The effects of block training on pacing during 20-km cycling time trial

Article in Applied Physiology Nutrition and Metabolism · December 2016
DOI: 10.1139/apnm-2016-0072

CITATIONS 0
READS 168

3 authors:

Vitor Pereira Costa
Santa Catarina State University (UDESC), Florianópolis
36 PUBLICATIONS 73 CITATIONS
SEE PROFILE

Luiz Guilherme Antonacci Guglielmo
Federal University of Santa Catarina
142 PUBLICATIONS 687 CITATIONS
SEE PROFILE

Carl D Paton
Eastern Institute of Technology
51 PUBLICATIONS 1,068 CITATIONS
SEE PROFILE

Some of the authors of this publication are also working on these related projects:

- The effect of prior exercise on the VO2 kinetics
- Blood flow restriction effects with trained cyclists

All content following this page was uploaded by Vitor Pereira Costa on 16 January 2018.

The user has requested enhancement of the downloaded file.
The effects of block training on pacing during 20-km cycling time trial

Vitor Pereira Costa, Luiz Guilherme Antonacci Guglielmo, and Carl David Paton

Abstract: The aim of this study was to determine the effects of block training (BL) on pacing during a 20-km hilly cycling time trial (TT) in trained cyclists. Twenty male cyclists were separated into 2 groups: control and BL. The training of each cyclist was monitored during a period of 3 weeks. In the first week cyclists performed an overload period of 7 consecutive days of high-intensity interval training followed by 2 weeks of normal training. Cyclists performed 1 TT before intervention and 2 TT after 7 and 14 days at the end of training. Each training session consisted of 10 sets of 3 repeated maximal-effort sprints (15, 30, and 45 s) with an effort/recovery duration ratio of 1:5. The main finding of this study was that the power output displayed a significantly higher start from the start until the half-way point of the TT (p < 0.05). Additionally, power output was characterized by a significant higher end spurt in the final 2 km in the BL after 2 weeks at the end of training (p < 0.05). In addition, after 2 weeks at the end of the overload period the distribution of cadence was significantly lower throughout the TT (p < 0.01). Therefore, a short period of consecutive days of intense training enhances cycling performance and changes the power output in the beginning and final part of the TT in trained cyclists.

Key words: cyclists, power output, pedal cadence, heart rate, time trial.

Résumé : Cette étude a pour objectif de déterminer les effets de l’entraînement par bloc (BL) sur la gestion de la cadence du pédalage chez des cyclistes entraînés lors d’un contre-la-montre (BL TT) de 20 km dans un circuit vallonné. On divise 20 cyclistes en deux groupes : contrôle et BL. On surveille l’entraînement de chaque cycliste durant une période de 3 semaines. Durant la première semaine, les cyclistes s’imposent durant 7 jours consécutifs une surcharge consistant en un entraînement par intervalle de haute intensité suivi d’un entraînement normal durant 2 semaines. Les cyclistes effectuent un TT avant le début de l’entraînement et deux TT : 7 et 14 jours suivant l’entraînement intensif. Chaque séance d’entraînement comprend 10 séries de 3 sprints maximaux (15, 30 et 45 s) selon un ratio travaillerécupération de 1:5. Le résultat principal est le suivant : la production de puissance suscite un meilleur départ et se poursuit jusqu’à mi-parcours du TT (p < 0.05). De plus, la production de puissance génère une plus grande bande de vitesse significative dans les 2 derniers km du groupe BL 2 semaines après la fin de l’entraînement intensif (p < 0.05). En outre, 2 semaines après la fin de la période de surcharge, la distribution de la cadence est significativement plus faible tout au long du TT (p < 0.01). En conséquence, une courte période d’entraînement intensif en des jours consécutifs améliore la performance en cyclisme et modifie la production de puissance au début et à la fin du TT chez des cyclistes entraînés. [Traduit par la Rédaction] Mots-clés : cyclistes, puissance produite, cadence du pédalage, rythme cardiaque, contre-la-montre.

