Physiological and Neuromuscular Responses of Competitive Cyclists during a Simulated Self-Paced Interval Training Session

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Abstract
Responses of twelve competitive cyclists performing an interval training session, consisting of three successive 10-min self-paced exercise bouts separated by two 15-min active recovery periods, were studied. Power output (PO), heart rate, pedaling cadence, ventilatory variables, overall ratings of perceived exertion (RPE) and electromyographic (EMG) activity of the vastus lateralis, vastus medialis, biceps femoris and medial hamstrings were recorded during each exercise bout. Mean PO (p < 0.05) decreased significantly across the self-paced bouts, while RPE (p < 0.01) increased significantly. PO and EMG activity did not show significant changes between the 3rd and 9th minute of each self-paced bout. Every self-paced bout showed an oxygen uptake (VO₂) slow component between the 3rd and 9th minute and there was no effect of bout order on the magnitude of the VO₂ slow component. This study reveals that during an interval training session, moderately trained competitive cyclists are able to repeat three 10-min self-paced exercise bouts with only a slight decrease in PO (~3%) and by maintaining unchanged physiological and neuromuscular responses. Moreover, the VO₂ slow component during each exercise bout was not related to changes in muscle activity, as every exercise bout was performed at a muscular work steady state with a constant PO.

Introduction
Training is a key factor to improve cycling performance. In their review of factors that improve cycling performance, Jeukendrup and Martin [20] reported that training was the most obvious way among several internal and external factors to improve power production in a simulated 40-km time trial (TT). As in the highly trained athlete an additional increase in submaximal exercise training (i.e., volume) does not appear to further enhance endurance performance or associated variables, it appears that further improvements in performance can only be achieved through high-intensity interval training (HIT) [27].

One type of interval training that is frequently used in practice by competitive cyclists (i.e., the professional cyclists of the French professional Pro-Tour cycling team “La Française des Jeux”). Personal communication, Frederic Grappe) in order to improve their second ventilatory threshold (VT₂), power output (PO) and their time trial (TT) performances, consists in repeating three 10-minute bouts around VT₂ intensity, separated by two 15-minute active recovery bouts. It is of theoretical and practical interest to know how cyclists self-pace their exercise without external pacing during the three 10-min bouts of this kind of training session.

Several studies have already shown that triathletes and cyclists are able to pace their exercise in an optimal manner during a simulated self-paced 30-min TT performed close to VT₂ intensity [12,14,32]. Perrey et al. [32] examined the physiological and metabolic responses during the 30-min TT and found a progressive increase in HR and minute ventilation, whereas oxygen consumption, PO and blood lactate remained unchanged. Duc et al. [12] focused on the neuromuscular responses and showed that EMG activity of lower limb muscles did not alter during the 30-min TT. They concluded that a large part (~80%) of a 30-min TT is performed at a muscular work steady state (i.e., stable EMG activity). These studies proved that the subjects were able to pace themselves in an optimal manner, i.e., performing with a constant PO. This minimizes lactate accumulation due to PO variations [30].
However, we wondered if subjects would also be able to pace their exercise in an optimal manner on a shorter duration and on a discontinuous exercise, as it seems more difficult to pace during intermittent exercise, compared to continuous exercise. Optimal pacing is attained when the cyclists keeps a constant PO during each exercise bout and when there are nearly no differences between the mean PO of each exercise bout. This would theoretically result in the highest mean PO for the whole 30 minutes of exercise.

Moreover, it is also important to examine self-pacing during intermittent rather than continuous exercise, because intermittent exercise is actually more common in the ‘real world’, and because pacing during intermittent activity has recently been deemed important in unravelling aspects of the central governor theory [44].

