Journal of Strength and Conditioning Research, 2007, 21(1), 265–269

Efficacy of Cycling Training Based on a Power Field Test

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Abstract. Klika, R.J., M.S. Alderdice, J.J. Kvale, and J.T. Kearney. Efficacy of cycling training based on a power field test. *J. Strength Cond. Res. 21(1):265–269. 2007.*—The efficacy of an 8-minute field test to prescribe exercise intensity and assess changes in fitness was evaluated before and after 8 weeks of indoor cycling, and the results were confirmed by laboratory assessment. Changes in maximal steady-state power (MSSP), power at lactate threshold (PT_{lact}), maximal power (Pmax), and maximal oxygen uptake ($\dot{V}O_2max$) were measured on 56 participants (20 women, 36 men; mean ± *SD*. 46.5 ± 10.0 years) who completed 1-hour, biweekly indoor stationary cycling classes on their own road bike outfitted with a Power Tap Pro power meter. The MSSP was defined as the average power during an 8-minute field test, which was administered at the beginning (pre) and end (post) of the training intervention. Individual training ranges were calculated from the pre-MSSP in accordance with Carmichael Training Systems. Laboratory assessments of PT_{lact}, Pmax, and $\dot{V}O_2max$ were made on 24 of the participants the same weeks MSSP was evaluated. After training, MSSP increased 9.2% (195.4 ± 56.6 vs. 213.8 ± 57.2 W; $p < 0.05$), and PT_{lact} increased 12.9% (178.3 ± 47.1 vs. 201.5 ± 47.6 W; $p < 0.05$). The MSSP was ~7.5 % higher than PT_{lact}. Pmax increased ~6.7% (315.2 ± 65.1 to 336.5 ± 65.9 W), and $\dot{V}O_2max$ increased ~6.5% (46.2 ± 10.7 to 49.1 ± 10.5 ml·kg^{-1}·min^{-1}). The MSSP and PT_{lact} were highly correlated ($r = 0.98$) as was MSSP and $\dot{V}O_2max$ ($r = 0.90$). The results of this research indicated that (a) the field test is a valid measure of fitness and changes in fitness, (b) it provided data for the establishment of training ranges, and (c) a biweekly power-based training program can elicit significant changes in fitness.

Key Words. lactate threshold, Power Tap, cycling

Introduction

It is well established in the training literature that a critical factor in eliciting an optimal training response is to match the prescribed training challenges to the physiologic capabilities of the trainee. To achieve specific adaptations to training, Carmichael Training Systems (CTS) has developed a unique methodology based on power at blood lactate threshold or average power during a field test (5). This methodology establishes narrower intensity ranges than typical training zones (e.g., Friel, United States Olympic Committee), allowing CTS coaches to increase training prescription precision for recreational cyclists (8, 15).

Power measured from field tests were originally designed to create a cost-effective and reproducible means to assess fitness of athletes who did not have access to laboratory testing. Field tests designed by coaches at the United States Cycling Federation (USA Cycling) and Olympic Training Center (Colorado Springs, CO) serve as the basis of the 8-minute field test primarily because similar tests were valid and reliable, sport specific, test administration followed a strict protocol, testing could be conducted at regular intervals (regardless of geographic location), and the results are applicable for training purposes.

As we conduct regular indoor cycling classes using power measuring devices under controlled conditions and perform metabolic laboratory testing, 2 questions of interest surfaced: is field test data measured with a commercially available power meter a reliable means to establish training intensities that produces a significant training effect, and second, after the training intervention, how do the changes in fitness evaluated with field test assessment compare with laboratory assessment.

The purpose of this study was to (a) use the Power Tap power meter to assess the participants' fitness using a field test, (b) develop and implement a training program based on the field test results and CTS training methodology (c) readminister the Power Tap monitored field test to asses the training program efficacy, and (d) evaluate the efficacy of the training in a subsample using traditional metabolic assessment. We hypothesized that there would be a significant increase in maximal steady state power (MSSP), power at threshold (PT_{lact}), maximal power (Pmax), and maximal oxygen consumption ($\dot{V}O_2max$) after 8 weeks of indoor cycling training and that exercise intensity could be prescribed from a valid 8-minute field test. Second, we hypothesized that the 8-minute field test would be a valid and reliable indicator of training status compared with traditional laboratory assessments.

