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Research article

Effects of high intensity training by heart rate or power in recreational cyclists

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Abstract
Technological advances in interval training for cyclists have led to the development of both heart rate (HR) monitors and powermeters (PM). Despite the growing popularity of PM use, the superiority of PM-based training has not been established. The aim of the present study was to investigate the relative effectiveness of HR-based versus PM-based interval training on 20 km time trial (20km TT), lactate threshold (LT) power, and peak aerobic capacity (VO_2max) in recreational cyclists. Participants (n =20; M age=33.9, SD =13) completed a baseline 20km TT to establish their VO_2max and LT and were then randomly assigned to either HR-determined or PM-determined training sessions. Over a period of up to 5 weeks participants completed 7.2 (± 1.1) interval training sessions at their specific LT for their respective interval training method. Repeated measures analyses of variances (ANOVAs) showed that both HR-based and PM-based training groups significantly improved their LT power ($F(1,16) = 28.$, $p < 0.01$, $eta^2 = 0.63$) and 20km TT time ($F(1,16) = 4.92$, $p = 0.04$, $eta^2 = 0.24$) at posttest, showing a 17 watt increase (9.8%) and a near 3-and-a-half minute improvement (7.8%) in 20km TT completion time. There were no significant group (HR vs. PM) x time (baseline vs. posttest) interactions for 20km TT completion time, LT power, or VO_2max ratings. Our results coincide with the literature supporting the effectiveness of interval training for endurance athletes. Furthermore, our findings indicate that there is no empirical evidence for the superiority of any single type of device in the implementation of interval training. This study indicates that there are no noticeable advantages to using PM to increase performance in the average recreational cyclist, suggesting that low cost HR monitor are equally capable as training devices.

Key words: Power, hear rate, training.

Introduction

Interval training in cycling has been well established as a means of increasing performance in both trained and untrained athletes (Laursen and Jenkins, 2002; Laursen, et al., 2002; Stepto et al., 1999). Advances in technology have led to the availability of more affordable training aids such as heart rate monitors and powermeters. Both laboratory-based and portable devices have been used to measure or demonstrate improvements in key physiological variables following interval-based training (Ebert et al., 2006; Laursen et al., 2005; Stepto et al., 1999). The popularity of these training devices has spawned a large market and the consumer press has produced training guides based on their use (Allen and Coggan, 2006). In particular, there has been a growing use of portable powermeters, but the superiority of power-based training compared to other methods of interval training has not been established. Recently, investigators have done the first direct comparison of heart rate (HR) based intervals and power-based intervals (Swart et al., 2009). In that study, Swart et al. found that both types of interval training were successful in improving performance and physiological fitness parameters in well-trained cyclists. However, they did not show superiority of either method.

To date, no study has investigated the differential effectiveness of HR versus power-based interval training in recreational cyclists. The relatively large market for HR monitors and power meters represented by the recreational cyclist, and the large difference in cost between the two types of devices are compelling reasons to compare the effectiveness of the devices. The purpose of the present study was to investigate the relative effectiveness of HR-based versus powermeter (PM) based interval training in recreational cyclists. It was hypothesized that both types of interval methods would lead to increased performance (20km Time Trial), power at lactate threshold (LT), and VO_2max. Similar to the Swart et al. (2009) study, we predicted that the differences between HR and PM based interval training would be small with little statistical or practical significance.

Methods

Participants

Eleven men and nine women were recruited from a community surrounding a large southeastern university in the United States of America via cycling group listserves. The average age of the participants was M = 33.9 (13) years. Average weight of participants was 70.8 (11.2) kg. Groups did not differ on weight ($p > 0.05$). Neither group showed a significant change in weight with training ($p > 0.05$). Participants did not participate in any interval training 6 months prior to beginning the study and had been cycling recreationally for at least one year. Chi-square analysis indicated that sex was evenly distributed across the groups (chi-square = 0.6, $p > 0.05$). Before the study began, the purpose and protocol of the study were explained and informed consent was obtained.

Procedures

Prior to beginning the interval program, participants completed baseline testing that involved a 20km time trial (20km TT), an assessment of peak aerobic capacity (VO_2max) and a lactate threshold test (LT). A 20km TT was chosen based upon the average training level of our sample. Before baseline testing each participant was instructed to exercise at a very moderate intensity or not exercise at all the day before the tests. Participants were asked to keep detailed training logs of their activity, and were instructed not to deviate from their normal cycling training during the testing and training periods. Pre and post testing was completed within a two week period with a minimum of 48 hours separating each test. After the baseline testing was completed participants were randomly assigned to HR-determined or Power-determined

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training sessions.