Introduction

Continuous and high-intensity interval training (HIIT) methods are frequently used in every phase of periodization to improve cycling performance (Laursen 2010). Continuous training is characterized by long durational efforts with constant low intensities. This method is frequently used during the basic phase of annual preparation to gradually improve cycling performances during the season (Paton and Hopkins 2004). Conversely, during the pre-competitive and competitive periods of the season, cycling performance increases with the addition of intense training in the training programme (Paton and Hopkins 2004). HIIT is performed by a combination of repetitive stimulus and a corresponding recovery period. There are several possibilities to alter intensity, such as duration, volume of the intervals, as well as the recovery period in-between efforts. Recently, a review of the effects of HIIT on cycling performance (Costa et al. 2014) classified HIIT into 3 categories: submaximal (below maximal oxygen uptake (\(\dot{V}O_{2\text{max}}\)), maximal (\(\sim\dot{V}O_{2\text{max}}\)) and supra-maximal (above \(\dot{V}O_{2\text{max}}\)). Irrespective of the type, the method has been regarded as one of the most efficient strategies to enhance cycling performance (2%–4%) (Laursen and Jenkins 2002; Costa et al. 2014).

The majority of the studies suggest that the optimal frequency of the HIIT to provide gains in cycling performance should be 6 to 12 training sessions over a period of successive weeks in trained cyclists (Paton and Hopkins 2004). More recently, some studies have been proposed to accumulate consecutive days (5 to 14 days) of HIIT to rapidly enhance physiological indexes (Rodas et al. 2000; Breil et al. 2010; Ronnestad et al. 2012b), alpine sky performance (Breil et al. 2010), and cycling performance (Rønnestad et al. 2012b). Consecutive training stimuli typically results in a large physiological overload and possibly a drop in performance in the following days because of incomplete recovery between the sessions (Meeusen et al. 2013). When followed by an appropriate...
recovery period, block training (BL) results in super-compensation and raises the level of performance above the levels already achieved by the training that had been completed (Meuksen et al. 2013).

A common sports-specific measurement in cycling performance is the time trial (TT) races. In a TT competition, cyclists race maximally against the clock, completing a pre-established distance in the shortest possible time. The majority of TT events cover a distance of between 5 to 60 km and are performed individually, except in grand tour and velodrome events that include team TT. As an individual sport, it has become important for the cyclists to determine their own pacing strategy for races. Pacing strategy starts prior to testing or from the beginning of exercise (Roelands et al. 2013). It is believed that sprint events (i.e., ≤15–120 s) are performed in an “all-out” strategy, while longer intervals (>2 min) may include a variety of pacing profiles such as negative, all-out, positive, even, parabolic-shaped, and variable pacing strategies (Abbiss and Laursen 2008). Indeed, a pacing strategy can be influenced by a number of factors such as training, nutritional strategies, aerodynamics, level ground of the terrain, environmental conditions, and psychology (Atkinson et al. 2007). The mathematical models of cycling performance reveal that athletes should vary the pacing in response to changes in environmental resistance (Boswell 2012; Swain 1997; Atkinson et al. 2007). Thus, it is important that cyclists select a variable pacing strategy to achieve optimal performance in cycling events when greater variations in environmental conditions such as hilly or windy TT occur.

The pacing studies in cycling have attempted to focus on the effects of short strategies, reproducibility, ergogenic aids, and environmental conditions on flat TT performances (Renfree et al. 2012; Santos et al. 2013; Thomas et al. 2012). Studies investigating the effects of a short period of consecutive days of HIIT on pacing during hilly TT were not found and could have provided important insights of the possible performance enhancements over a task from the beginning through to the final point. In fact, to the best of our knowledge, we found only 1 study that reported enhancements (−7%) (p = 0.006–0.044) in pacing during the last 3 km on a 10-km running TT after 8 weeks of resistance training (Damasceno et al. 2015). Moreover, recent studies reported that BL enhances endurance performance with only a few training sessions, which enables competitive athletes to achieve peak performance rapidly (Rennestad et al. 2012). Therefore, the aim of this study was to determine the effects of BL on pacing during a 20-km hilly cycling TT in trained cyclists.