Methods

Experimental Approach to the Problem

To test our hypotheses, we retrospectively analyzed power data after an 8-week indoor cycling class. A relatively large sample of the class completed laboratory testing pre- and post-8 weeks of training; therefore, the 8-minute field test efficacy was evaluated. Changes in average power from the 8-minute field test were compared with changes in physiological variables related to performance.

Subjects

Participants, 20 women (age range, 32–59 years) and 36 men (age range, 36–66 years), with a combined mean age of 46.5 ± 10.0 years, participated in an 8-week indoor cycling training class, which met twice a week for 1 hour·session^{-1}. The 56 adults ranged from novice cyclists to master athletes and could be considered recreational cyclist enthusiasts. All participants signed informed consent and waivers for participation in the project. Training and testing took place at an altitude of 2,400 m, and all participants were residents of the area. Height and weight were recorded before and after the 8-week session. A subsample ($N = 24$; $n = 10$ women; $n = 14$ men; combined mean age, 46.3 ± 9.5 years) underwent laboratory testing to measure PT_{lact}, Pmax, and $\dot{V}O_2max$ the same

TABLE 1. Characteristics of subjects.*

		Age (yr)		Weight (kg)	
	N	Mean	*SD*	Mean	*SD*
Total sample	56	46.5	10.0	76.8	13.5
Men	36	48.6	9.9	82.5	13.5
Women	20	43.0	9.6	66.2	9.2
Laboratory testing sample					
Total lab sample	24	46.3	9.5	76.4	13.7
Men	14	48.1	9.5	82.4	16.1
Women	10	43.7	9.4	67.8	10.7

* Differences between total and laboratory samples age and eight are not significant, $p < 0.05$.

weeks that pre- and post-MSSP was tested. Descriptive characteristics of the participants are presented in Table 1. There were no significant differences in age or weight between the total and subsamples.

Procedures

Each participant's personal road bike was fitted with a Power Tap Pro power meter (Saris Products, Madison, WI), built on a 700-cm rim (rear wheel) with a 9 or 10 speed cassette (12–25 T; participants' rear wheels are simply replaced with the Power Tap wheel). All road bikes had clipless pedals, and each individual's pedals were used on the cycle ergometer for laboratory testing (see below). Each bike was wired with a receiver unit mounted on the handle bars of the bike per manufacturer's operating instructions, and the power meters were calibrated (zeroed) according to instructions before each field test effort and all training sessions. This process takes 20 minutes to complete. Resistance was applied to the rear wheel using a CycleOps Fluid[2] (Saris Products) stationary trainer according to manufacturer's operating instructions. This allowed the individual to adjust resistance (power) by changing the gears of the bicycle. The Power Tap power monitoring system has been shown to be both reliable and valid (9).

Procedures for 8-Minute Field Test

Each participant completed an 8-minute field test, measured at the beginning (pre-) and end (post-) of the 8-week session. Intraclass correlations on a sample of 8 subjects indicated that the 8-minute field test has high reliability ($r = 0.93$; unpublished observations). The first session of each 8-week class was used as an introductory session to familiarize each person with the class structure, use of the power meter, and to troubleshoot any abnormalities in power recordings. The field tests were held during sessions 2 and 16 of the class. After approximately 20 minutes of warm-up (10 minutes easy cycling followed by 3 medium-to-hard 1-minute efforts and 5 minutes of easy cycling), each participant completed the 8-minute field test. Participants were instructed to maintain a cadence between 80 and 100 revolutions·min^{-1}, select a gear of their choice to complete the task, and pace themselves for the 8 minutes with an "all-out" effort. An instructor verbally gave the time remaining each minute. Participants completed the field test effort indoors under constant conditions (average temperature, 24° C; average humidity, ~20%). After being downloaded from the Power Tap Pro receiver unit, average power, cadence, and heart rate for the 8-minute field test was recorded using Cycling Peaks Software (Training Peaks, Boulder, CO). The MSSP was

TABLE 2. Carmichael training systems training ranges.

