teams in an ultra-cycling race (11). These formats have previously been defined as high intensity ultra-endurance events because they induce repeated bouts of high-intensity exercise (> 75% of VO_{2max}) with limited recovery, performed over an ultra-endurance duration (11). Despite this definition, to the best of our knowledge, there are no studies that have reported an accurate analysis of the intensity profile yielded during ultra-endurance events involving a team relay format. Investigations at cycling events are about the relationship between laboratory-measured variables of exercise capacity, for instance the performance of mountain bikers during a 24-h relay race (12), to the changes in blood lactate, hematocrit and hemoglobin (12), and to the muscle injury markers and blood immune cells of

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Table 1. Main characteristics of the cyclists

Category	4C (n = 8)								6C (n = 3)			4C		6C	
Subjects	1	2	3	4	5	6	7	8	9	10	11	**Mean**	***SD***	**Mean**	***SD***
Age (years)	34.4	39.7	29.6	38.3	43.3	39.8	31.0	37.5	34.1	30.8	23.9	**36.7**	**4.7**	**29.6**	**5.2**
Height (cm)	167.0	172.4	189.1	165.1	177.6	173.5	176.0	176.0	173.5	179.4	173.0	**174.6**	**7.3**	**175.3**	**3.6**
Body mass (kg)	65.3	68.9	79.9	65.7	73.9	74.5	72.5	72.4	64.5	77.3	70.3	**71.6**	**4.9**	**70.7**	**6.4**
VO_{2peak} (mL/kg/min)	70.2	71.9	62.5	63.1	69.1	56.4	74.7	60.2	72.4	59.9	62.4	**66.4**	**6.8**	**64.9**	**6.6**
W_{peak} (W/kg)	6.1	6.2	6.3	5.7	6.4	6.0	5.5	5.9	6.2	5.2	6.4	**6.0**	**0.3**	**5.0**	**0.7**
HR_{max} (beats/min)	184	165	177	162	167	189	177	171	184	196	186	**174**	**9**	**189***	**6**
HR_{rest} (beats/min)	36	40	32	38	33	47	50	43	48	57	44	**43**	**7**	**50**	**7**
VT, HR (beats/min)	133	124	132	137	124	145	142	145	154	168	152	**135**	**9**	**158***	**9**
% VO_{2peak} (mL/min)	60.7	62.6	69.2	74.1	64.5	65.3	68.0	69.4	63.3	69.6	65.7	**66.7**	**4.3**	**67.1**	**3.3**
% HR_{max}	72	74	75	83	74	77	80	85	84	86	82	**77**	**5**	**84**	**2**
RCP, HR (beats/min)	167	149	160	147	152	169	159	158	169	184	173	**158**	**8**	**175***	**8**
% VO_{2peak} (beats/min)	85.4	85.3	82.2	83.3	89.5	80.8	82.3	84.1	86.0	82.5	89.8	**84.5**	**2.6**	**86.1**	**3.7**
% HR_{max}	91	89	90	89	91	89	90	92	90	92	91	**90**	**1**	**91**	**1**

4C: teams with four participants; 6C: teams with six participants; VO_{2peak}: peak oxygen uptake; W_{peak}: peak power output; HR_{max}: maximum heart rate; HR_{rest}: resting heart rate; VT: ventilatory threshold; RCP: respiratory compensation point; % HR_{max}: percentage of maximum heart rate.
*Statistically significant difference ($P < 0.05$) found for the corresponding values between the 4C and 6C groups.

athletes during an 800 km (≈ 23-h) relay cycling competition (3). On the other hand, the exercise intensity performed by solo riders during an ultra-endurance event is well described in literature by studies of Neumayr *et al*. (17, 18).

The exercise intensity profile can be useful in understanding the physiological demands of this particular format of competition, and to provide essential information for optimal preparation of the team athletes. In recent years, heart rate monitoring has been applied to determine exercise intensity in long distance cycling (16-18, 21). Intensity during a race was estimated by using a pre race determined heart rate in an incremental test (12, 14, 16, 18, 20, 21). This method has been used to estimate not only the exercise intensity of elite cyclists during Grand Tours such as the Vuelta in Spain, or the Tour de France (6, 17, 19, 20), but also the total exercise load (intensity X volume) performed during different stages (time trial, flat or mountainous) by using the training impulse (TRIMP), which can be applied in order to estimate the training and/or competition load of endurance athletes (2).