The practical interest concerns the question if cyclists can pace themselves in an optimal manner during training and racing without external pacing. Although power meters and heart rate monitors are available for intensity monitoring during training and racing, not all cyclists use these devices and both devices have some drawbacks. Power meters are still expensive and PO is highly variable during an outdoor ride due to environmental conditions. This PO variability can complicate the maintenance of a certain exercise intensity [19]. Heart rate (HR) is much less variable than PO, but is influenced by day-to-day variability, fatigue, cardiovascular drift, hydration status, temperature and altitude [1]. These factors can limit the utility of a heart rate monitor when a particular exercise intensity has to be maintained.

Besides, in real road races, most cyclists self-pace their exercise (i.e., just led by perception of effort) and those who have power meters or heart rate monitors make efforts without often making allowance for the intensity that is being displayed.

So the aim of this study was 1) to establish if competitive cyclists pace themselves in an optimal manner during a simulated interval training session that included three successive 10-min bouts at self-paced intensity, and 2) to evaluate the physiological and neuromuscular responses related to the pacing during these three 10-min exercise bouts.

### Methods

#### Subjects

Twelve male competitive cyclists, involved in endurance training on a regular basis (> 4 times wk⁻¹) and skilled in time trial cycling, voluntarily participated in this study. They were classified in regional category (n = 7), national category (n = 4) or elite 3 category (n = 1) of the French Cycling Federation (F.F.C.). Their mean physical and training characteristics are listed in Table 1. Before participating, subjects were given verbal and written explanation of the purpose and the procedures of the study, and written informed consent was obtained. The study was conducted with the approval of the institutional research ethics committee.

#### Experimental design

The study took place in the pre-competition season (from January to March), when the cyclists had just begun to engage in vigorous training. They had maintained a steady “off season” physical activity in the winter, which was increased in the weeks before this study to an average of 300 (150 – 600) km wk⁻¹ at moderate/high intensity.

Each subject performed two test sessions in the laboratory with his own racing bicycle equipped with a power measuring crankset (SRM, Schoberer Rad Messtechnik, Jülich, Germany) and mounted onto an electromagnetically braked ergometer (Axiom PowerTrain, Elite s.r.l., Fontaniva, Italy). The first test session was an incremental test to exhaustion to determine peak power output (PPO), maximal oxygen consumption (VO₂max) and maximal heart rate (HRmax). The second test session was a simulated interval training session, that consisted of three successive 10-min self-paced exercise bouts separated by two 15-min active recovery periods. Subjects were instructed to deliver their best performance (i.e., the highest averaged PO) in each of the three 10-min exercise bouts, but with the knowledge that three self-paced 10-min exercise bouts were to be performed. Most subjects were familiar with this kind of interval training session, because they were used to doing this kind of interval training on the road or on their hometrainer. All subjects were aware of the criteria that were used to define such a training session as successful, i.e., a constant PO during each exercise bout and no differences between the mean PO of each exercise bout. Both test sessions were held within a period of one week and separated by at least two days. Subjects were instructed to treat each test session as a race day. They were required to refrain from heavy physical activity for the 48 hours preceding the test days, to avoid caffeine and alcohol use in the 24 h prior to each test day, and to arrive at the laboratory fully rested and hydrated. Test sessions were conducted at approximately the same time of the day in a climate-controlled laboratory (ambient temperature 21 to 25 °C, relative humidity 41 to 52 %). During all the tests, the subjects were cooled by an electric fan to minimize sweat rate. Before performing the interval training session, subjects underwent a habituation session in order to familiarize themselves with the testing procedure.

#### Physiological measurements

The Axiom PowerTrain has recently been described by Bertucci et al. [6] and enabled subjects to ride on their own bicycles. It is a stationary computerized electromagnetically braked ergom-

