Time Course of Learning to Produce Maximum Cycling Power

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Martin JC, Diedrich D, Coyle EF. Time Course of Learning to Produce Maximum Cycling Power. Int J Sports Med 2000; 21: 485–487

Accepted after revision: February 10, 2000

The purpose of this investigation was to determine the time course and magnitude of learning effects associated with repeated maximum cycling power tests and to determine if cycle-trained men exhibit different learning effects than active men who are not cycle-trained. Cycle-trained (N = 13) and active men (N = 35) performed short maximal cycling bouts 4 times per day for 4 consecutive days. Inertial load cycle ergometry was used to measure maximum power and pedaling rate at maximum power. Maximum power of the cycle-trained men did not differ across days or bouts. Maximum power of the active men increased 7 % within the first day and 7 % from the mean of day one to day three. Pedaling rate at maximum power did not differ across days or bouts in either the cycle-trained or active men. These results demonstrate that valid and reliable results for maximum cycling power can be obtained from cycle-trained men in a single day, whereas active men require at least 2 days of practice in order to produce valid and reliable values.

Key words: Skeletal muscle, exercise test, validity, reliability.

Introduction

Measurements of maximum cycling power have been used to determine the effectiveness of exercise training programs [9, 11,15] and ergogenic treatments [1,13], and to explain physiological factors responsible for individual differences in performance [5,8]. Similarly, the pedaling rate for maximum power production has been shown to be highly related to muscle fiber type composition [6]. Thus, maximum cycling power and pedaling rate at maximum power seem to represent intrinsic muscle function. Recently, however, Capriotti and coworkers [4] reported that maximal cycling power of non-cycle-trained men increased due to learning effects associated with repeated testing during a fatiguing protocol. Such learning effects may confound the results of investigations that use maximum power as a dependent variable. Consequently, valid evaluation of training programs, ergogenic treatments, or physiological factors requires that learning be completed prior to collection of experimental data. Therefore, the purpose of this investigation was to determine the time course and magnitude of learning effects associated with repeated maximal cycling power tests during a non-fatiguing protocol, and to determine if cycle-trained men exhibit different learning effects than active men who are not cycle-trained.

Methods

Cycle-trained (N = 13, 27 ± 6 yr, 72 ± 9 kg; mean ± SD) and active men (N = 35, 24 ± 4 yr, 78 ± 17 kg; mean ± SD) were recruited to participate in this study. The cycle-trained men were competitive amateur road and off-road cyclists. The active men participated in racquet sports, weight lifting, running, or American football but did not cycle regularly. This study was approved by the Institutional Review Board at The University of Texas at Austin and meets the ethical standards of the Helsinki Declaration of 1975. All subjects provided written informed consent.

Each subject reported to the laboratory at the same time each day for 4 consecutive days. They performed a 5-minute warm-up by cycling at 100 to 120 rpm at a power of 100 to 120 watts, then rested for 2 minutes prior to performing 4 bouts of maximal acceleration with 2 minutes resting recovery between bouts. Subjects started each bout from rest and accelerated maximally for 3–4 seconds on a verbal command with standardized encouragement. They were instructed to remain seated throughout each bout. Data were recorded for 6.5 crank revolutions. Seat height was self selected and the same height was used for all trials. The ergometer was fitted with bicycle-racing handlebars, cranks, pedals, and seat, and was fixed to the floor. Each subject wore cycling shoes that were fitted with a cleat that locked into a spring-loaded binding on the pedal. A subset of the active men (N = 13) returned the following week and performed 4 days of additional testing under the same protocol.

Maximum cycling power was measured using the inertial load method which determines torque delivered to an ergometer

Int J Sports Med 2000; 21: 485–487

ISSN 0172-4622

flywheel across a range of pedaling rates. Details of this method have been described previously [12]. Briefly, inertial loading measures the reaction torque of an accelerating flywheel. Power was calculated as the product of flywheel inertia, angular velocity, and angular acceleration with no frictional resistance applied to the flywheel. The reported values for power and pedaling rate were averaged over each complete revolution of the cranks. Maximum power was defined as the highest value within each bout (i.e. apex of the power-pedaling rate relationship) and the pedaling rate for maximum power was the pedaling rate at which maximum power occurred.

Differences in maximum power and pedaling rate at maximum power were evaluated with a repeated measures ANOVA. If the ANOVA indicated significant group by day or group by bout interaction, separate ANOVA were performed for each group. Bonferroni post-hoc analysis was used to determine which days or bouts differed. Significance level was set at $p = 0.05$ for all analyses.

Results

For the cycle-trained men, maximum power (Fig. **1**) and pedaling rate at maximum power (Fig. **2**) did not differ across days or bouts. For the active men, maximum power increased 4.3% ($p < 0.001$) from day 1 to day 2 and 2.5% ($p = 0.001$) from day 2 to day 3 (Fig. **1**). Within day 1, power increased 5.1% ($p < 0.001$) from bout 1 to bout 2, and 1.6% ($p = 0.001$) from bout 2 to bout 3 (Fig. **1**). Pedaling rate at maximum power of the active men (Fig. **2**) did not differ across days or bouts. Maximum power of the subset of active men who returned for additional testing did not differ from day 3 through day 8 (Fig. **3**).