The TRIMP was originally developed by Banister (2) to integrate both intensity and volume into a single term. More recently, a modified version has been used by Foster *et al*. (9) integrating total volume, on one hand, and total intensity relative to three intensity zones, on the other. For instance, exercise intensity can be divided into three zones according to the reference HR values obtained during a previous incremental cycle-ergometer test: Zone I ("light intensity", below the ventilatory threshold), Zone II ("moderate intensity", between the ventilatory threshold and the respiratory compensation point) and Zone III ("high intensity", above the respiratory compensation point). Therefore, by using these methods, we can estimate and compare the total load accumulated during an ultra-endurance event in cyclists of different categories, such as teams of 4 or 6 riders.

In the present investigation, we monitored the HR of the athletes that competed in teams of 4 and 6 riders during a 24-h relay race in order to provide the first comprehensive description of the physiological demands of this format in an ultra-endurance cycling event. Physiological principles of an ultra-endurance event indicate that if the volume of exercise is increased, intensity should be decreased (25). Thus, assuming that the volume of exercise performed should be higher in riders of teams with 4 participants in comparison to teams of 6 athletes, we hypothesized that these two formats of competition showed different profiles of exercise intensity. However, despite these supposed differences in volume and intensity, we hypothesized that the total work load (TRIMP) of exercise would be similar for both categories, because the less volume performed by 6C should be compensated for by higher levels of exercise intensity.

Materials and Methods

Subjects

Eleven well-experienced, non-professional male cyclists and triathletes participated voluntarily for this study. Eight subjects participated in teams of 4 riders (4C) and the remaining three athletes competed in teams with 6 riders (6C). Physical and physiological characteristics are summarized in Table 1. For all of them, it was the first experience in an ultra-endurance cycling event. The subjects had 10.6 ± 6.2 years of experience in endurance events, their average weekly training volume ranged from 15 up to a maximum of

30 h, with a total volume of between 800 and 1,000 h per year. All subjects passed a medical examination and gave their informed written consent, approved by the Catalonian Sports Administration ethics committee, prior to their participation.

The Race

The first official edition of the 24-h cycle race in Montjuïc (Barcelona) was on the first weekend of July 2009. The competition started at 19:00 and consisted of completing the greatest distance possible during 24 h on a closed road circuit of 3,790 meters in length, and 60 meters of elevation, per lap. The time and velocity taken by each cyclist to complete each lap were recorded. The strategy chosen by the athletes during the race was up to them; every team decided the order and duration of their relays. Environmental conditions registered during the race indicated that the ambient air temperature was 27.5°C (range: 24.6-31.0°C) and the relative humidity 53.9% (range: 33.0-72.0%). Mean velocity of wind was 1.7 m/s (range: 3.0-0.6 m/s).

During the event, HR was continuously monitored, beat-by-beat, using portable HR monitors, Polar RS800 SD (Polar Electro, Kempele Finland), that were properly programmed for gender, age and weight. Values of HR were averaged at 10 s intervals.

Preliminary Testing

One week prior to the competition, all the athletes reported to a physiology laboratory under controlled conditions (22 ± 1°C, 40-60% relative humidity, 760-770 mmHg) to perform an incremental $\dot{V}O_{2max}$ test. They were asked to refrain from caffeine, alcohol and heavy exercise on the day before the tests, and to report to the laboratory well-hydrated after having eaten. After the test, all the athletes received nutritional guidelines and were encouraged to follow a high carbohydrate diet during the three days prior to the competition. The $\dot{V}O_{2max}$ was determined on an electronically braked cycle ergometer (Excalibur Sport, Groningen, The Netherlands) modified with clip-on pedals. The saddle and handlebar positions of the cycle ergometer were adjusted to resemble each athletes own bike. The exercise protocol started at 25 W and was increased 25 W every minute until exhaustion. The pedaling cadence was individually chosen in the range of 70-100 rpm.