| Table 1 Physical and training characteristics of the 12 subjects |
|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Age (yr)         | Height (cm)      | Body weight (kg) | Peak power output (W) | Maximal oxygen uptake (mL.min⁻¹) | Maximal heart rate (beats.min⁻¹) | Power output at VT₂ (W) | Heart rate at VT₂ (beats.min⁻¹) | Cycling experience (yr) | Training (km.yr⁻¹) |
| Mean             | 27.2             | 178.4            | 71.7               | 383.0            | 5.088            | 190.3           | 305.4           | 170.2           | 8.4              | 10042            |
| SD               | 8.1              | 6.2              | 6.0               | 26.4             | 0.426            | 10.4            | 23.7            | 9.1             | 3.5              | 2378             |
In this study, data was collected from three exercise bouts during incremental tests to exhaustion. The incremental test protocol was designed using the Axiom PowerTrain computer program, which allowed for the creation of a workload that increased at a rate of 130 W every 2 minutes until exhaustion. The protocol started with a 1-minute recovery period at a low workload of 130 W, followed by an increase in workload of 30 W every 2 minutes until exhaustion.

The primary outcome measures included oxygen uptake (V\text{O}_2), carbon dioxide production (V\text{CO}_2), respiratory exchange ratio (RER), and minute ventilation (V\text{E}). Calibration was verified after every test session, and the zero power output of the SRM was reset according to the manufacturer's specifications.

Neuromuscular measurements were obtained using a CPX automated breath-by-breath metabolic cart (Medical Graphics, St. Paul, MN, USA). VO\text{2}, CO\text{2}, tidal volume (VT), ventilatory equivalents for oxygen and carbon dioxide (VE/VO\text{2} and VE/V\text{CO}_2, respectively), and breathing frequency (B_r) were continuously recorded and averaged every 5 s. The pneumotachograph and analyzers of the CPX system were calibrated before each test session according to the manufacturer's specifications.

During every 10-min exercise bout, surface electromyographic (EMG) activity was obtained from vastus lateralis (VL), vastus medialis (VM), and the long head of the biceps femoris (BF) and medial hamstrings (MHAM). All the EMG electrodes were placed over electrically neutral sites (vertebrae), and the EMG signals were amplified (gain = 25 000), band-pass filtered (50 – 500 Hz), and analog-to-digital converted at a sampling rate of 1000 Hz. The raw EMG were expressed in root mean square (RMS, mV) and were normalized to the highest value of 10 s for comparison among the three exercise bouts.

Exhaustion was defined as the incapacity of the subject to maintain the pedalling cadence of 90 rpm despite strong verbal encouragement. All subjects were verbally encouraged by the same person. PPO was defined as the last completed workload (W) stage plus the fraction of time spent in the final workload stage multiplied by the increase in workload of the last stage: PPO = W\text{completed} + (t\text{completed}/t\text{stage duration}) \cdot AW [26].

### Interval training session

The interval training session consisted of three self-paced 10-min exercise bouts, separated by two 15-min active recovery periods. Each subject warmed up prior to the first 10-min exercise bout according to their own precompetitive preference. As has been described by Mattern et al. [30], competitive cyclists may fail to select an optimal start strategy in self-paced efforts (e.g., TTs) and often start too fast, which does not optimize performance. To prevent these overratings, subjects were instructed to start the first minute of each exercise bout with a PO between 75 and 78% of PPO obtained during the incremental test. The PO was set between these percentages as it corresponds to the mean PO that cyclists obtain during a simulated 30-min TT [32]. From a practical point of view, these percentages led to a “target PO-zone” with a range of approximately 10 Watts, which is easier to maintain than one fixed PO value, due to fluctuations in PO measurements. To maintain this PO, the subjects referred to the PO displayed on the SRM power control unit. After this first minute, subjects were free to vary their PO and pedalling cadence at their own discretion. During the 9 last minutes of each exercise bout, the SRM power control unit was turned off, and the subject’s PO was regulated by a handlebar wave (i.e., seat on the brake hoods or hands on top of the handlebars) during every 10-min exercise bout in order to minimize biomechanical and physiological changes due to differences in posture. Subjects were told to deliver their best performance (i.e., the highest averaged PO) in each of the three 10-min exercise bouts, but with the knowledge that three self-paced 10-min exercise bouts were to be performed. They were told not to accelerate during the last minute of each exercise bout, as many cyclists always tend to do at the end of self-paced efforts (e.g., TTs), but just to maintain their speed for the last 60 s.

