Nonconsecutive- versus Consecutive-Day High-Intensity Interval Training in Cyclists

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ABSTRACT

GROSS, M., T. SWENSEN, and D. KING. Nonconsecutive- versus Consecutive-Day High-Intensity Interval Training in Cyclists. Med. Sci. Sports Exerc., Vol. 39, No. 9, pp. 1666–1671, 2007. Purpose: We compared the effects of a high-intensity interval training (HIT) program completed on three consecutive or nonconsecutive days per week for 3 wk on VO2peak, peak aerobic power output (PPOa), and 5-km time trial (TT5k) performance in trained cyclists. Methods: Fifteen trained cyclists completed a TT5k and an incremental test to exhaustion for VO2peak and PPOa determination before and after training. Pretraining TT5k times were used to form groups, one of which (N = 9) performed three HIT sessions per week on consecutive days (CD), while the other (N = 6) did so on nonconsecutive days (NCD). Each interval session consisted of up to eight 2.5-min intervals at 100% of PPOa separated by 4 min of active recovery. Pre-and posttraining TT5k Performance, VO2peak, and PPOa were compared using 2 x 2 (group x time) ANOVA with repeated measures on time. Results: HIT significantly improved VO2peak, PPOa, and TT5k performance in both groups across time (P < 0.05); there were no differences between groups. In both groups combined, VO2peak and PPOa increased by 0.2 ± 0.2 L·min⁻¹ (5.7%) and 23 ± 15 W (7.2%), respectively, and TT5k velocity and power output increased by 0.9 ± 0.8 km·h⁻¹ (2.6%) and 17 ± 19 W (6.9%), respectively. Despite comparable group changes, the individual response varied widely. Conclusion: CD and NCD similarly improved TT5k Performance, VO2peak, and PPOa but the individual variation varied widely in each group. Thus, athletes should experiment with both designs to discern which one optimizes their training. Key Words: BLOCK TRAINING, TIME TRIAL, PEAK POWER OUTPUT, HIT

High-intensity interval training (HIT) improves peak oxygen consumption (VO2peak) and peak aerobic power output (PPOa) in trained athletes (10,11,14,15,17–22). Recent data show that intervals completed at approximately 100% of PPOa for approximately 60% of the time to exhaustion at this intensity (Tmax) may best improve endurance performance in highly trained athletes (11,12). Typically, HIT is performed several days a week for 3–4 wk at a time (3,10,11,14,15,17–22). Philosophies differ, however, on the optimal weekly layout of work and rest when completing HIT. Most training plans and studies recommend or have used one or more recovery days between HIT sessions, a method that consistently improves performance (2,3,5,10,11,14,18–22). In contrast, other plans advocate several consecutive days of intervals followed by several days of recovery (15,17). This latter training scheme is called block-training (4,15).

It is hypothesized that block-training is more efficacious than traditional training, because it may elicit a stronger training stimulus and provide a superior recovery period (4,15,17). The basis for block-training stems from data collected with powermeters used to monitor training in cyclists. These data show that cyclists can train at a similar high power output for two to four consecutive days even though the heart rate associated with this power output changes (4,15). Before this finding, the change in HR seen after consecutive-day intense training was regarded as an indication that the athlete had not recovered fully from the previous day’s efforts; thus, another interval session was typically not prescribed (4,15). To date, no study has systematically examined the efficacy of block-training. Our purpose, therefore, was to compare the effects of a HIT program completed on three consecutive or nonconsecutive days per week for 3 wk on VO2peak, PPOa, and 5-km time trial (TT5k) performance in trained cyclists.