During the test, oxygen uptake (VO_2), minute ventilation (V_E), carbon dioxide production (VCO_2) and the respiratory exchange ratio (RER) were measured, breath-by-breath, using a computerized gas analyzer (Cosmed Quark PFT-Ergo, Rome, Italy). Before each test, the ambient conditions were measured and the gas analyzers and inspiratory flowmeter were calibrated using high-precision calibration gases (16.00 ± 0.01% O_2 and 5.00 ± 0.01% CO_2, Scott Medical Products, Plumsteadville, USA). After the test, all respiratory data were averaged at 30 s intervals to determine $\dot{V}O_{2peak}$, taken as the highest average value. The Ventilatory Threshold (VT) and the Respiratory Compensation Point (RCP) were measured by three independent reviewers according to methods described Wasserman *et al.* (23). In addition, heart rate (HR) was con-tinuously recorded, beat-by-beat, using a portable heart rate monitor (Polar RS800 SD, Kempele, Finland). In order to establish a reference for heart rate, we identified three zones of physical exertion based on the ventilatory threshold (VT) and the respiratory compensation point (RCP): Zone I (ZI), below VT (low intensity exercise); Zone II (ZII), between AT and RCP (moderate intensity exercise); and Zone III (ZIII), above RCP (high intensity exercise). To calculate the TRIMP during competition, the score for each HR zone was computed by multiplying the accumulated duration in this zone by a multiplier for this particular phase, *e.g.* 1 min in Zone I was given a score of 1 TRIMP (1 X 1), 1 min in Zone II was given a score of 2 TRIMP (1 X 2), and 1 min in Zone III was given a score of 3 TRIMP (1 X 3). The total TRIMP score was obtained by summating the results of the three zones [(min of ZI HR [< VT] × 1) + (min of ZII HR [> VT – < RCP] × 2) + (min of ZIII HR [> RCP] × 3)].

Statistics

Descriptive data are presented as individual and means ± SD. The use of only three athletes in group 6C limited the statistical power, and the non-parametric Mann-Whitney test was used to compare physiology ($\dot{V}O_{2peak}$, W_{peak}, HR_{max}, HR_{rest}, VT and RCP) and physical (height, body mass, BMI and body fat) variables among the two groups. The same analysis was applied in order to identify the differences in performance variables: intensity, time spent in ZI, ZII and ZIII, distance, load and velocity. We assessed the relationship with Pearson's product between laboratory and competition variables only for 4C, because the limited sample from 6C made it difficult to perform a correlation. Significance was set at $P < 0.05$ and all analyses were performed using SPSS v 15 (SPSS Inc., Chicago, IL, USA).

Results

Preliminary Testing

The results of the $\dot{V}O_{2max}$ tests are shown in Table 1. Significant differences were found between the groups in the values of HR_{max} (4C: 174 ± 9; 6C:

Table 2. Intensity, time, distance and speed performed during the race

Relays	1	2	3	4	5	6	7	Mean	*SD*
Intensity (% HR_{max})									
4C	91 ± 3	87 ± 4	86 ± 4	87 ± 2	87 ± 4	85 ± 4	83 ± 8	87	3
6C	89 ± 3	89 ± 2	88 ± 1	87 ± 1	84 ± 3		86 ± 3	87	1
Time (min)									
4C	61 ± 4*	99 ± 14*	65 ± 20*	52 ± 8	40 ± 9	35 ± 17	32 ± 21	361	65*
6C	28 ± 3	40 ± 2	45 ± 6	46 ± 8	44 ± 4	40 ± 7		242	25
Distance (km)									
4C	35 ± 3*	55 ± 9*	36 ± 11	29 ± 5	22 ± 5	19 ± 9	17 ± 3	200	40*
6C	16 ± 2	23 ± 0	25 ± 4	25 ± 4	24 ± 2	22 ± 4		135	18
Velocity (km/h)									
4C	34.6 ± 1.5	33.2 ± 1.2	33.2 ± 0.8	33.0 ± 1.1	32.2 ± 0.1	32.9 ± 0.8	30.9 ± 1.5	33.2	0.9
6C	35.0 ± 1.4	33.9 ± 1.5	33.5 ± 1.4	33.3 ± 0.2	33.1 ± 1.0	32.7 ± 1.1		33.6	1.0

% of HR_{max}: percentage of maximum heart rate during relay; 4C: teams with four participants; 6C: teams with six participants.
(*) Statistically significant difference ($P < 0.05$) found for the corresponding values between the 4C and 6C groups.