Materials and methods

Subjects

Twenty trained male cyclists volunteered to participate in this study (Table 1). The cyclists had a minimum experience of 2 years in competitions and were training a minimum of 10 h per week (~300 km per week). All cyclists were informed of the purpose and risks associated with participation before giving their written informed consent to participate. The study was performed in accordance with ethical standards (Harris and Atkinson 2013). Also, the study was approved by the institutional research ethics committee in accordance with the declaration of Helsinki.

Study design

First, the cyclists reported to laboratory to have their anthropometric measures recorded to estimate the percentage of body fat according to Jackson and Pollock’s 3-site formula: pectoral, abdomen, and quadriceps (Jackson and Pollock 1978). Cyclists were randomly assigned to 1 of 2 conditions: control (C) group (n = 10) and BL group (n = 10) (Table 1). The training of each cyclist in both groups was monitored for a period of 3 weeks in total. During the first week the BL cyclists performed 7 consecutive days of HIIT followed by 2 weeks of normal training. At 24 h before the TT and training intervention, cyclists performed a graded exercise test (GXT) and a TT for familiarization. The study design included 1 TT before the HIIT and 2 TT, which were performed 7 and 14 days after the cyclists finished the HIIT. The normal training weeks were based on previous studies in tapering that showed a period of approximately 2 weeks to be optimal to enhance performance after intense training (Hatle et al. 2014; Mujika 2010). The BL performed a flat tapering and was recommended to avoid high-intensity and high-volume training during the normal training. The C group completed 2 TT separated by 3 weeks, which they continued with their own personal training programmes different to the normal training of the BL group. The C group training included 1 or 2 sessions of HIT interspersed by moderate and light training sessions. Also, the C group cyclists were in the competitive period of their annual season training of approximately 10 to 12 h per week, and they were allowed to keep their own racing schedule programs during the weekends. All cyclists had previously participated in laboratory cycle ergometer testing and were familiar with general exercise testing procedures. In the 24 h before any testing session, participants were instructed to avoid strenuous physical activity and any performance altering supplements and to replicate nutrition as closely as possible before each TT. Throughout all the tests, cooling was provided via two 30-cm pedestal fans and the ambient temperature of the laboratory was controlled at 20 °C with a relative humidity level of 50%–60%.

GXT

Cyclists completed GXT until volitional exhaustion to determine their maximal physiological parameters. The cycle ergometer was adjusted to replicate the participants’ preferred racing position, which was recorded and replicated for the GXT. All tests were conducted on an electronically braked cycle ergometer (Velotron Dynafit Pro, RacerMate Inc., Wash., USA). Cyclists performed a 15-min warm-up at a self-selected intensity followed by 5 min of rest. Thereafter, the GXT started at 100 W and the power output was increased at a rate of 40 W every 4 min until volitional exhaustion. The participants were instructed to maintain their preferred cadence. The criteria to terminate the test were set when the cyclist could not maintain the preferred cadence for more than 10 s during the final stage of the test. If the final stage of the exercise test was not completed, the peak power output (PPO) was calculated using the equation of Kuipers et al. (1985):

\[
PPO = Pf + \left( \frac{t}{240 \times 40} \right)
\]

where Pf is the last completed workload, t is the time in seconds of the uncompleted workload, 240 is the time of each stage in seconds, and 40 is the workload augments in each stage. The expired respiratory gases were collected into metabolic Metamax 3B sys-