METHODS

Subjects. On the basis of the data from a similar study (11) and an a priori assumption that a 4% change in velocity and PPOa from pre- to posttraining is meaningful,
we used GPOWER software (Bonn, FRG) to determine that a sample size of 18 was needed to give us a power of 0.80 with an alpha of 0.05. To that end, we recruited 17 trained collegiate cyclists (13 males, 4 females) to serve as subjects, all of whom gave their written informed consent to participate in the study, which was approved by the Ithaca College human subjects review board. Mean ± SD for subject age, mass, sum of seven skinfolds, and VO2peak were 21 ± 3 yr, 68.8 ± 8.9 kg, 54.4 ± 23.3 mm, and 62.2 ± 11.7 mL·kg⁻¹·min⁻¹. All subjects had three or more years of endurance training, one or more years of competitive cycling experience, and had trained regularly together as members of collegiate cycling teams. Subject participation in the project followed 2 months of base training, which was prescribed by the investigators; the base training program and subsequent participation in the project served as the subjects' preparation training for the ensuing collegiate cycling season. Compliance to the base training program was verified by monitoring the training logs maintained by the subjects; log data showed that the subjects completed 5–20 h of training divided over two to five sessions each week during base training.

Experimental design. In week 1, a subset of subjects (N = 6) completed two practice TT5k that were separated by 48 h of recovery. The remaining subjects (N = 11) continued base training. In week 2, these remaining 11 subjects completed the two practice TT5k as described above, while the first subset of subjects completed an actual TT5k and 48 h later, an incremental test to exhaustion for the determination of VO2peak and PPO₅. Before each subject’s initial practice TT, we twice measured body mass and sum of seven skinfolds (triceps, subscapular, chest, abdomen, suprailliac, thigh, and midaxilla). After the first practice TT, we familiarized the subjects to the incremental test to exhaustion by having them complete the first three stages of that test while they were connected to a metabolic cart.

In week 3, all subjects performed an actual TT5k and, 48 h later, an incremental test to exhaustion. For the first subset of subjects (N = 6), this was their second actual TT5k and incremental test to exhaustion. Data from these two actual TT5k and incremental tests to exhaustion on these six subjects were used to examine the week-to-week reliability of these measures, which was determined by calculating the coefficients of variation (CV) and intraclass correlations (ICC) for them. The CV for TT5k velocity and power were 1.0 and 2.7%, respectively; the corresponding ICC was 0.99 for both variables (N = 5). The CV for VO2peak and PPO₅ were 1.5 and 2.0%, respectively; corresponding ICC were 0.98 and 0.99, respectively (N = 6). At the end of week 3, therefore, the first subset of subjects (N = 6) had completed two practice TT5k and two actual TT5k and incremental tests to exhaustion, which were used to determine the reliability of our measures. The larger subset of subjects (N = 11), on the other hand, had completed two practice TT5k and one actual TT5k and incremental test to exhaustion. Thus, before training, all subjects had completed a minimum of three TT5k.

On the basis of the pretraining TT5k performance data collected during week 3, matched pairs of subjects were placed into consecutive-day (CD; N = 9) and nonconsecutive-day (NCD; N = 8) training groups. Over the course of the project, two NCD subjects dropped out; consequently, final group sizes for CD and NCD were nine and six, respectively. As shown in Table 1, there were no significant differences between the groups, based on those subjects that completed the project, for any pretraining dependent variable. Both groups completed three weekly HIT sessions for 3 wk. On nonscheduled HIT days, subjects cycled lightly or rested completely. After completing the training program, the subjects were tested again in pattern with their training schedules, such that CD and NCD had at least four and two recovery days, respectively, before performing the posttraining TT5k and incremental test to exhaustion on nonconsecutive days.

Subjects tested and trained with their own bicycles mounted on a CompuTrainer indoor trainer (Pro Model 8002; RacerMate, Seattle, WA). Coaching Software 1.5 and MultiRider III retail version (RacerMate, Seattle, WA) operated the trainers and collected training and testing data. Polar heart rate monitors (F1, Polar Electro Oy, Kempele, Finland) measured heart rate (HR) during all lab sessions. Testing. Subjects completed all pre- and posttraining tests at approximately the same time of day, under similar laboratory conditions. Pre- and posttraining tests for the female subjects also occurred in the same phase of their menstrual cycles, which were monitored over the course of the project. Subjects also trained and ate similarly for the 24-h period before each test, which was preceded by a standardized warm-up consisting of 8 min at 2.2 W·kg⁻¹, 5 min at 2.6 W·kg⁻¹, and 2 min at 3.3 W·kg⁻¹ for males; corresponding warm-up power outputs for females were
1.8, 2.2, and 2.6 W kg\(^{-1}\). Subjects then cycled at a self-selected intensity for 5 min, during which they completed three 15-s sprints. The CompuTrainer was calibrated before and after the warm-up.