### V\text{O}_2, V\text{CO}_2, \text{RER}, \text{and VE data from the CPX and PO, HR and pedalling cadence data from the SRM were averaged for every minute.}
during each 10-min exercise bout. Except for the first minute, every minute of each exercise bout the subjects indicated their overall RPE using Borg’s CR10 scale [7]. This scale ranges from 0 to 11 and measured the overall feelings of subjective sensation of effort accompanying exercise.

Subjects were instructed to recover as best as possible and in their preferable way within the two 15-min active recovery periods. The CPX mouth piece was removed and the subjects could drink carbohydrate energy drinks and water ad libitum.

Statistical analysis

Statistical analyses were carried out using SPSS version 7.5 (SPSS Inc., Chicago, IL, USA). For the EMG data analyses of the VL, VM, BF and MHAM muscles activity, the number of subjects was respectively n = 10, n = 7, n = 8 and n = 9, due to signal loss during the interval training session. All statistical analyses were performed with the values from the 3rd to the 9th minute of each exercise bout, in order to eliminate the fast increase in these variables at the onset of the exercise and influences of less constant PO during the last minute. The Kolmogorov-Smirnov test was applied to demonstrate the Gaussian distribution of the data of the present study, which enabled the use of parametric statistics. A two-way (exercise bout order × time) ANOVA repeated measures was used to analyze main effects and interaction for all variables. When time-effects were significant, a one-way (time) ANOVA repeated measures was conducted for each exercise bout order to analyze simple effects. For all ANOVA’s used, where appropriate, post hoc analyses were performed using Tukey’s test as described by Vincent [43]. For all statistical analyses, the level of statistical significance was set at p < 0.05. All data presented are expressed as means ± standard deviation (SD) unless otherwise stated.

The within-cyclist coefficient of variation (CV) for PO, HR, RPE, \( \dot{V}_O_2 \), RER and VE of each interval training session was calculated, by taking each subject’s three mean values (averaged between the 3rd and 9th minute of each of the three 10-min exercise bouts) and averaging them. CV was calculated as the ratio of the standard deviation by the mean, multiplied by 100. Mean CV was obtained by averaging all the within-cyclist CV values and also presented using the 95% confidence interval (CI) to estimate the likely range of the true value.

Results

The subject’s determined PPO, \( \dot{V}_O_2_{\text{max}} \), \( H_R_{\text{max}} \), and PO and HR at VT2 are shown in Table 1. \( \dot{V}_O_2_{\text{max}} \) was reached before the end of the incremental test (49 ± 36 s) and PO at \( \dot{V}_O_2_{\text{max}} \) was significantly lower (p < 0.005) than PPO (− 12 ± 9 Watts). The mean PO during each 10-min exercise bout of the interval training session is shown in Fig. 1. After the first minute at approximately 78% PPO, all subjects increased significantly (p < 0.01) their PO during the second minute of the first exercise bout and kept a relatively constant PO for the last 8 minutes during each exercise bout, although during the last minute of the first and second exercise bout there were trends of slight decreases. There was no significant effect of time on PO between the 3rd and 9th minute of the exercise bouts.