Table 1. Characteristics of the participants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>C group</th>
<th>BL group</th>
<th>p</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>36.2±8.9</td>
<td>33.2±10.9</td>
<td>0.26</td>
<td>−0.30</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>76.6±8.7</td>
<td>74.8±6.0</td>
<td>0.26</td>
<td>−0.24</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177±5.8</td>
<td>172±4.9</td>
<td>0.45</td>
<td>0.00</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>12.8±5.9</td>
<td>11.8±6.3</td>
<td>0.38</td>
<td>−0.16</td>
</tr>
<tr>
<td>PPO (W)</td>
<td>338±48</td>
<td>335±27</td>
<td>0.44</td>
<td>−0.08</td>
</tr>
<tr>
<td>VO2max (L·min−1)</td>
<td>4.7±0.6</td>
<td>4.6±0.5</td>
<td>0.15</td>
<td>−0.08</td>
</tr>
<tr>
<td>VO2max (ml·kg−1·min−1)</td>
<td>61.6±10.4</td>
<td>61.45±5.1</td>
<td>0.18</td>
<td>−0.03</td>
</tr>
<tr>
<td>HRmax (beats·min−1)</td>
<td>183±6</td>
<td>180±9</td>
<td>0.27</td>
<td>−0.40</td>
</tr>
<tr>
<td>[La]max (mmol·L−1)</td>
<td>9.7±2.8</td>
<td>8.4±2.1</td>
<td>0.04</td>
<td>−0.50</td>
</tr>
<tr>
<td>OBLA (W)</td>
<td>297±3</td>
<td>293±33</td>
<td>0.38</td>
<td>−0.31</td>
</tr>
<tr>
<td>OBLA (beats·min−1)</td>
<td>167±6</td>
<td>165±27</td>
<td>0.30</td>
<td>−0.31</td>
</tr>
</tbody>
</table>

Note: BL, block training; C, control; ES, effect size; HRmax, maximal heart rate; [La]max, maximal blood lactate concentration; OBLA, onset blood lactate accumulation; PPO, peak power output; VO2max, maximal oxygen uptake. *, p < 0.05.
tem (Cortex, Leipzig, Germany). Prior to each test, the system was calibrated in accordance with manufacturer’s instructions using known alpha gas standards. \( \text{VO}_{2\text{max}} \) was defined as the highest oxygen uptake over a 30-s value recorded during the test. During the final 30 s of each stage, 25 \( \mu \text{L} \) of blood was collected from the participant’s fingertip and immediately analysed for whole-blood lactate concentration using an automated system (YSI 1500, Yellow Springs, Ohio, USA) calibrated to the manufacturer’s specifications. The onset of blood lactate accumulation was determined as the power output at which blood lactate reached a concentration of 4 mmol·L\(^{-1} \) (Sjödin et al. 1982).

### 20-km hilly TT

Cyclists completed the variable graded cycling 20-km TT using the same cycle ergometer as previously used in the GXT. The TT course profile (Fig. 1) was recently investigated in a group of competitive cyclists and showed lower coefficient of variation from mean power output and final time (2% and 1%, respectively) (Clark et al. 2014). Cyclists initially completed a 20-min standardised warm-up consisting of 3 repeated increasing-intensity bouts. The first 2 min were at 2–2.5 W·kg\(^{-1} \), followed by 2 minutes at 3–3.5 W·kg\(^{-1} \) and finally 1 minute at 4–4.5 W·kg\(^{-1} \) and repeated consecutively. For the final 5 min cyclists pedalled at a fixed intensity of 100 W. Thereafter, a 20-km self-paced maximal TT was performed. Cyclists were able to view their progress over the course, distance, and gear selection; all other information was blinded to remove any potential pacing effect. Furthermore, no verbal encouragement was provided. Cyclists were recommended to complete each TT in a self-selected pacing as fast as possible with no restriction on gear selection, cadence, or cycling posture. Throughout the TT participants were able to consume water ad libitum. Power output, cadence, and heart rate (HR) were recorded during the TT by the cycle ergometer.

### Training

The BL cyclists completed 7 consecutive days of HIIT. The total training session time was ~120 min, including ~15 min of accumulated HIIT, 75 min of recovery period, and 15 min of warm-up and cooldown for each period. The warm-up and cooldown were performed in self-selected intensity <150 W. Cyclists completed 10 sets of maximal sprints lasting 15, 30, and 45 s and the work to rest ratio was 1:5. The sprints were performed at maximal effort and recovery intervals at a self-selected intensity below 30%–40% of maximal aerobic power as a form of active recovery. The first, fourth, and seventh training sessions were performed indoors using the laboratory cycle ergometer as previously described. Participants completed each indoor sprint sessions under the supervision of a researcher to ensure the sprints were adhered to as stringently as possible. The cyclists used their own bicycle on the road when performing the remaining training sessions. Power output during all training sessions was controlled and registered using the PowerCal device. Recent studies reported that PowerCal device is unreliable and not valid to measure power output during cycling sprints and TT (Costa et al. 2015, 2017). Therefore, we did not use PowerCal data for the analysis in the study. Moreover, cyclists used a prerecorded audio signal that indicated the time for sprint and recovery periods.