Training range	Percent of maximal steady state power
Recovery miles	40–55
Endurance miles	45–65
Tempo	81.5–85
Steady state	85.5–90
Climbing repeats	95–100
Power intervals	Maximal sustainable power

defined as the average power output (W) during the 8-minute effort.

Training Sessions

Each session consisted of a 10-minute warm-up period, 10-minute cool-down period, and a 40-minute workout of prescribed volume and intensity. Each workout was unique and had a particular focus (tempo riding, power intervals, fast pedaling, etc.). Duration for each session was 60 minutes for the entire 16 sessions, but intensity progressed incrementally over the 8 weeks (e.g., longer duration intervals or greater number of high-intensity intervals). All workouts were written before the beginning of the class but were adjusted to group dynamics and client feedback as the sessions progressed. Individual power training ranges (intensities) were calculated from pre-MSSP in accordance with Carmichael Training Systems (CTS) (5). CTS training ranges, as a percent of MSSP, are presented in Table 2. Percent time spent in each training range during the 8-week session is presented in Figure 1. Time spent in recovery and endurance ranges were combined because recovery riding was typically at the low end of the endurance miles range.

Measurement of Lactate Threshold

Twenty-four subjects completed a continuous 3-minute stage incremental exercise test on a Excalibur Sport cycle ergometer (Lode, Groningen, The Netherlands) the same week the MSSP field test efforts were tested. The incremental protocol began at 100 W and increased to 125 W for women and 150 W for men, followed by 25-W increments (for both sexes) every 3 minutes thereafter until threshold was obtained (see criteria below). Subjects were instructed to maintain a cadence of 80–100 revolu-

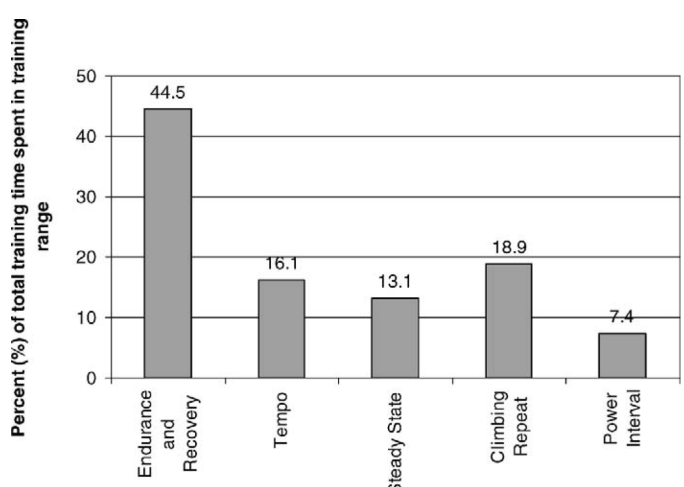

FIGURE 1. Percent of total training volume in each Carmichael Training Systems training range.

tions·min^{-1}, and at the end of every stage, power, heart rate, and blood lactate (mmol·L^{-1}) were recorded. Blood samples were obtained by piercing of the ring (third) fingertip, collected in a 32-μl capillary tube to ensure equivalent blood volumes (16 μl), and analyzed with an Accusport (Sports Resource Group, Hawthorne, NY) lactate analyzer. The Accusport lactate analyzer has good reliability (3, 7, 13) and has been reported to give slightly elevated blood lactate concentrations at simulated altitude (13). Subjects continued with the protocol until they reached a workload where lactate concentration increased 1 mmol·L^{-1} over baseline, followed by a subsequent increase in lactate ≥1 mmol·L^{-1}. After the preceding increases in blood lactate were observed, resistance was decreased to 75 W for an 8-minute recovery period. Maximal oxygen consumption was measured immediately after recovery. The blood lactate threshold was determined by graphing the lactate vs. power relationship and by determining the power at which blood lactate increased 1 mmol·L^{-1} above baseline, as described by Coyle et al. (6).