The mean responses for the measured variables during each 10-min exercise bout, averaged between the 3rd and 9th minute, are summarized in Table 2. There were significant effects of exercise bout order for PO and RPE, whereas all other measured variables showed no significant exercise bout order effects. PO of exercise bout 3 was significantly lower (p < 0.05) than PO of exercise bout 1 (− 3.6%) and PO of exercise bout 2 was nearly significantly lower (p = 0.052) than PO of exercise bout 1 (− 3.2%). Mean PO and HR of the three exercise bouts were not significantly different from PO and HR at VT2. RPE of exercise bout 3 was significantly higher than RPE of exercise bout 1 (p < 0.01) and RPE of exercise bout 2 (p < 0.05) (1.2 and 0.7 units higher, respectively). Significant effects of time between the 3rd and 9th minute were present (p < 0.001) for HR, pedalling cadence, RPE, \( \dot{V}_O_2 \), \( V_CO_2 \), and VE. Fig. 2 shows the group mean responses of HR, RPE, \( \dot{V}_O_2 \), and VE during the 3rd to 9th minute of each exercise bout (standard deviations have been omitted to preserve clarity). \( \dot{V}_O_2 \) increased significantly from 83.9 to 89.0% \( \dot{V}_O_2_{\text{max}} \) and HR increased significantly from 87.1 to 92.6% \( H_R_{\text{max}} \). The significant effect of time for \( \dot{V}_O_2 \) indicates a slow component of exercise involving sustained lactic acidosis [28]. The mean magnitude of the \( \dot{V}_O_2 \) slow component (in this study defined as from the end of the third minute to the end of the ninth minute) was 50.6 ± 46.0, 38.8 ± 36.5 and 40.3 ± 35.4 ml·min\(^{-1}\) for exercise bout 1, 2 and 3, respectively. These values were not significantly different (p = 0.433). A significant interaction between exercise bout order and time was found for RER (p < 0.01) and VE (p < 0.05).

Discussion

The main finding of this study is that competitive cyclists are able to repeat three 10-min self-paced exercise bouts with only a slight decrease in PO (− 3%), and maintain unchanged physiological and neuromuscular responses. It seems that trained cyclists seem to be able to pace their effort in an optimal manner during an interval training session, that is often used in practice.

Power output and ratings of perceived exertion
Compared to exercise bout 1, mean PO significantly decreased 3.6% and 3.2% respectively for exercise bouts 2 and 3, while there was a significant increase in mean overall RPE between exercise bout 3 and exercise bouts 1 and 2. These findings indicate that fatigue occurred during the interval training session. Several definitions of fatigue are employed, and according to Davis and Bailey [11], fatigue has been defined as an acute impairment of exercise performance that includes both an increase in the perceived effort necessary to exert a desired force or PO and the eventual inability to produce that force or PO.

There was nearly no difference in PO between the second and third exercise bout. A possible explanation for this finding is that although a maximal performance for each exercise bout was emphasized, subjects could have used strategies when performing the three exercise bouts. Consciously or subconsciously, subjects could have been aware of fatigue resulting from the first exercise bout and with the subsequent third exercise bout already in mind, could have reduced PO during the second exercise bout. This prudent PO strategy during the second exercise bout is supported by the mean overall RPE that did not increase significantly between the first and second exercise bout, in spite of a significant decrease in PO of ~3%. Furthermore, when performing the third exercise bout, subjects knew it was their last effort and could have generated higher PO to fully exhaust themselves. This psychological “last ride” effect is not novel and was, for example, also observed by Hickey et al. [17].

These pacing strategies during the interval training session can be explained in light of the central governor hypothesis put forth by St. Clair Gibson et al. [37], and the process of teleoanticipation as described by Ulmer [42]. In brief, the central governor hypothesis suggests that athletes organize exercise in a manner designed to prevent critical metabolic disturbances during exercise. This is achieved through the process of teleoanticipation. Exertion is thereby set by a feedforward system of central commands and is subsequently altered by afferent feedback once the exercise is underway. According to Ulmer [42], this preemptive mechanism would not only pattern a single time trial, but would also be responsible for the pacing strategy adopted in consecutive trials that comprise an entire exercise bout. Recently, St. Clair Gibson et al. [39] have described how pacing strategies during exercise are controlled by information processing between the brain and peripheral physiological systems.

Our PO results indicate that moderately trained cyclists are able to pace their exercise in an optimal manner during three consecutive 10-min exercise bouts, as is indicated by just a slight 3% variation in PO between each exercise bout. The PO results of our study differ from the study of Ansley et al. [2] that showed no difference in mean PO of highly trained cyclists between successive 4-km TTs, each separated by 17 min. Although
the protocols of both studies are nearly the same, the absence of a decrease in mean PO between the TTs (i.e., fatigue) in their study could be due to the shorter duration of their TTs (approximately 5 min) and/or the higher training status (highly vs. moderately trained) of their cyclists.