**TT\(_{5k}\).** A flat 5-km TT course was created using Coaching Software. We selected a 5-km TT rather than the 40-km TT, which has been used in previous HIT studies with cyclists, for several reasons. First, the exercise intensity elicited during a short TT more closely approximates the exercise intensity of our interval program than the exercise intensity elicited by a longer TT (16). Second, preliminary testing, as discussed above, showed that the CV for time or velocity for a 5-km TT was approximately 1.0%, which is similar to the corresponding value for a 40-km TT (11,14,20,21). Third, performance in either TT type in the lab is contingent on the ability to sustain a high maximum power output (7,9). Last, 5-km TT are shorter than 40-km TT and, therefore, more convenient. Subjects began pre- and posttesting TT\(_{5k}\) in the same starting gear, chosen during practice runs before pretesting. After the start, subjects were allowed unrestricted use of their gears, with the goal of completing the TT\(_{5k}\) as fast as possible. During the TT\(_{5k}\), HR and cadence data were visible to the subject, while researchers gave verbal updates of elapsed distance every 500 m, and at 250 and 100 m to go. No other data were available to the subjects during the TT\(_{5k}\). Verbal motivation was not provided. Coaching software recorded total elapsed time (t\(_{TT,5k}\)), and means for velocity (v\(_{TT,5k}\)) and power output (P\(_{TT,5k}\)). Mean TT\(_{5k}\) HR was calculated as the average of readings taken every 30 s. Five minutes after the TT, blood lactate concentration (BL\(_{TT}\)) was measured using an Acutrend lactate analyzer (type 30112522, Roche, Mannheim, Germany), as described elsewhere (1).

**Incremental test to exhaustion.** The incremental test began at 2.5 W kg\(^{-1}\) for males and 1.5 W kg\(^{-1}\) for females; thereafter, workload increased 10 W every 30 s. Subjects completed as many stages as possible before they reached exhaustion or could no longer maintain the wheel speed necessary to ensure the intended workload on the CompuTrainer. Peak VO\(_2\) was verified if two of the following three criteria were met: 1) the increase in VO\(_2\) approached a plateau or dropped slightly in the last completed stage of the test; 2) 90% of age-predicted HR\(_{max}\) was attained; and 3) respiratory exchange ratio was 1.10 (11).

Oxygen consumption was measured every 15 s using a TrueMax 2400 metabolic measurement system (Parvo Medics, Salt Lake City, UT). The flow meter was calibrated using a 3-L syringe (Hans Rudolph, Inc., Kansas City, MO) and the gas analyzer with a known standard gas mixture. VO\(_{2peak}\) was the highest average of two consecutive VO\(_2\) readings (7); PPO\(_{a}\) was the average workload corresponding to those two readings. The highest HR attained in the test was recorded as peak HR (HR\(_{peak}\)).