Measurement of $\dot{V}O_2$max

$\dot{V}O_2$max was measured using a calibrated Sensor Medics 2900 metabolic cart (VIASYS, Anaheim, CA). The initial workload for this procedure was equivalent to the last workload attained during the PT_{lact} assessment. Workloads were increased in 25-W increments every minute. $\dot{V}O_2$max was recorded when the subject reached volitional exhaustion or when there was a decease or plateau in oxygen consumption with increasing workload and a respiratory exchange ratio (R) >1.1. Maximal power (Pmax) was recorded as the highest workload that was maintained for a minimum of 20 seconds.

Statistical Analyses

Data were analyzed using SPSS for Windows (version 13.0; SPSS, Inc., Chicago, IL). Age and weight were compared using independent *t*-test. Analysis of variance (ANOVA) was used to evaluate changes in MSSP in the total sample and for PT_{lact}, Pmax, and $\dot{V}O_2$max in the subsample. Pre-and post-MSSP, PT_{lact}, Pmax, and $\dot{V}O_2$max were compared using one-tailed paired *t*-tests. The strength of the relationships was assessed using Person's product-moment correlation coefficients. Alpha level was set at $p \leq 0.05$ for all analyses.

RESULTS

Responses to training for men and women, as well as for those subjects in the whole and subgroup on MSSP, PT_{lact}, Pmax, and $\dot{V}O_2$max, were analyzed with ANOVA and were not significant allowing data to be grouped for subsequent analyses.

Over the course of 8 weeks of training, there were significant increases in all physiologic variables. Comparisons pre- and posttraining are presented in Table 3.

The MSSP in the total sample increased 18.4 ± 9.4 W and 19.8 ± 10.0 W in the laboratory sample. Post-training, PT_{lact} increased 23.2 ± 8.6 W, Pmax increased 21.3 ± 0.8 W, and $\dot{V}O_2$max increased 2.9 ± 1.7 ml·kg^{-1}·min^{-1}. These positive training adaptations are presented in percent change format in Figure 2.

There were significant differences between MSSP and PT_{lact} both before and after 8 weeks of training (MSSP: 195.4 ± 57.0 vs. 213.7 ± 57.2 W; PT_{lact}: 178.3 ± 47.1 vs. 201.5 ± 47.6 W, $p < 0.001$). On average, MSSP was 7.5% higher than PT_{lact} before and after training. However, the magnitude and direction of change for MSSP and PT_{lact} were similar. MSSP and PT_{lact} both pre- and posttraining were, on average, 64 and 57% of Pmax, respectively.

TABLE 3. Pre-post training comparisons of physiologic characteristics.*

		Pre		Post	
	N	Mean	*SD*	Mean	*SD*
MSSP (W)	56	195.4	57.0	213.8†	57.2
PT_{lact} (W)	24	178.3	47.1	201.5†	47.6
Pmax (W)	24	315.2	65.1	336.5†	65.9
$\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	24	46.2	10.7	49.1†	10.5

* MSSP = mean steady-state power; Pt_{lact} = power at threshold; Pmax = maximal power.
† Significant difference pre-post training, $p < 0.05$.

Correlations among the physiological variables pre- and posttraining are presented in Table 4. All correlations were significant at $p < 0.05$. The strongest relationships were between MSSP and PT_{lact} ($r = 0.98$, both pre- and posttraining), and MSSP was strongly related to Pmax and $\dot{V}O_2$max ($r = 0.76$–0.90).

DISCUSSION

The goal of this project was to assess initial fitness using a power-based field test, use the power results to prescribe and monitor a training program, reuse the power test to measure training adaptation, and confirm the training results with traditional laboratory testing. The major findings of the study were that the field test was effective in evaluation of initial fitness, served as the foundation for training prescription, was highly correlated to but 7.5% (18 W) higher than a laboratory-based lactate threshold, and accurately measured the training response. The 8-minute field test is easy and relatively quick to administer to a large group (after the Power Tap apparatus has been installed) and can be used to monitor fitness at any time during a training intervention.