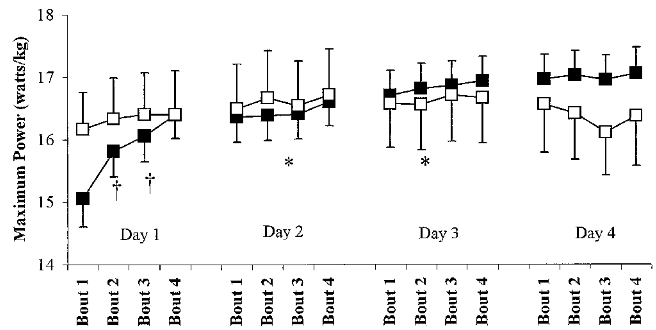

Fig. 1 Maximum power during four days of testing. The power of the cycle-trained men (□) did not differ across days or bouts. Power of the active men (■) increased significantly within day 1 (†) and between days 1, 2, and 3 (*). Error bars represent standard error of measurement.

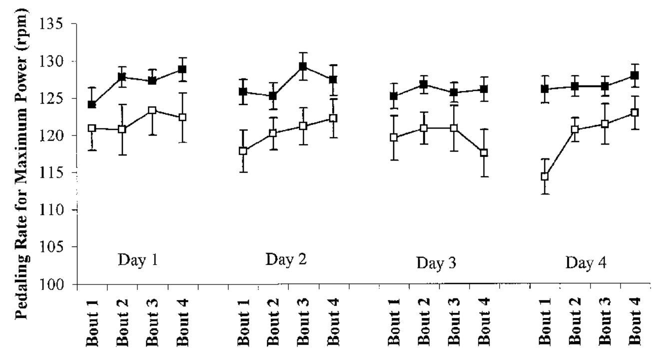

Fig. 2 Pedaling rate at maximum power during four days of testing. Pedaling rate did not differ across days or bouts for either the cycle-trained (□) or active men (■). Error bars represent standard error of measurement.

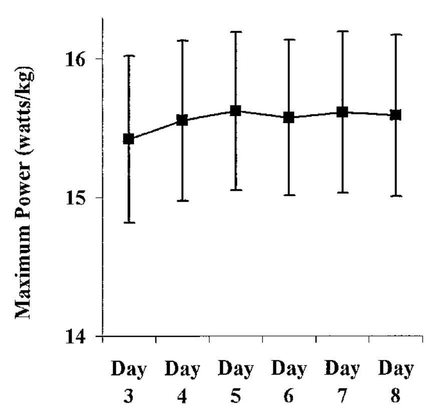

Fig. 3 Maximum power from day 3 to day 8. For the 13 active men who returned for an additional week of testing, maximum power was stable from day 3 to day 8. Error bars represent standard error of measurement.

Discussion

This study was designed to determine the time course and magnitude of learning effects associated with repeated maximal power testing in order to determine when stable values for maximal power and pedaling rate at maximum power may be obtained. Our results demonstrate that stable values for maximum cycling power can be obtained from cycle-trained men in one day. This suggests that field studies in which subject access is limited to one test session can provide valid data if the subjects are familiar with the testing activity. The same was not true for the active men, for whom maximal cycling was a novel task. Those men required two days of practice in order to produce stable values for maximum power on subsequent days.

These results are similar to those of Capriotti et al. [4] who reported that mean power (i.e. mean over each 1 sec interval) increased approximately 11% during repeated testing and was stable after two days of practice. Those subjects performed a fatiguing protocol of 10 sprints of 7 seconds each with 30 seconds recovery, and the ergometer was heavily loaded (11.34 kg). Subjects in the present study performed only 4 sprints of approximately 3.5 seconds with full recovery between sprints. Thus our subjects exerted maximal effort for a total of 14 seconds per day compared with 70 seconds per day for the subjects of Capriotti et al. [4]. Even though the protocol used by Capriotti et al. [4] was quite different than that of the present study, the results are remarkably similar. Thus, valid inferences regarding training programs, ergogenic treatments, or physiological factors depend on adequate familiarization with the test activity which appears to require two days of familiarization prior to experimental data collection.

Pedaling rate at maximum power did not change across the testing period in either the cyclists or the active men. Hautier et al. [6] have reported that pedaling rate at maximum power is highly correlated with the percentage of cross sectional area occupied by fast twitch muscle fibers. Our finding that the pedaling rate for maximum power of active men did not change corroborates the findings of Hautier et al. [6] and suggests that pedaling rate for maximum power is dictated by neuromuscular properties even when performing a novel task.

Power of the active subjects exhibited a non-significant increase of 1% from day 3 to day 4. Thus we could not be certain that learning was complete. Therefore, 13 of the active subjects returned the following week for additional testing. Maximum power produced on test days 5 – 8 did not differ from that produced on days 3 and 4, suggesting that learning was truly complete by day three.

The inertial load method used in this investigation is unique in that resistance is provided solely by flywheel inertia. Several other investigators [2,3,7,10,14] however, have reported methods that employ both flywheel inertia and frictional resistance. Those methods, like ours, determine maximum power and describe the power vs. pedaling rate relationship in a single exercise bout. Consequently, the present findings have broad application to other methods in which the ability to obtain repeatable and valid results is essential.

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