### Statistical analysis

Simple descriptive statistics are shown as means ± between-subject standard deviations. Data from the study were analyzed using both significance- and magnitude-based inferential approaches. Significance-based analyses were performed using IBM SPSS (version 20; IBM Corp., Armonk, N.Y., USA) with alpha set at 0.05. Initially, the characteristics of the C group and BL group were compared using a \( t \) test. Also, the C group’s first and second TTs (TT1 and TT2, respectively) average indexes were compared using a \( t \) test. The BL group’s TT1 and TT2 average scores were compared using a 1-way ANOVA with repeated measures. The distribution of power output, cadence, and HR over the TT in each group was compared using a 2-way ANOVA with repeated measures, with factors training (pre- and post-training) and distance over the TT (every 2 km). When necessary, subsequent post hoc comparisons were made using Bonferroni corrections. In addition, the percentage of change in power output, cadence, and HR over the TT between the groups were compared using 2-way repeated-measures ANOVA with post hoc comparisons using the Bonferroni test. In the magnitude-based approach, the mean effects of training and their confidence limits were estimated with a ready-made for purpose spreadsheet (Hopkins 2006), which utilizes the unequal-variances \( t \) statistic to perform between-group comparisons. Group-wise comparisons were computed for change scores between the mean values of the pre-test (TT) and each of the 2 post-tests (TT1 and TT2) in the BL group and between the pre-test (TT1) and post-test (TT2) in the C group. Each subject’s change scores between the trials were expressed as a percent of the baseline score via analysis of log-transformed values. Data were log-transformed to reduce bias arising from any nonuniformity of error in the data. The spreadsheet also computes changes that the true effects are substantial when a value for the smallest worthwhile change is entered. We used a value of 1% for the performance power measures, as previous research has shown that this value represents the smallest worthwhile enhancement in power for cyclists competing in TT events (Paton and Hopkins 2006). To date no research has established how percentage changes in physiological measures would translate directly to percent changes in cycling performance; therefore, we interpreted changes in our physiological measures using default standardized effects (the change in mean divided by the between-subject standard deviation). The magnitudes of the standardised effects for the testing measures were also interpreted and reported using the established effect size (ES) thresholds of 0.2, 0.5, and 0.8 for small, moderate, and large effects, respectively, in accordance with the recommendations of Cohen (1996). ES values <0.2 were deemed trivial differences and considered to be not worthwhile.

### Results

Table 1 shows the characteristics of the cyclists in both groups. There was a significant difference between the groups in maximal blood lactate (9.7 ± 1.8 mmol·L\(^{-1} \) vs. 8.4 ± 1.1 mmol·L\(^{-1} \); \( p = 0.04 \)) for the C group and BL group, respectively. In addition, large ES of ~0.90 was found between the groups.

Table 2 shows that there were no significant differences in all measures of the TT of the C group. Also, we found trivial ES for the majority of the variables. Furthermore, Table 2 shows the comparisons between the TT before and after training intervention for the BL group. The cyclists reported a large to very large decrease in final time and cadence after 1 and 2 weeks of the overload period, respectively. Also, the final time and cadence ES were moderate to high after cyclists finished the 1 and 2 weeks of training. Mean power output demonstrated a moderate to high increase after the 1 and 2 weeks of the postoverload period. The
mean power output ES was also moderate to high. The HR values did not change significantly before and after training intervention. In addition, we did not find any significant enhancements in performance indexes and cadence in the post-training period.