189 ± 6 beats/min; $P = 0.048$), HR at VT (4C: 135 ± 9; 6C: 158 ± 9 beats/min; $P = 0.012$) and HR at the RCP threshold (4C: 158 ± 8; 6C: 175 ± 8 beats/min; $P = 0.012$). There were no differences in physical characteristics between the groups.

Performance during Competition

All 11 athletes successfully finished the race. Table 2 presents the main performance variables during the event. All the athletes completed six relays, except the two participants of the 4C group who completed seven relays. Significant differences were found in the total race time (4C: 361 ± 65; 6C: 242 ± 25 per min; $P = 0.012$) and the distance covered (4C: 200 ± 40; 6C: 135 ± 18 km; $P = 0.012$) between the two groups. These differences occurred especially during the first three relays where the 4C athletes performed a greater volume of exercise. In the second half of the event, the time and distance were similar for both groups (Table 2).

The means ± SD % of HR was no different compared to the 4C group (4C: 87 ± 3%; 6C: 87 ± 1%). The athletes in 4C started the event with a higher intensity, performing the first relay at a mean intensity over the RCP threshold (91 ± 3% of HR_{max}). In the second relay, the exercise intensity was lower (87 ± 4% of HR_{max}). Thereafter, the mean % of HR_{max} remained at 86-87% until the last relay, where a further decrease in performance was observed (87 ± 4 and 83 ± 4%, respectively). In the 6C group, intensity was maintained at the same level throughout the first two relays (89 ± 3 and 89 ± 2%). Later, a considerable shift towards lower HR values was observed between the third (88 ± 3%) and the fifth relay (84 ± 3%). In the last relay the intensity was slightly increased (86 ± 3%). The mean HR decline over the race in the 4C group was 6.6 ± 2.0% for the athletes who performed six relays, and 7.3 ± 4.7% in those who cycled seven relays. In the 6C group the mean decline of HR was 4.4 ± 1.1%. The distance between % of HR_{max} ratio corresponding to the RCP threshold and the mean % of HR during the event was 3.5 ± 3.6% for the 4C group, and 4.3 ± 0.9% for the 6C group.

Racing time spent in the three zones of intensity (ZI, ZII and ZIII) is illustrated in Fig. 1. Despite that 6C showed a significantly lower volume of exercise (Table 2) the time spent in ZIII was lower compared to 4C, especially during the fourth (4C: 34.8 ± 19.6; 6C: 4.6 ± 2.8%; $P = 0.024$) and fifth (4C: 36.8 ± 24.7; 6C: 1.5 ± 0.6%; $P = 0.024$) relay. However, at the end of exercise the average time spent in ZI (4C: 9.5 ± 6.2; 6C: 13.5 ± 8.8%), ZII (4C: 49.4 ± 17.4; 6C: 62.6 ± 10.8%) and ZIII (4C: 41.1 ± 19.6%; 6C: 23.8 ± 8.3%) was no different between both groups.

The mean results of the % of HR_{max} rate during the recovery periods are summarized in Table 3. The % of HR_{max} of recovery in the first (4C: 42 ± 4%; 6C: 49 ± 5%) and the second (4C: 41 ± 4%; 6C: 46 ± 3%) relay were significantly lower ($P = 0.012$ and $P = 0.048$, respectively) for 4C. Data for HR during the recovery periods show an increase over the race for both 4C (13.9 ± 6.6%) and 6C (9.3 ± 5.8%).

Load of Exercise

The amount of TRIMP corresponding to 4C (801 ± 98, CI 95%: 719 – 884) was higher compared with 6C (513 ± 25, CI 95%: 451 – 575), being statistically different ($P = 0.012$) (Fig. 2).