The 8-week training period was structured such that approximately 32% of the total time was spent near and slightly above threshold power and approximately 7.4%

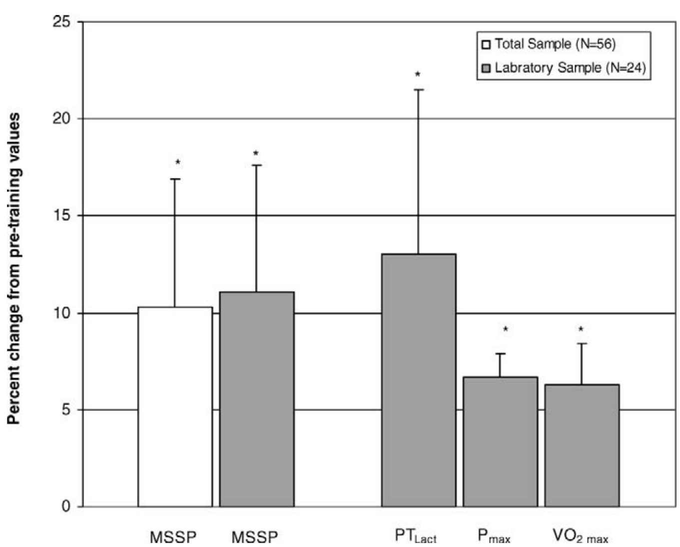

FIGURE 2. Percent change in performance markers.
* Significant increase over pretraining values ($p < 0.05$). Differences between total sample and laboratory sample maximal stead state power (MSSP) were not significant. †PT_{lact} = power at threshold; Pmax = maximal power.

TABLE 4. Correlations among physiological variables pre-and posttraining.*

	Pretraining				Posttraining			
	MSSP	PT_{lact}	P_{max}	$\dot{V}O_2max$	MSSP	PT_{lact}	P_{max}	$\dot{V}O_2max$
MSSP		0.98†	0.76†	0.88†		0.98†	0.82†	0.90†
PT_{lact}			0.75†	0.86†			0.79†	0.89†
Pmax				0.71†				0.80†
$\dot{V}O_2max$								

* MSSP = maximal steady state power; Pt_{lact} = power at threshold; Pmax = maximal power.
† Significant correlation, $p < 0.05$.

was spent at maximal sustainable power. The classes were considered hard by the participants, although approximately 45% of the total training volume prescribed was at or below lactate threshold. The classes were designed to provide 2 at or above threshold training sessions per week, and while not every class session consisted of sprint intervals, most contained some version of short (<3 minutes) intervals at maximal sustainable power.

Increases in power over the 8 weeks can be ascribed to increased fitness (central and peripheral adaptations), increased mechanical efficiency, and better pacing strategies. The results from the subgroup, which completed a pre- and posttest metabolic profile, support the conclusion that the power-based training program elicited physiologic adaptations. The increase in maximal aerobic capacity suggests either central or peripheral adaptations occurred that allowed for an increase in either cardiac output and/or oxygen delivery. We believe the increase in aerobic capacity was caused in part by increased cardiac adaptations, and we speculate those may be a result of increased blood and stroke volumes.

Recently, Burgomaster et al. (4) reported significant muscle oxidative improvements using multiple high-intensity sprint workouts. Our indoor training session did not include supramaximal efforts similar to Burgomaster et al. (4) but support the idea that short, intense exercise programs may have a significant impact on muscle oxidative capacity. The mechanism of this adaptation remains unknown.