Nevertheless, we have to emphasize that the instructions for the first and last minute of each exercise bout have consequences on the pacing of each exercise bout during the interval training session. It prevents subjects from starting the exercise at a PO which they will not be able to maintain until the end of the exercise bout, and it guides them to an exercise intensity that they could theoretically maintain until the end of the exercise bout. The instruction for the last minute prevents the subjects from accelerating at the end of the exercise bout and to finish with an all-out effort during this last minute.

Heart rate and oxygen consumption
While mean PO decreased – 3% for both the second and third exercise bout compared to the first, mean HR across the 3 exercise bouts remained the same. Jeukendrup and Van Diemen [19] showed similar findings in a 1-hour training session of a professional cyclist. When exercising twice for 15 minutes at HRs between 167 and 170 bpm, the mean PO of the second 15-min bout was 23 W lower than the mean PO of the first 15-min bout. These results can be explained by the cardiac drift phenomenon [19]. Cardiac drift is mainly due to an increased core temperature and to a lesser degree to dehydration, as euhydration or hyperhydration may not always prevent cardiovascular drift [1,19]. Furthermore, our mean HR across exercise bout results agree with the HR findings of the study of Ansley et al. [2]. Nevertheless, they did not find a significant HR increase all along each TT as we did. The latter could be explained by their shorter TT duration (5 vs. 10 min).

Mean VO₂ between the three exercise bouts was not different and this agrees with the VO₂ results of the study of Ansley et al. [2]. As the anaerobic energetic contribution to each exercise bout is unknown, it is unclear if the PO decrease across the exercise bouts is caused by diminished anaerobic energetic contribution, or by diminished gross mechanical efficiency.

Neuromuscular responses
There were no significant inter-exercise bout changes in mean RMS during the simulated interval training session. As PO decreased – 3% for the second and third exercise bout compared to the first, this could theoretically suggest that there is a slight peripheral muscle fatigue for the second and third exercise bouts. Peripheral muscle fatigue has been defined by Taylor et al. [40] as a decrease in the force generation capacity of the skeletal muscle because of action potential failure, or excitation-contraction coupling failure, or impairment of cross-bridge cycling, in the presence of unchanged or increasing neural drive. However, the fact that neuromuscular activity is not modified could be associated with the fact that PO drops, as our experimental conditions allow this spontaneous modification. Moreover, it is doubtful if EMG measurements are sensitive enough to detect neuromuscular changes associated with such a small PO decrease of – 3%. However, if the EMG measurements are sensitive enough, our inter-exercise bout results are contradictory with central tenets of the central governor hypothesis and the findings of St. Clair Gibson et al. [38], Kay et al. [22] and Ansley et al. [2], namely that neuromuscular and PO changes are related during stochastic and constant TT exercise [37]. However, Hetta et al. [16] have shown recently that centrally mediated downregulation of neural drive does not necessarily accompany fatigue in 4-km time trial exercise.

The EMG intra-exercise bout results showed no significant time effect on EMG data during each exercise bout. This implies that during each exercise bout, competitive cyclists select a constant PO that corresponds to a muscular work steady state. A muscular work steady state during a non-stochastic TT has previously been reported in the studies of Ansley et al. [2] (constant iEMG for rectus femoris muscle) and Duc et al. [12]. The latter recorded EMG activity of VM, rectus femoris, BF and gastrocnemius medialis of nine competitive cyclists during a 30-min TT. The EMG activity of the four muscles was unchanged during the TT. Duc et al. [12] suggested that the lack of increase in the EMG activity seems to indicate that competitive cyclists perform a TT at a muscular work steady state that prevents neuromuscular fatigue (i.e., decreased muscle fiber contractility) during the TT. Nevertheless, we have to consider that although we measured EMG activity of 4 limb muscles, subjects could still have used different muscle recruitment strategies and the resulting individual variability due to these strategies could have precluded statistically significant findings during each exercise bout and between the exercise bouts. As has been suggested by Prilutsky and Gregory [33], the functional significance of muscle coordination strategy in cycling may be minimization of fatigue and/or perceived effort. Moreover, Hug et al. [18] have shown a high level of variation in the recruitment of lower limb muscles in professional cyclists during both incremental and constant-load exercises.