Relationship between Ultra-Endurance Performance and Laboratory Variables

Correlation analysis of the 4C group showed a

Table 3. Heart rate during recovery periods

Relays	1	2	3	4	5	6	7	Mean	*SD*
(% HR_{max})									
4C	42 ± 4*	41 ± 4*	46 ± 4	47 ± 4	47 ± 4	49 ± 8	49 ± 16	46	4
6C	49 ± 5	46 ± 3	46 ± 2	47 ± 4	48 ± 4	54 ± 7		49	2

% of HR_{max}: percentage of maximum heart rate during recovery period; 4C: teams with four participants; 6C: teams with six participants. (*) Statistically significant difference ($P < 0.05$) found for the corresponding values (Mean ± SD) between the 4C and 6C groups.

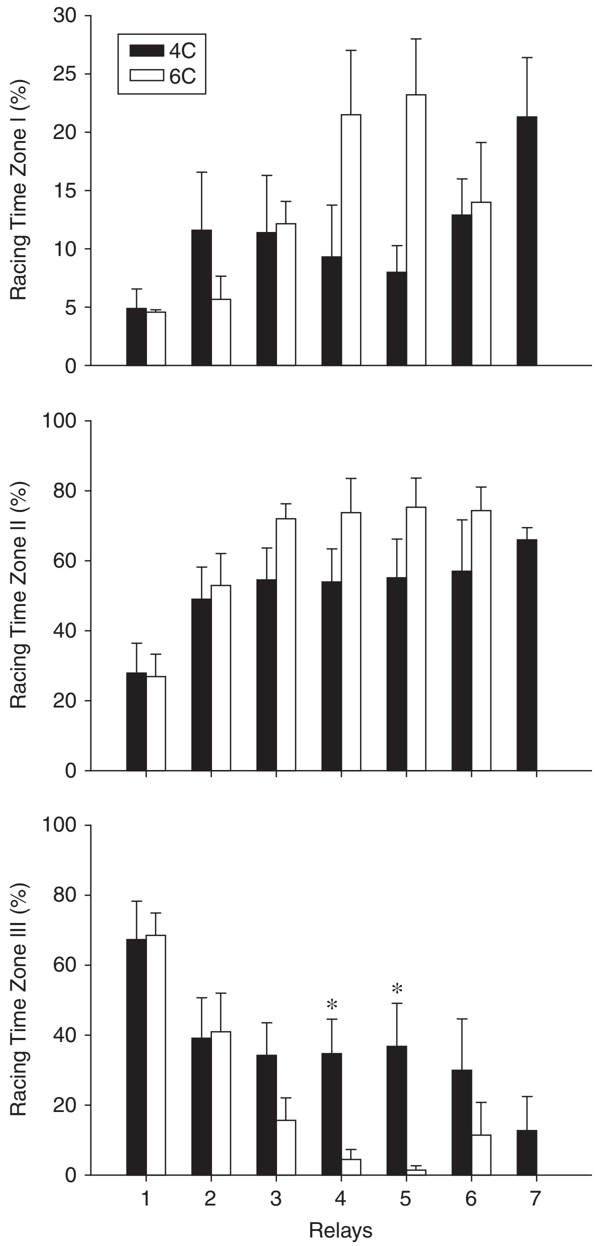

Fig. 1. Time spent in Zone I (ZI: below VT), Zone II (ZII: between VT and RCP) and Zone III (ZIII: above RCP) expressed as % of the total racing time for 4C (black) and 6C (white). Statistical differences were found between time spent in Zone III during the fourth (4C: 34.8 ± 19.6; 6C: 4.6 ± 2.8%; $P = 0.024$) and fifth (4C: 36.8 ± 24.7; 6C: 1.5 ± 0.6%; $P = 0.024$) relay.