For all testing and training sessions, participants brought their own bicycle that was attached to an electronic bicycle ergometer (Computrainer Lab, Racermate, Inc. Seattle, WA), as was used in Swart et al. (2009). The accuracy and reliability of this ergometer has been well established (Abbiss et al. 2007; Lamberts et al. 2009b). During a period of 5 weeks, participants completed 7.2 (±1.1) interval training sessions at their specified lactate threshold for power or heart rate. Before every testing and training session, the bicycle was calibrated according to the manufacturer's rolling resistance calibration procedures. To eliminate tire slip during testing and training a press on force between 2.0 lbs and 2.5 lbs was obtained after the system was warmed up.

Measurements

20km time trial: The time trial test was performed on the Computrainer using a custom created 20 km, 0% grade course (.3dc) created in the RacerMate Interactive 3D software (RacerMate, Inc. Seattle, WA). It consisted of a 10 minute self-paced warm-up, followed by completion of the 20 km TT in the fastest time possible. Participants were allowed to switch gears and drink water ad libitum during the test. Total time to complete 20 km TT, average heart rate and average power were recorded at the conclusion of the test. As we did not know the physical abilities of our participants before the testing period, a 20 km distance for the time trial was chosen over the 40 km time trial distance commonly used in USA Cycling sanctioned events as a well-established measure predicting competitive performance (Paton and Hopkins, 2001).

LT, and VO_2max tests: LT was determined using an incremental cycling test after participants completed a 10 minute self-paced warm-up. Starting at an initial load of 100 W (male) and 80 W (female), participants cycled for 5 minute intervals. During the last 30 seconds of the 5 minute interval, blood was taken from a free flowing digit puncture for blood lactate analysis. A Lactate Pro portable analyzer (Arkray, Japan) was used to analyze blood lactate levels at the completion of each interval. After the 30 second sampling period the load was increased by 30 W (male) and 20 W (female). The participants continued cycling in 5 minute intervals until they could no longer maintain the load (i.e. were unable to continue cycling at the desired power). The participants were allowed to recover by resting or cycling with no load for a period of 10 minutes. Immediately after the recovery period VO_2max was determined using an incremental cycling test. Beginning at the same load as the LT test, the participants cycled for 5 minutes. After the 5 minute interval, the load increased similar to the LT test (i.e. the power was incrementally increased by 30 W for men and 20 W for women), however the interval time period was 1 minute. The test continued until the participants could no longer maintain the load. Expired gases were collected in a mixing chamber and measured using a metabolic gas exchange system (TrueMax 2400 Metabolic Measurement System, Parvo Medics, Salt Lake City, Utah). Expired gases were analyzed and VO_2max was determined as the highest reading of VO_2 measured in $ml \cdot kg^{-1} \cdot minute^{-1}$. Prior to each test the gas analyzer was calibrated against a standard gas mixture and the air flow was calibrated through a low-resistance breathing valve (Rudolph No. 2700, Hans Rudolph, Inc. Kansas City, MO). Gas values were manually obtained in 10 second intervals, and the VO_2 values were automatically recorded by a metabolic cart in the last 15 second of each 1 minute interval. HR, average power output and RPE were recorded at the end of each interval throughout the testing. Peak power output (PPO) was calculated by averaging the power output for the final minute of the VO_2max test. RPE was obtained using a modified Borg Scale ranging from 0 to 10 (Borg, 1982).

Determination of lactate threshold was achieved by plotting a lactate performance curve, using lactate, heart rate and power output (W). The power and HR at which a blood lactate accumulation of 4 $mmol \cdot L^{-1}$ occurred was referred to as the LT (Sjodin, Jacobs, & Karlsson, 1981).