VO₂ slow component
Each exercise bout showed a VO₂ slow component. The VO₂ slow component appears at exercise intensities above lactate threshold, when the rate of appearance of blood lactate exceeds the rate of disappearance and therefore blood lactate increases [45]. The underlying mechanisms of the VO₂ slow component still remain to be determined, but the major contributor is likely to be the high energy cost of contraction of the type II fibers that are proportionally more recruited at intensities above lactate threshold [3,34,45]. EMG is an indirect method of assessing muscle fiber recruitment and has been used to study the VO₂ slow component phenomenon [5,28,34,41]. In our study, every exercise bout showed a VO₂ slow component, but there were no intra-exercise bout changes in EMG activity. However, studies investigating VO₂ slow component and EMG responses are contradictory. Some studies [8,9,25,31,34,36] related the VO₂ slow component with changes in muscle activity. Other studies [5,28,35,41] confirm our results and did not find changes in EMG variables when a VO₂ slow component was identified. As explanations for the lack of muscular activity changes, Schuemann et al. [35] suggested that the increased O₂ cost (i.e., VO₂ slow component) associated with performing heavy exercise is coupled with a progressive increase in ATP requirements of the already recruited motor units rather than to changes in the recruitment pattern of slow- versus fast-twitch motor units.

Although several studies have demonstrated a reduction in VO₂ slow component after prior high-intensity exercise due to a greater O₂ availability as a consequence of induced metabolic acidosis [23,24,41], our results did not show significant changes in magnitude of a VO₂ slow component between the three exercise bouts. This could be explained by the fact that our subjects were able to recover at their own discretion during the 15-min
active recovery bouts and reduced the metabolic acidosis of the previous exercise bout. This was especially achieved by cycling at reduced intensity immediately after the termination of each exercise bout, while in the previously mentioned studies, subjects had immediately complete (inactive) rest for several minutes. Active recovery is known to reduce postexercise blood lactate faster than passive recovery, because it facilitates lactate removal [4,15].

Practical considerations

The simulated interval training session performed in the laboratory is almost identical to the type of interval training that is frequently used on a hometrainer and on the road by competitive cyclists in order to improve their VT2 PO. Instructions during their training sessions on the road and on a hometrainer at home are the same as the ones applied in this study. The only difference between a training session on a hometrainer (at home or in the laboratory) and on the road, is that the total resistive force on the road varies more during each exercise bout due to changes in environmental conditions (i.e., wind and road gradient). This can influence the PO and thus the pacing of the cyclists during their road training sessions.

Our results indicate that, after being paced the first minute, competitive cyclists are able to self-pace their effort in an optimal manner (i.e., optimal pacing). This can influence the PO and thus the pacing of the cyclists during their road training sessions. Instructions during the first minute, they do not seem to need feedback from power meters or heart rate monitors during the exercise bouts to properly perform the training session.

Conclusions

In summary, this study revealed that during a frequently practiced interval training session, moderately trained competitive cyclists are able to repeat three 10-min self-paced exercise bouts at ~VT2 intensity with only a slight decrease in PO (~3%) and maintain unchanged physiological and neuromuscular responses. Cyclists attained the same mean VO2 and VO2 slow component in each exercise bout. The VO2 slow component was not related to changes in muscle activity, as every exercise bout was performed at a muscular work steady state with a constant PO. In spite of an increase in fatigue during the training session shown by increased overall RPE and slightly decreased PO, cyclists seem to be able to pace their effort in an optimal manner and can reproduce three self-paced 10-min intervals with identical physiological and neuromuscular responses.

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