**Training.** Subjects completed HIT in groups of two to four in the exercise physiology lab at Ithaca College. Warm-up consisted of 8-, 5-, and 2-min segments at 45, 60, and 75% of PPO\(_{a}\), respectively, followed by 5 min at a self-selected intensity. Training sessions for both groups consisted of eight 2.5-min intervals at 100% of PPO\(_{a}\), separated by 4 min of recovery at 25% of PPO\(_{a}\). Interval length was approximately 60% of the time to exhaustion at 100% of PPO\(_{a}\) (T\(_{max}\)), as estimated from earlier work (11,12). The length of the recovery period was also derived in part from one of the aforementioned works (11). A training session ended when the subject failed twice in a row to complete an interval or had attempted eight intervals. If eight intervals were completed at the prescribed power output, load was increased by about 10 W for the next session. Subjects were aware of time progression as well as their HR and cadence during HIT. Data collected during HIT included intervals attempted (I\(_{att}\)) and completed (I\(_{com}\))), total training time (t\(_{train}\)) and total work (W\(_{train}\)) at PPO\(_{a}\); the mean training load or power output (P\(_{train}\)) during an interval session; peak HR (peakHR) for each attempted interval; number of intervals in which subject came within 5 bpm of HR\(_{peak}\); and BL at 5 min after the final attempted interval (BL\(_{train}\)). Subjects drank water and Accelerade (PacificHealth Laboratories, Inc., Matawan, NJ) ad libitum during the workout and were directed to drink a serving of Endurox R4 (PacificHealth Laboratories, Inc.) within 30 min of completing each session.

**Statistics.** A 2 × 2 (group × time) ANOVA with repeated measures on time compared the effects of HIT in CD and NCD on v\(_{TT,5k}\), P\(_{TT,5k}\), VO\(_{2peak}\), PPO\(_{a}\), relative TT\(_{5k}\) intensity, and BL\(_{TT}\). A 2 × 4 (group × time) ANOVA with repeated measures on time compared the effects of HIT in CD and NCD on P\(_{train}\); the four time periods examined were before and after training and the beginning of weeks 2 and 3. Differences in t\(_{train}\), W\(_{train}\), peakHR, I\(_{att}\), I\(_{com}\), and BL\(_{train}\) and percentage of prescribed work completed between groups were compared with independent t-tests. Pearson product–moment correlations were used to examine relationships between variables. Statistics were performed with SPSS 13.0 for Windows; alpha was set at 0.05. Data are expressed as means ± SD.

**RESULTS**

As shown in Table 2, HIT significantly improved TT\(_{5k}\) performance, VO\(_{2peak}\) and PPO\(_{a}\) across time in both groups (P ≤ 0.0004); there were no differences between groups at any time or interactions. HIT did not change relative TT\(_{5k}\) intensity, as expressed as a percentage of HR\(_{peak}\) (95.9 ± 2.5%) or PPO\(_{a}\) (83.8 ± 7.2%), across time in either group; there was no difference in relative TT intensity between groups at any time or interactions. HIT also did not alter BL\(_{TT}\) across time in either group; the respective BL\(_{TT}\) values before and after training were 10.2 ± 3.9 and 11.5 ± 2.8 mM in CD and 12.0 ± 3.8 and 11.8 ± 1.3 mM in NCD. There was no difference in BL\(_{TT}\) between groups at any time or interactions. HIT also did not change P\(_{train}\) across
time in either group. The respective \( P_{\text{train}} \) values before and after training were 319 ± 73 and 334 ± 74 W in CD and 323 ± 89 and 344 ± 97 W in NCD. There was no difference in \( P_{\text{train}} \) between groups at any time or interactions.

Table 3 shows the cumulative mean values for \( W_{\text{train}} \), \( t_{\text{train}} \), \( I_{\text{fat}} \), \( I_{\text{com}} \), peakHR, and BL at the 3-wk training period. There was no difference for any value between groups. CD (66.5 ± 8.5%) and NCD (70.3 ± 6.4%) completed similar percentages of prescribed training. Training group also did not affect the progression of \( W_{\text{train}} \) from the first to the third interval session each week (Fig. 1).

Mean \( V_{\text{TTSK}}, P_{\text{TTSK}}, VO_{2\text{peak}}, \) and \( PPO_{a} \) were significantly correlated with each other (\( r \geq 0.96; P \leq 0.0000 \)). However, changes in mean \( V_{\text{TTSK}}, P_{\text{TTSK}}, VO_{2\text{peak}}, \) and \( PPO_{a} \) were not well correlated with \( I_{\text{fat}} \), \( I_{\text{com}} \), \( W_{\text{train}} \), \( t_{\text{train}} \), and peakHR. As expected, increases in \( VO_{2\text{peak}} \) were negatively correlated to initial \( PPO_{a} \) (\( r = -0.518; P = 0.048 \)) and \( VO_{2\text{peak}} \) (\( r = -0.638; P = 0.010 \)); similarly, increases in \( P_{\text{TTSK}} \) were negatively correlated to initial \( P_{\text{TTSK}} \) (\( r = -0.583; P = 0.032 \)).

