

RELIABILITY OF THE LODE EXCALIBUR SPORT ERGOMETER AND APPLICABILITY TO COMPUTRAINER ELECTROMAGNETICALLY BRAKED CYCLING TRAINING DEVICE

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ABSTRACT. Earnest, C.P., R.P. Wharton, T.S. Church, and A. Lucia. Reliability of the Lode Excalibur Sport Ergometer and applicability to Computrainer electromagnetically braked cycling training device. *J. Strength Cond. Res.* 19(2):344–348. 2005.—New technology allows cyclists to train via power output (PO) in addition to heart rate (HR). For those athletes undertaking seasonal laboratory testing (e.g., $\dot{V}O_2$, lactate threshold), it is imperative that athletes be able to directly apply this information to their training device. We examined the reliability of a standardized laboratory ergometer (Lode Excalibur Sport) and its applicability to an electromagnetically braked ergometer (Computrainer) in 2 phases. Phase I ($n = 12$) examined the reliability of the Lode. Phase II ($n = 14$) compared the Lode to the Computrainer using a randomized, counterbalance assignment. Following warm-up, each trial started at 100 W, progressing 50 W every 3 minutes to exhaustion. Outcomes were time-to-exhaustion (TTE), peak PO (W) (PO_{peak}), peak HR (HR_{peak}), and ventilatory (VT) and respiratory compensation (RCP) thresholds. We used a repeated measures analysis of variance (ANOVA), Tukey post hoc analysis, regression analysis, Bland-Altman plots, and coefficient of variation (CV) analysis for each variable. During phase I, we found no significant difference for any variable, minimal dispersion of $\dot{V}O_2$ during Bland-Altman analysis, and a low CV at each test stage ($\leq 5\%$). During phase II, significant differences and higher CV for most parameters (all data; $p < 0.001$) were observed for Lode versus Computrainer: TTE (21 minutes, 12 seconds \pm 3 minutes, 12 seconds vs. 19 minutes, 9 seconds \pm 2 minutes, 36 seconds; CV = 16%), PO_{peak} (335 \pm 57.8 W vs. 295 \pm 47.1 W, CV = 17%), as well as PO at VT (CV = 51%) and RCP (CV = 24%; $p < 0.01$). We conclude that coaches and cyclists may need to use some caution when directly transferring results obtained from laboratory testing to the Computrainer training device.

KEY WORDS. exercise, oxygen uptake, validation

INTRODUCTION

Classical exercise prescription uses heart rate (HR) as a means of establishing training zones for exercise intensity during training. A relatively new trend for competitive cyclists is to train through the use of power output (PO) or wattage (W). Currently, several modalities have become available for accomplishing this goal (7–9). These options include devices located on the cyclist's bike, which are placed within or upon the pedal crank, the wheel hub, or the chain stay. In addition, various devices, known as “trainers,” exist that provide electrical braking and allow the rider to attach their own bikes to the training unit (Figure 1). Such devices provide the cyclist with the ability to

test in a laboratory setting and then apply the information learned in the lab to a training program relative to known thresholds (i.e., ventilatory and lactate), heart rate (HR) zones, and corresponding PO. Inherent in this endeavor is the ability for cyclists to use the information gathered in the lab and then transfer the information accurately to their training program.

Though these devices are heavily marketed to cyclists as training tools, only a few studies have examined the accuracy or transferability of what is recorded in the lab to what is practiced in the field (1, 7, 9). Reiser et al. (9) recently demonstrated the concept of transferability in the Schoberer Resistance Measurement pedal system using a portable device for measuring oxygen uptake ($\dot{V}O_2$) (9). Ideally, riders should be able to apply this information directly to their training programs with little or no adjustment to PO levels. However, if discrepancies do exist, then the cyclists should be aware of the incongruity and make appropriate adjustments to best facilitate their training goals. It is the aim of this investigation to examine the physiologic responses of a laboratory cycle ergometer (Lode Excalibur Sport; Lode Medical Technology, Groningen, The Netherlands) to those obtained from an electromagnetically braked training ergometer known as the Computrainer (Seattle, WA).