Power-determined training session procedures

Prior to the training session, a data file was created using the Computrainer Coaching Software (CS) based on the participant's pre lactate threshold test. The participants were given instructions on how to maintain the correct power during the training period and were monitored by someone who recorded wattage, HR, PRE every minute during the test. Each training session began with a self-paced warm up (5 minutes) and calibration of the ergometer. The interval training session lasted an hour-and-a-half and consisted of 11 intervals - 5 minute work periods at the participant's determined lactate threshold power, followed by a 4 minute recovery period based on a protocol of 65% of maximum HR. The duration of the interval was chosen based on the interval length that would elicit physiological adaptations that cause an improvement in lactic acid buffering capacity and endurance performance (Weston, Myburgh, and Lindsay, 1997). Training intensity was gradually increased approximately 5-15% of predetermined Lactate threshold per week (Bompa, 1999). If the participant was unable to maintain the prescribed workload from the previous session, the workload stayed the same; if the participant was able to maintain the workload for the duration of the intervals, the workload was increased in the next session. HR, power and rating of perceived exertion were recorded every minute during the training sessions.

HR-determined training session procedures

The participants of the HR-determined group followed a similar training protocol for the Power-determined group except the power was controlled manually by using the manual ergo mode in the Computrainer Coaching Software (CS) program. Participants HR's were monitored and the power was adjusted to maintain their HR within the lactate threshold HR during work intervals; in other words, training resistance was constantly monitored and adjusted to maintain the target HR. Identical to the Power training group, rest intervals were based on a protocol of 65% of maximum HR.

Statistical analyses

Data were analyzed using SPSS version 17.0. A repeated measures analysis of variance (ANOVA) was run to determine differences in training gains before and after the intervention for 20 km TT, LT power, and VO_2max. Statistical significance was evaluated by $p \leq 0.05$ criteria. To determine if the two groups arrived at similar training loads, a repeated measures ANOVA was conducted on the first session power used for training vs. the last session power. A separate repeated measures ANOVA was conducted to determine whether HR and Power training groups had similar workouts across sessions by comparing work interval power for the average number of completed training sessions (group served as the between subject factor in all ANOVA analyses).

Results

Participant characteristics (e.g. age, body mass, VO_2max, etc.) by training group are presented in Table 1. No significant differences were found between the two groups on any of the listed descriptive in this table.

Table 1. Heart rate training and Power training group descriptive statistics. Data are means (±SD).

	Heart rate	Power
Age	36.9 (15.7)	30.9 (9.5)
Body mass (kg)	72.0 (13.8)	67.7 (8.3)
$V0_2$ max ($L \cdot min^{-1} \cdot kg^{-1}$)	48.4 (9.3)	50.3 (9.7)
PPO (W)	255.0 (75.7)	261.0 (65.9)
PPO (W/Kg)	3.5 (.7)	3.8 (.6)
PRE 20km TT time (s)	2348.8 (314.5)	2501.4 (562.5)
POST 20km TT time (s)	2233.7 (222.5)	2220.6 (239.3)
20km TT AP (W)	173.4 (49.1)	176.4 (51.2)
AP across intervals (W)	131.7 (44.7)	134.1 (43.8)
AP % (across intervals) of PPO	51.6%	51.4%

No significant differences ($p > 0.05$) between the two groups. PPO : peak power output, TT : time trial, AP : average power.

Pre-interval training and post-interval training averages for 20 km TT, LT power, VO_2max, and PPO measures are provided in Table 2.

20K TT: Results for the 20km TT indicated a main effect for time ($F(1,16) = 4.92$, $p = 0.04$, $eta^2 = 0.24$). There was no main effect for group ($F(1,16) = 0.27$, $p > 0.05$, $eta^2 = 0.02$) or group by time interaction ($F(1, 16) = 1.0$, $p > 0.05$, $eta^2 = 0.06$). On average, both groups improved their TT times by 3 minutes and 25 seconds (7.8%).

LT Power: For average power at LT, there was a significant main effect of time ($F(1,16) = 28.8$, $p < 0.01$, $eta^2 = 0.63$). There was no main effect for group ($F(1,16) = 0.001$, $p > 0.05$, $eta^2 < 0.00$) or time by group interaction ($F(1,16) = 0.44$, $p > 0.05$, $eta^2 = 0.03$). On average, participants increased their LT power by 17 watts (9.8%).

VO_2max: Interval training had no effects on VO_2max as indicated by non-significant main effects for time ($F(1,16) = 0.2$, $p > 0.05$, $eta^2 = 0.01$), group ($F(1,16) = 0.7$, $p > 0.05$, $eta^2 = 0.008$), or time by group interaction ($F(1,16) = 0.6$, $p > 0.05$, $eta^2 =0 .036$).