**DISCUSSION**

Our purpose was to compare the effects of a HIT program completed on three consecutive or nonconsecutive days per week for 3 wk on \( VO_{2\text{peak}}, PPO_{a}, \) and \( TT_{5k} \) performance in trained cyclists. As shown in Figure 2, HIT completed at 100% of \( PPO_{a} \) and approximately 60% of \( T_{\text{max}} \) similarly improved \( VO_{2\text{peak}} \) and \( PPO_{a} \) in either group. The 5.7% increase in \( VO_{2\text{peak}} \) in both groups combined (\( P < 0.05 \)) is consistent with the increases reported for trained runners (5.5%) and cyclists (6.7%) following similar training stimuli (11,18,19). Likewise, the combined 7.2% increase in \( PPO_{a} \) (\( P < 0.05 \)) is also consistent with the literature, which shows that a similar training stimulus improved \( PPO_{a} \) by 5.4% in trained cyclists (11).

Consecutive- and nonconsecutive-day HIT similarly improved \( TT_{5k} \) performance (Fig. 2). In both groups combined, time trial power output and velocity increased (\( P < 0.05 \)) by 6.9 and 2.6%, respectively. To the best of our knowledge, the influence of HIT on TT power output in trained cyclists has not been reported. The 2.6% increase in 5-km TT velocity is lower than the 5.4% increase in 40-km TT velocity reported for trained cyclists after a similar training stimulus (11). The inconsistency in the magnitude of change in TT velocity between the respective studies may be related to the difference in TT length and, therefore, intensity, as shorter TT are completed at a higher relative intensity (16).

We also found that neither HIT program changed \( BL_{TT} \) or relative 5-km TT intensity. Our BL finding contrasts with data that show 40-km TT BL increased (31%) or tended to increase (13%) after similar HIT programs to ours (13). This same study also showed that HIT increased 40-km TT HR, which suggests that relative TT intensity increased if one accepts that \( HR_{\text{max}} \) was unchanged by training. The difference in TT length and, therefore, intensity in the respective studies may partially account for the inconsistencies in the effects of HIT on \( BL_{TT} \) and relative TT intensity.

Lastly, the physiological and performance variables we measured were significantly correlated to one another (\( r \geq 0.96; P \leq 0.0000 \)). Our \( r \) value for \( VO_{2\text{peak}} \) and TT power or velocity (0.96) is consistent with the value (0.78) found between \( VO_{2\text{peak}} \) and 3000-m run time (19) and exceeds the value (0.64) found between \( VO_{2\text{peak}} \) and 40-km TT velocity (13) in studies using similar training stimuli to ours. The inconsistency in the \( r \) value between \( VO_{2\text{peak}} \) and TT velocity in our study and the latter one (13) may be related to the difference in TT length and, therefore, intensity. Collectively, our data suggest that the improved TT performance we measured was largely attributable to aerobic adaptations, as \( BL_{TT} \) and relative TT intensity did not change, whereas \( VO_{2\text{peak}} \) and \( PPO_{a} \) increased significantly. Enhanced TT performance, moreover, was positively correlated to \( VO_{2\text{peak}} \) and \( PPO_{a} \) (\( P \leq 0.0000 \)).