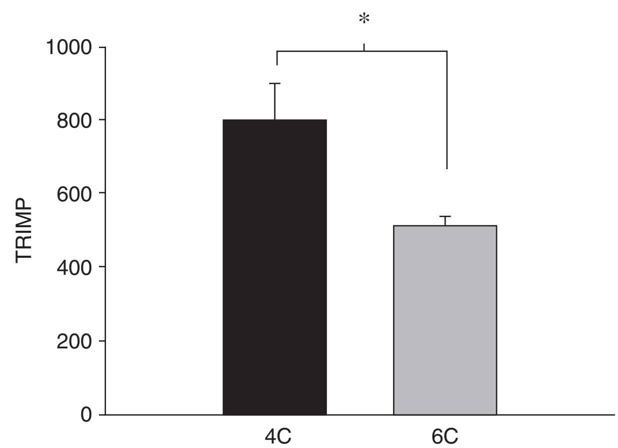

Fig. 2. Amount of TRIMP corresponding to 4C and 6C groups. Significant differences were found between them (4C: 801 ± 98, CI 95%: 719 – 884; 6C: 513 ± 25, CI 95%: 451 – 575; $P = 0.012$).

significant and positive relationship between the values of relative power (W/kg) performed during an incremental laboratory test and the completed distance (km) ($r = 0.80$; $P = 0.016$) and speed during the race ($r = 0.85$; $P = 0.007$). The VO_{2max} results were not related to distance ($r = 0.45$; $P = 0.264$) and speed ($r = 0.28$; $P = 0.506$). Physical characteristics (body mass, body fat and BMI) were not related to distance and velocity.

Discussion

This study is the first attempt to evaluate the physiological demands of ultra-endurance cyclists during a 24-h relay race. The mean exercise intensity was higher and closer to the RCP threshold for both groups (4C: 87 ± 3%; 6C: 87 ± 1% of HR_{max}). In agreement with our first hypothesis, 4C performed a significantly higher volume of exercise than 6C (4C: 361 ± 65; 6C: 242 ± 25 min; $P = 0.012$). But, contrary to the second hypothesis, 6C did not compensate for their shorter duration of exercise with a higher relative intensity, differing significantly in the total amount of TRIMP for both groups (4C: 801 ± 98, CI 95%: 719 – 884; 6C: 513 ± 25, CI 95%: 451 – 575; $P = 0.012$).

Intensity of Exercise

Team relay events were defined previously by Laursen *et al*. (12) as competitions which induce repeated bouts of high intensity exercise (> 75% $\dot{V}O_{2max}$) with limited recovery, performed over ultra-endurance duration (> 6 h). In accord with this definition, all the athletes in the present investigation performed the exercise > 75% of $\dot{V}O_{2max}$, showing a higher % of HR_{max} (4C: 87 ± 3; 6C: 87 ± 1) corresponding to ≈ 83% of $\dot{V}O_{2max}$. However, the total racing time for the 6C athletes (242 ± 24/min) was substantially below 6 h (360/min). Thus, in strict terms, this format should not be considered as an ultra-endurance event being classified in a group of endurance activities (*i.e.*, marathon, cycling tours, long distance triathlon and the like).

In professional endurance cyclists, studies of HR response have consistently shown that exercise intensity decreases as follows: time trials > high mountain stages > flat stages (14, 19, 21). Elite cyclists are capable of sustaining intensities of 85-89% of HR_{max} during time trials around 40 km, and even 78-80% during high mountain stages (15). In comparison to these data, the effort performed by cyclists in the present study was somewhat analogous to repeated time trials during a long term event. Surprisingly, the values of HR during the first bout of exercise for 4C were above the RCP threshold (91 ± 3% of HR_{max}), showing hard strategy in the first phase of the race. On the contrary, the strategy followed by the 6C athletes was more conservative in the first bouts of exercise.