Interval Training Power: Results indicated that Indexing training by a priori power (5-15 % increase of predetermined lactate threshold per week) vs. HR determined training load, showed that both groups increased their workload across sessions ($F(1, 64) = 5.23$, $p < 0.001$, $eta^2 = 0.25$) , but there was no group by session interaction effect ($F(1, 64) = 1.2$, p +.3, $eta^2 = 0.07$). There was also no group by session interaction for power across completed training sessions ($F(6,78) = 162.42$, $p = 0.390$, $eta^2 = 0.07$). These results suggest that the two training methods resulted in roughly equivalent workouts.

Table 2. Pre-interval training and post-interval training descriptive statistics. Data are means (±SD).

	Pre	Post
Power		
PPO (W)	261.0 (66.0)	278.5 (70.0)
PPO (W/kg)	3.8 (.6)	4.1 (.6)
VO_{2max} ($ml \cdot min^{-1} \cdot kg^{-1}$)	50.3 (9.7)	50.7 (7.4)
LT (W)	176.7 (57.3)	195.6 (55.0)
20km TT time (s)	2501.4 (562.5)	2382.6 (611.7)
20km TT power (W)	176.4 (51.2)	196.4 (47.4)
Heart rate		
PPO (W)	255 (75.7)	285 (58.5)
PPO (W/kg)	3.5 (.7)	3.9 (.6)
VO_{2max} ($ml \cdot min^{-1} \cdot kg^{-1}$)	48.5 (9.2)	48.4 (7.4)
LT (W)	169.9 (38.8)	192.9 (39.09)
20km TT time (s)	2348.8 (314.5)	2233.7 (222.5)
20km TT power (W)	173.4 (49.1)	183.4 (38.7)

PPO : peak power output, LT : lactate threshold, TT : time trial, AP : average power.

Discussion

The purpose of the study was to assess the effects of interval training on 20K TT, LT power, and VO_2max from HR-based training and PM–based training protocols. Results indicated significant improvements in 20K TT times of nearly three and a half minutes or 7.8%. Similarly, power at LT improved by nearly 10 percent. These are meaningful improvements and are consistent with other reports (Laursen et al., 2005; Swart et al., 2009). Similar to Swart et al. (2009), who studied well-trained cyclists, no significant differences were obtained between HR and PM-based training protocols in our sample of recreational cyclists. VO_2max did not show a training effect and similar results have been noted in other training studies (Swart et al. 2009; Henritze et al. 1985). However, the interval sessions were of a lesser intensity (close to LT) and may not have been sufficient to show an effect on maximal oxygen consumption (Laursen et al., 2002).

From a practical perspective, this study demonstrates that for the average recreational cyclist, there may not be any discernable advantage to using a PM to obtain increased performance and the concomitant physiological changes. The changes from a relatively modest training protocol with respect to time involved in the training were substantial. The results parallel those of Swart et al. (2009) and suggest that the relatively low cost HR monitors are equally capable as training devices compared to the PM. Results of this study indicated that the two methods resulted in roughly equivalent workout loads across training sessions, which resulted in the similar training effects observed for the two groups.

Proponents of the PM often espouse the advantage of the increased precision, the greater temporal responsiveness, and the fewer artifactual influences on power as an indicator of effort when compared to HR as a training tool (Allen and Coggan, 2006). There is little reason to dispute these claims that PM power is a very direct measure of work that it can be very precisely measured and that changes in power can be nearly instantaneously measured and observed with a PM. It is true that the relationship between measurable HR change and a change in effort is likely to have a temporal lag. However, the relationship between HR measures and power is high (Grazzi et al., 1999; Lamberts et al., 2009a; 2011). However, these purported advantages are, at this point, unsubstantiated in any sort of controlled trial and remain theoretical. The existing evidence points to the effectiveness of both HR and PM based interval training.

Conclusion

Proponents of PM training (Allen and Coggan, 2006) often suggest that using a PM will result in a different type of training. Future research may be needed to operationalize these claims and evaluate them in controlled trials. At present, there is substantial support for interval training for endurance athletes and no evidence for the superiority of any single type of device in the implementation of interval training. Until additional studies are conducted to address the potential benefits of new types of training based on PM feedback, there remains no empirical evidence for the superiority of PM-based training.

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Key points

- Interval training improves performance for recreational cyclists as measure by changes in lactate threshold watts and 20km time trial time
- No evidence of superiority of either heart monitor training and power meter training
- Low cost heart rate monitors are equally capable as training devices

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