Our most novel finding was that consecutive-day HIT was as effective as more traditional nonconsecutive-day HIT. It has been theorized that consecutive-day HIT or block-training may provide a more effective training stimulus and recovery period than traditional or nonconsecutive-day HIT training (15,17). Our data show, however, that the physiological response was similar whether the cyclists trained on three consecutive or nonconsecutive days per week for 3 wk. Although both training

| TABLE 2. Physiological and performance data before and after training. |
|---|---|
| | CD (\( N = 9 \)) | NCD (\( N = 6 \)) |
| \( v_{\text{TTSK}} \) (km·h\(^{-1}\)) | Pre | 37.5 ± 3.5 | 37.0 ± 5.2 |
| | Post | 38.3 ± 3.4* | 38.1 ± 4.9* |
| \( P_{\text{TTSK}} \) (W) | Pre | 279 ± 74 | 276 ± 97 |
| | Post | 295 ± 76* | 294 ± 99* |
| \( VO_{2\text{peak}} \) (L·min\(^{-1}\)) | Pre | 4.25 ± 1.15 | 4.34 ± 1.34 |
| | Post | 4.48 ± 1.09* | 4.54 ± 1.34* |
| \( PPO_{a} \) (W) | Pre | 325 ± 78 | 328 ± 79 |
| | Post | 348 ± 74* | 351 ± 96* |

Data are means ± SD. CD, consecutive-day training group; NCD, nonconsecutive-day training group; \( v_{\text{TTSK}}, TT_{5k} \) velocity; \( P_{\text{TTSK}}, TT_{5k} \) power output; \( PPO_{a}, \) peak aerobic power output. * Significant increase pre- to posttraining (\( P < 0.05 \)).

| TABLE 3. Cumulative mean ± SD for interval training variables. |
|---|---|---|
| | CD (\( N = 9 \)) | NCD (\( N = 6 \)) |
| \( P_{\text{ave}} \) (W) | 325 ± 75 | 330 ± 95 |
| \( I_{\text{fat}} \) (s) | 807 ± 97 | 843 ± 76 |
| \( W_{\text{ave}} \) (kJ) | 261 ± 81 | 279 ± 91 |
| \( I_{\text{com}} \) | 6.1 ± 0.6 | 6.3 ± 0.6 |
| \( t_{\text{com}} \) | 4.8 ± 0.7 | 4.2 ± 0.5 |
| PeakLact | 3.2 ± 1.9 | 3.9 ± 1.4 |
| \( BL_{\text{com}} \) (mM) | 10.4 ± 2.2 | 11.5 ± 1.4 |

CD, consecutive-day training group; NCD, nonconsecutive-day training group; \( P_{\text{ave}}, \) training workload; \( I_{\text{fat}}, \) total completed training time; \( W_{\text{ave}}, \) total completed work at \( P_{\text{ave}}; \) \( t_{\text{com}}, \) intervals attempted per session; \( I_{\text{com}}, \) intervals completed per session; peakLact, number of intervals per session in which subject came within 5 bpm of \( HR_{\text{max}}; BL_{\text{com}}, \) blood lactate concentration 5 min after the last attempted interval of training session.
designed similarly improved \( \text{VO}_{2\text{peak}} \), \( \text{PPO}_a \), and \( \text{TT}_{5k} \) performance, variability among subjects was high, as illustrated by the SD shown in the tables and in Figure 2.

The variability we measured exceeded the variability reported in a similar study (11). The subjects in this latter study were more homogeneous in terms of fitness than ours, as reflected by the SD for pretraining \( \text{VO}_{2\text{peak}} \) values. Indeed, the mean pretraining \( \text{VO}_{2\text{peak}} \) for the subject cohort in the latter study was \( 64.5 \pm 5 \text{ mL.kg.min}^{-1} \), whereas the corresponding value for our subjects was \( 62.1 \pm 12.5 \text{ mL.kg.min}^{-1} \). Given the significant negative correlations that we found between initial and final fitness, it is clear that our less-trained subjects benefited more from HIT than our better-trained ones. Thus, if our subject cohort had been more homogenous, the response to training might have varied less. The latter study (11) also used individualized interval durations based on each subject’s \( T_{\text{max}} \) whereas we used a fixed interval duration based on an estimated population mean for \( T_{\text{max}} \) derived primarily from that study. Interval duration is an important factor for eliciting \( \text{VO}_{2\text{max}} \) (8), which was the main objective of the HIT in both studies. Because interathlete variability in \( T_{\text{max}} \) is high (6,8), it is possible that our fixed interval duration was too long or short to optimize training adaptation in some subjects, thereby leading to greater variability in the primary dependent variables.