Changes in mechanical efficiency (ME) were not evaluated in the study, but a significant portion of each class was devoted to increasing pedaling cadence in a range of 80–100 revolutions·min^{-1}. This sample's increased posttraining power gains could be attributed to higher type 1 muscle unit activation. Horowitz et al. (11) has shown that the preferential use of type 1 fibers to be more efficient in well-trained cyclists. We feel that teaching our participants to spin at higher cadences may increase gross efficiency (by decreasing the cost of limb movement) and may cause altered hemodynamics by increasing muscle blood flow and venous return as suggested by Gotshall et al. (10).

Over the course of 8 weeks, less experienced cyclists may have learned how to pace themselves better for the 8-minute field test effort, and this may have contributed to the increase in posttraining field test power. A learning effect for field test pacing was not evaluated. However, average power for the field test effort appeared visually more consistent posttraining, thus suggesting that the individual learned how to maintain a high output for the entire 8-minute effort. Approximately 19% of the class training time was devoted to climbing repeat intervals, which were designed to work at or slightly above lactate threshold. These intervals were typically 8–20 minutes long and were repeated 2–4 times in a session. This type of workout may have assisted our clients in learning how to sustain high power outputs over extended time periods.

Our data were in agreement with others who report that average power for field test/time trial efforts were typically above power at lactate threshold determined in the laboratory (2, 12, 14). MSSP values measured in this project were approximately 7.5% higher than power at blood lactate threshold values. It should be noted that, as a percent of Pmax, our MSSP and PT_{lact} values were relatively low (58–64%, respectively). Our definition of Pmax is a power output value greater than or equal to the power required to elicit $\dot{V}O_2max$, which is greater than the power that can be maintained at $\dot{V}O_2max$. Hence our reported values are slightly below typical values of MSSP of 70–80% of power to elicit $\dot{V}O_2max$.

Our laboratory has conducted more than 500 $\dot{V}O_2max$ tests, and residents of this area are typically at or above the 80th–100th percentile of aerobic fitness compared with normative data (1); thus, we postulated that this group, before participation in the class, was already very aerobically fit. However, the classes are held in the winter season where aerobic fitness levels typically decline because of a severe drop in training volume (weather related). The high aerobic capacity of these recreational cyclists is most likely caused by extremely active lifestyles characteristic of our population and living at a higher altitude (personal data from our laboratory). Because the participants of this class were middle-aged and only 6 individuals in the class reported being competitive master cyclists, the 13.0 and 6.3% increase in PT_{lact} and $\dot{V}O_2max$, respectively, were noteworthy. We feel the CTS training methodology, based on training programs originally designed for competitive cyclists (including Lance Armstrong) and scaled appropriately for recreational cyclists, worked well in this population of middle-aged men and women and would work well for any population of cyclists. Further research is needed to confirm this statement.

In summary, increases in MSSP and $\dot{V}O_2max$ were most likely a result of both central and peripheral physiologic adaptations, changes in lactate kinetics, and possibly increased mechanical efficiency, better pacing strategies, and improved muscle oxidative capacity. While the changes in efficiency and pacing strategies were not evaluated, the goal of the class was to increase fitness using a field test as a guide for exercise prescription. We found the use of the Power Tap power meter valuable in pre- and posttraining fitness assessment, helped with exercise prescription, and allowed our athletes to monitor their training intensity accurately during this training intervention. Using training volumes and power ranges according to CTS methodology, we increased fitness significantly in this very fit population of middle-aged recreational cyclists.

Practical Applications

An 8-minute indoor field test completed on a subject's own bike outfitted with a Power Tap Pro power meter positioned on a stationary trainer is an effective means for assessing MSSP and changes in fitness. The Power Tap system also proved to be an efficient tool for monitoring exercise intensity during training. MSSP was approximately 7.5% higher than PT_{lact} measured under laboratory conditions, and if exercise intensity is to be prescribed around a theoretical lactate threshold point, appropriate adjustments must be made. If exercise training follows approximate percentages and intensities as described, there should be a significant training effect in as little as 8 weeks of indoor cycling training.

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Acknowledgments

The authors are employees of Carmichael Training Systems. The results of this study do not constitute endorsement of the product by the authors or the National Strength and Conditioning Association.

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