Table 3 shows the relative change score (as a percentage) for all measured variables during the performance tests between the groups. There were large ES, 0.68–0.91; gains in performance measures for the BL group relative to the C group.

For the C group the 2-way ANOVA with repeated measures showed significant interaction between the factors training versus distance for power output (F = 26.7; p < 0.0001), cadence (F = 26.2; p < 0.0001), and HR measures (F = 7.9; p = 0.03). There were no significant differences in power output, cadence, and HR between TT1 and TT2 over each 2 km in the C group (Figs. 2A, 2B, 2C, ES = 0.006–0.08).

For the BL group the 2-way ANOVA with repeated measures showed significant interaction between the factors training versus distance for power output (F = 23.3; p < 0.0001), cadence (F = 27.1; p < 0.0001), and HR measures (F = 6.7; p = 0.02). After 1 week of training intervention, the magnitude of the augment of power output during each 2 km of the TT was significantly higher in the beginning and through to the halfway point of the event (10 km), kilometre 16, and kilometre 20 (Fig. 3A; p = 0.05 to 0.0003). The effects of training on distribution of power output were slightly higher after 2-weeks at the end of the training (Fig. 3A; p = 0.01 to 0.0001); however, we did not find any significant differences between the TTs at post-training (p = 0.44 to 0.08).

After 1 week of training intervention, cadence decreased at each 2 km of the TT, except at kilometre 16 (Fig. 3B; p < 0.05). Cadence was significantly lower after 2 weeks at the end of training (TT2) compared with the TT and TT1 (Fig. 3B; p < 0.01; p < 0.05, respectively). Cadence was also significant different between TT1 and TT2 from the beginning of the trial to kilometre 8. HR did not change significantly during the TT irrespective of training (Fig. 3C; p > 0.05).

Figure 4 shows the percentage change (pre- and post-training) in power output, cadence, and HR during the TT in both groups. For the BL group the 2-way ANOVA with repeated measures showed significant interaction between the groups versus distance for power output (F = 19.1; p < 0.001), cadence (F = 22.7; p < 0.001), and HR measures (F = 8.2; p = 0.01). It was observed that the percentage change for power output and cadence was significantly higher and lower for BL group than C group over the entire course, respectively (p = 0.003–0.039). In turn, no statistical differences were observed between the HR response before and after training for both groups (p = 0.193–0.942).

### Discussion

The aim of this study was to investigate the effects of a short period of HIIT on pacing during a 20-km hilly cycling TT. To the best of our knowledge, this is the first study that attempted to verify the effects of a training intervention on pacing during a hilly TT. The main finding shows that the power output displayed a significantly higher start from the beginning to the halfway point of the TT after 1 and 2 weeks at the end of the overload period. In addition, the power output was characterized by a significantly higher end spurt in the final 2 km after a short period of cumulative intense training.

The pacing profiles have a variety of shapes during different exercise tasks and conditions (Atkinson et al. 2007). In a recent review (Abbiss and Laursen 2008), such profiles were classified in negative, positive, even, all-out, parabolic (i.e., U, J, or reverse J-shaped), and variable pacing strategies. It is believed that a curved parabolic (i.e., strong and rapid start, the middle portion slower and the final sprint) is commonly described in many types of events from a duration of 2 min to hours (Roelands et al. 2013). In the present study, the power distribution over the tests was characterized by a parabolic shape regardless of the group and performance gains. After training, cyclists still displayed a steeper parabolic shape with higher power distribution over the self-selected performance test. Indeed, power output was significantly higher from the beginning of the TT throughout the first 10 km after the intervention. Moreover, power output was statistically higher at kilometre 16 and at the final metres of the post-TT. In contrast, the C group did not change their power distribution substantially between the tests. The TT chosen was not flat and was based upon numerous changes in the gradient represented by both ascents and descents (Clark et al. 2014). We found a drop in the power output characterized by the long descent section of the TT (from kilometre 12 to 14) regardless of both intervention and group. The decrease in the power output was due to the resistive forces on the flywheel of the cycle ergometer simulating the downhill phase of the course profile (Clark et al. 2014). The accentuated end spurt in the final metres showed a higher power output after a short period of intense training. The higher end-spurt phenomenon increased the considered reserve that the cyclists maintained for the majority of the TT to reduce the hazard of catastrophic collapse (Roelands et al. 2013). Thomas et al. (2012) also reported a parabolic shape (i.e., U-shape) power distribution between the three 20-km flat TT tests. However, the authors found high levels of variability in the power output during the first kilometre between the self-paced 20-km TT compared with the low degree of variability in power output for most of the remainder of the distance between the trials. Also, the authors reported that cyclists increased the power output in the final kilometre of the TT. Indeed, there is possibly some level of variability in the power output between the trials in our study; even previous studies showed a high level of reliability in the 20-km hilly TT used in our study (Clark et al. 2014). A likely reason for the changes in performance and consequently on distribution of power is probably due to the adaptations of
Fig. 2. Power output (A), cadence (B), and heart rate (C) distribution during 20-km cycling hilly TT of the control group. bpm, beats per minute; TT, time trial; TT1 and TT2, first and second TT, respectively; rpm, revolutions per minute.