Another explanation for the variability in our primary measures may be that some subjects were better suited for either CD or NCD HIT, depending on their physiological and psychological responses to training stimuli. Figure 1, for example, shows how fatigue vastly decreased training performance by week’s end in some subjects but had little effect on others, regardless of group. Similarly, four out of the five greatest responses to training occurred in CD, as did the three smallest. A crossover study with CD and NCD HIT programs is warranted, to see whether individual athletes respond better to one design or the other.

In contrast to recent work that has examined the effects of HIT on cycling performance (11), we used a slightly more intense training program, with nine sessions during 3 wk instead of eight sessions during 4 wk. One might expect that the more compact training program we used in general, and the consecutive-day program in particular, may have led to greater subject fatigue relative to the aforementioned study (11). The data do not support this expectation, as our subjects completed 68.4% of the prescribed work, whereas subjects in the aforementioned study, who performed intervals twice rather than three times per week, only completed 64% of the prescribed training. The greater amount of interval training completed in our study (~6%) may reflect the possibility that interval duration, which we estimated to approximate 60% of \( T_{\text{max}} \), was too short in relation to the individualized one used in the aforementioned study (11). We cannot verify this supposition, as we did not measure \( T_{\text{max}} \) directly. On average, however, subjects were within 5 bpm of their peak HR in 3.5 out of the 4.2 intervals they completed each session, which suggests that interval duration was adequately approximated irrespective of the inherent issues of gauging intensity with HR.

In contrast to other studies that have examined the effects of HIT on TT performance, we used a 5-km TT rather than a 40-km TT (11,14,20–22). In all but one of these studies (11), the predominant training stimulus was 4- to 8-min intervals at 80–85% of \( \text{PPO}_a \). The exercise intensity elicited by such intervals is similar to the one evoked by TT that are 40-km or longer (16). A 40-km TT, therefore, is a logical test with which to assess the effects of the aforementioned HIT programs. Because we used an HIT program consisting of 2.5-min intervals at 100% of \( \text{PPO}_a \), a more logical performance test for us was a short TT, which elicits an exercise intensity closer to the one used in our training program than does a longer TT (16). Future investigators studying HIT may also wish to consider the use of shorter rather than longer TT, irrespective of training intensity. The coefficient of variation for either TT, for example, is approximately 1%, as shown in this study for the 5-km TT and elsewhere for the 40-km TT (11,20,21). Performance in either TT type in the lab, moreover, requires the

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**Figure 1**—Mean work completed (kJ) during the first and third interval-training sessions of a training week. Black segmented lines represent consecutive-day subjects (\( N = 6 \)); gray solid lines represent nonconsecutive-day subjects (\( N = 9 \)).

**Figure 2**—Mean ± SD for percent change in \( \text{TT}_{5k} \) velocity (\( \Delta \text{TT}_{5k} \)), \( \text{TT}_{5k} \) power output (\( \text{P}_{\text{TT}_{5k}} \)), \( \text{VO}_{2\text{peak}} \), and peak aerobic power output (\( \text{PPO}_{a} \)). CD, consecutive-day training group (\( N = 6 \)); NCD, nonconsecutive-day training group (\( N = 9 \)).
same physiological attribute: namely, the ability to sustain a high maximum power output (7,9). Shorter TT are also more convenient for the subject and investigator than are longer TT.

In summary, 3 wk of consecutive- or nonconsecutive-day HIT completed at 100% of PPO and approximately 60% of $T_{\text{max}}$ produced similar increases ($P < 0.05$) in VO$_{\text{peak}}$ (5.7%), PPO (7.2%), TT$_{5k}$ velocity (2.6%), and TT$_{5k}$ power output (6.9%). Because the individual responses varied widely in each group, athletes should experiment with both programs to discern which one optimizes their training.

REFERENCES