Distribution of Exercise Intensity

The observed distribution of exercise intensities characterizes the energy supply in long distance events (18). Contrary to our hypothesis, although no statistical differences were found in the average time spent in ZIII over the race, 6C athletes showed clearly a deficiency in sustaining exercise to the RCP threshold. This incapacity to sustain higher exercise intensity was especially observed between the fourth and fifth relays where statistical significances were found among the two groups (Fig. 1). However, it is difficult to know this low capacity to sustain effort in zone III of 6C riders. It is known that many factors such as nutrition, hydration and environmental conditions affect the performance during long distance events (1). In unpublished nutritional data, we found that the 6C riders ingested more carbohydrates in comparison than the 4C cyclists (6C: 194 ± 26; 4C: 157 ± 37 g/h of competition) and the total fluid intake was not different between them (6C: 8,603 ± 1,877; 4C: 10,497 ± 2,654 ml during 24 h). In addition, mean body mass reduction was similar between both groups (6C: 2.6 ± 0.6; 4C: 2.2 ± 0.9 kg). Thus, whether environmental conditions were the same for all riders, and nutritional factors, at least during competition, were not the cause of the low time spent by 6C riders in zone III. Other factors such as training or nutrition (carbohydrate load) before the race could be related with this fact.

Total Load of Exercise (TRIMP)

The TRIMP score for 4C (801 ± 98, CI 95%: 719 – 884) surpassed significantly the values of 6C (513 ± 25, CI 451 – 575; P = 0.012) due to the differences in the total volume of exercise (Table 2). Compared with data of elite cyclists during high mountain stages of the Tour de France (≈ 600 TRIMP) (16), 6C riders showed similar values to those of elite cyclists during the hard stages of the most famous professional race. But, the TRIMP accumulated by 4C surpassed significantly the TRIMP score of the "queen" stages of the Tour de France indicating higher physiological demands of the 24 h cycling events in the format of team with 4 members. Only individual ultra-endurance events lasting more than 12 h, or duo ones lasting ≈ 24 h, are likely to surpass the loads of a 4C-team relay format in an ultra-endurance event.

Relationship between Laboratory and Ultra-Endurance Performance Variables

The second aim of this study was to examine the relationship between laboratory measures and the variables of performance (distance and velocity) while racing during the event. Relative power output was positively and significantly correlated with distance (r = 0.80; P = 0.016) and velocity (r = 0.85; P = 0.007). However, these relationships are not surprising because power has been shown previously as the main predictor of performance in time trials on professional cyclists (7) and ultra-endurance mountain-bikers (7, 12, 13). Therefore, our results confirm that power output information is useful in predicting performance during high-intensity longer events. A power/weight ratio > 6.0 W/kg is considered a necessary prerequisite to perform successfully. But, this criterion must be used with caution as the protocol used during testing can affect the outcome of power output, therefore, further reinforcing the need for a common protocol (8).

Limitations and Implication for Future Research and Conclusions

Despite the innovation of our current analysis, we acknowledge that there are several limitations in the present study. One of the most important limitations was the very small sample size of the 6C group. Nevertheless, the collection of data from the ultra-endurance athletes during the event is difficult. This fact is corroborated because much of the knowledge of the physiological effects in athletes is based only on case studies (4, 10, 22, 24). We decided to include athletes from the 6C group format due to the higher performance that they showed during the event. They were placed in the first and second position in their category (6C) and in the general classification, respectively. A further limitation is the analysis of the exercise response based on HR. Potential systemic dehydration and plasma volume shifts, making the plasma volume decline, have been defined as confounding factors that influence HR response (5). Despite these disadvantages, HR monitoring has been the main methodology employed to assess exercise intensity, and recommended by the American College of Sports Medicine as one method of prescribing exercise intensity[1]. Moreover, in recent years, many studies have used this methodology to describe exercise intensity during endurance and ultra-endurance events (6, 14, 15, 17, 18, 20, 21). A way to avoid factors of the HR shift confounding the HR response is to examine the power output surrounding the TRIMP zones we have examined. Unfortunately, the portable cycling power measurement systems are expensive and were not available for all cyclists analyzed in this study.

In conclusion, the main aim of those who wish to perform successfully in a team relay format comprised of four or six athletes should be to reduce, as far as possible, the attenuation of HR tolerating repeated bouts with limited recovery periods. We have identified that the ultra-endurance threshold in a team relay format was slightly lower than the RCP threshold, corresponding to a mean intensity of about 85 to 90% of HR_{max}. Further research is needed to confirm these results and to analyze thoroughly the physiological and metabolic response, not only to improve the performance but also to preserve the health of the athletes.

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