Fig. 3. Power output (A), cadence (B) and heart rate (C) distribution during 20-km cycling hilly TT of the block training group. a, Significantly different from control group ($p < 0.01$); b, significantly different from control group ($p < 0.05$); c, significantly different from control group and TT2 ($p < 0.05$). bpm, beats per minute; TT, time trial; TT1 and TT2, first and second TT, respectively; rpm, revolutions per minute.
the training rather than any potential effects of pacing strategy (i.e., fast, even, low start) since cyclists were instructed to perform a self-selected maximal TT in both groups. To the best of our knowledge, we found 1 study regarding the effects of training intervention on pacing during running (Damasceno et al. 2015). Damasceno et al. (2015) reported the effects of weight strength training on neuromuscular adaptations and on pacing during a 10-km running performance. The authors found that the addition of 8 weeks of explosive leg strength training during a normal training run improved running performance by 2.5%. In addition, the running performance improved mainly because of the end spurt achieved in the last 2800 m of the 10-km running trial. Therefore, heavy strength training improved the neuromuscular characteristics of endurance runners, resulting in changes in pacing with a faster and more-sustained end-spurt during a 10-km running TT.

Damasceno et al. (2015) reported that the changes in pacing during a 10-km TT was not accompanied by an alteration in the rating of perceived exertion (RPE), indicating that athletes were able to maintain higher speeds with similar RPEs after strength-training period. Indeed, previous studies proposed that the RPE is generated as a result of the numerous afferent signals during exercise and acts as a mediator of subsequent alterations in skeletal muscle activation (De Morree et al. 2012). Thus, the RPE represents the integration of the alterations in physiological systems during dynamic exercise and could be related as a primary regulator of pacing strategy (Tucker and Noakes 2009). In our study, we unfortunately missed the RPE and we cannot confirm if the changes in pacing strategy induced by training may have allowed the cyclists to exercise at a greater intensity for the same level of perceived exertion. These would support the notion that neuromuscular mechanisms related to peripheral fatigue are some of the possible variables utilized by central nervous system to regulate exercise intensity, particularly during the beginning and final phase of a cycling time trial.

The basis of the training programme used in our study included the method of training (i.e., HIIT) and type of periodization (i.e., BL training). The effects of HIIT suggested that the main physiological adaptations occurred by increasing the concentration of energetic stores (i.e., glycogen), activities of anaerobic-aerobic enzymes, buffer capacity, and recruitment of type II muscular fibers (Jacobs et al. 1987; Laursen and Jenkins 2002; Creer et al. 2004). Also, HIIT has been found to improve lactate thresholds, VO2max, PPO, and economy in cyclists and noncyclists. BL training periodization is referred to as a training cycle of highly concentrated specialized workloads. In cycling, the BL training can be performed using high-volume/low-intensity (i.e., continuous exercise) or low-volume/high-intensity (i.e., HIIT). Indeed, the concentrated period of training had an impact on physiological systems because of the cumulative and residual effects of the intervention. These concepts are strongly related to the “ideal” dose of training called “functional overreaching” instead of deleterious overtraining. However, the physiological adaptations from consecutive days of training are not well understood. A recent study reported larger improvements of VO2max (8.8%) in a group of trained cyclists after 12 weeks of BL periodization (Rønnestad et al. 2012b). Furthermore, the authors found that even in endurance-trained individuals, a concentrated period of HIIT may increase lactate threshold (22.0%), hemoglobin mass (5.6%), and gross efficiency (2.9%) (Rønnestad et al. 2012b). This is in accordance with the increase in VO2max (6.0%) and lactate threshold (9.6%) found in response to an 11-day of HIIT in alpine skiers (Breil et al. 2010). Collectively, the enhancements in physiological variables associated with endurance performance (i.e., VO2max, lactate thresholds, and economy) (Joyner and Coyle 2008) shown in our and previous studies support the changes that we found in the distribution of power output during the cycling TT post-intervention.
A second find of the present study was that mean free chosen cadence during the TT was significantly lower to post-training (88 ± 6 revolutions per minute (rpm)) compared with the TT pre-training (94 ± 2 rpm). Furthermore, the distribution of cadence during the TT was significantly lower at each kilometre after the training intervention. The majority of studies investigating the effects of training in cycling cadence have focused on adaptations from strength training instead of the effects of HIIT. Indeed, when cyclists pedal at low cadences the muscle force applied to the cranks increase (Bertucci et al. 2005). Rønnestad et al. (2012a) reported that freely chosen cadence during a constant 5-min cycling at 125 W reduced by 12 ± 2 rpm from pre strength training intervention to 4 weeks into the intervention period in noncyclists. Conversely, well-trained cyclists did not change their freely chosen cadence after the addition of strength training in the cycling training program even though they improved in the 1-repetition maximum test. Given the short period of strength training related in the later study (i.e., 4 weeks), it is expected that greater adaptations in the first phase of strength training can occur in the nervous system rather than in muscular fibers. The strength training adaptations suggests that the reduction in the inhibitory feedback from mechanoreceptors and Golgi tendon organs could be related to an increase in strength and consequently a decrease in the freely chosen cadence (Rønnestad et al. 2012a). Cycling using all out HIIT is a complex movement and it is likely that the neural adaptations also occur after a short period of concentrated sprint training (Creer et al. 2004). Ross et al. (2001) suggested potential neural mechanisms influenced by sprint performance, including changes in temporal sequencing of muscle activation for more efficient movement, preferential recruitment of the fastest motor units, higher muscle innervations, and increased ability to maintain muscle recruitment and rapid firing for the duration of the sprint activity. Indeed, it is not well understood if these adaptations above are well established after cycling sprint training. Also, to generate and sustain higher forces during sprint training, the muscles use an additional recruitment of type II fibers (Jacobs et al. 1987). Collectively, the neuromuscular adaptations after a short period of HIIT probably increased the capability of the cyclists to produce more force, resulting in less cadence and consequently higher power output over the course during the TT.

Conclusion

Our results suggest that a short period of HIIT provides substantial positive effects during a self-paced, computer-simulated, variable-graded cycling TT. Furthermore, the training intervention demonstrated that the cyclists displayed a higher power output during the first half of the task and a higher end spurt while the cadence was lower over the cycling TT compared with the baseline period. Also, the time course of distribution of power output showed that the main augment were after 1 week at the end of overload period with nonsignificant enhancements in the following week. Analysing the course profile before and after the training intervention could provide important insights into showing the possible performance enhancements over a task from the beginning through to the end point. The feedback from the pacing can inform the cyclist of the exact moment where the training would be the most effective. This study gives an opportunity for coaches to include a short-term of HIIT in a cyclist’s training program for rapid improvements in the pacing profile and consequently on the performance during a variable-graded cycling TT. In addition, cyclists could use the high-intensity BL for the main races during the competitive annual season.

Conflicts of interest statement

The authors state that there are no personal conflicts of interest in the present study.