METHODS

Experimental Approach to the Problem

We used 2 phases of testing to examine the relationship between a laboratory ergometer known as the Lode Excalibur Sport Ergometer and an electromagnetically braked training ergometer known as a Computrainer (Computrainer, Seattle, WA; Figure 1). During phase I of our trial, we recruited 12 competitive amateur male cyclists to test twice on the Lode in order to establish its test-retest reliability. Though the Lode ergometer is broadly used in many labs throughout the world and is considered to be a “gold standard,” we are unaware of any reports examining the reliability of this ergometer. During phase II of our trial, we recruited a separate cohort of 14 competitive amateur male cyclists and administered each test using a randomized, counterbalanced assignment while measuring all cardiorespiratory parameters via indirect calorimetry (described below). Because we tested each athlete twice on the Lode during phase I, we were unable to employ a randomization procedure.

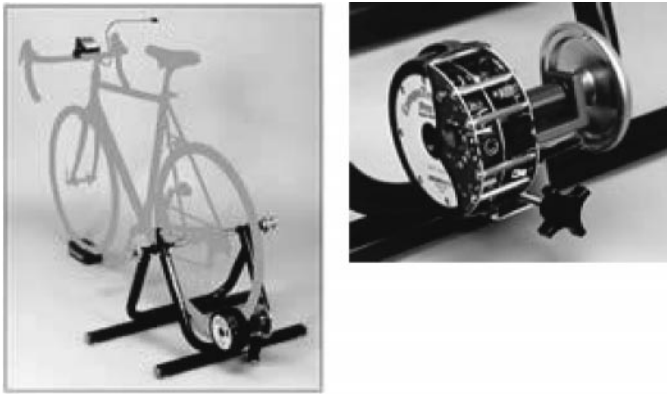


FIGURE 1. Computrainer electromagnetic ergometer training device designed to allow cyclists the capability of mounting their own bicycles.

Subjects

All cyclists in this study were active in category III/IV racing events, had previously undertaken maximal exercise testing in our center, and were familiar with exercise testing procedures. The United States Cycling Association categorizes amateur riders into five categories, with category V being the lowest and category I being the highest. Before testing, all subjects signed a written informed consent statement approved by the Human Subjects Review Committee of our institution, outlining the potential risks associated with the trial. Each subject reported to the laboratory for exercise testing on 2 separate days, 7 days apart. Each testing period entailed having the subject perform a staged cycling test to exhaustion. During this latter test, cyclists used their own bike calibrated to a standardized rolling resistance according to manufacturer recommendation. We examined the coefficient of variation (CV) for our laboratory calibration procedures and found it to be 2.5%. Further, we insured that riders performed their test using the same tire pressure (120 pounds per square inch [psi]). For each test performed on the Lode, we adjusted the ergometer before each test to duplicate the measurements of each cyclist's personal bicycle.

Testing Protocol

We instructed each cyclist to prepare for each test as if preparing for a race. This preparation included not changing their training parameters or dietary patterns for the week preceding each test. On the day before each test, subjects followed a similar type of high-carbohydrate (CHO) diet (CHO intake of approximately 450–500 g per day). Subjects ate a light snack 2 to 3 hours before the test. We also asked each subject to abstain from ingesting any drug that would influence HR on the day of each test. The exception was caffeine, which we asked the subjects to refrain from consuming for at least 5 hours before testing.

Each cyclist began the testing protocol with a self-selected warm-up between 50 and 100 W for 10 minutes. Following this warm-up, we prepared each rider with the necessary mouthpiece breathing apparatus to perform indirect calorimetry measurements. The test then began at 50 W for 2 minutes, progressed to 75 W for 2 minutes, and then to 100 W for 3 minutes. Once PO was set at 100

W, each stage progressed 50 W every 3 minutes until the rider reached exhaustion. Each rider was allowed to choose their own pedal cadence as both the Lode and Computrainer auto-adjust resistance according to the rotations per minute (rpm) of the subject. Exhaustion was determined when each rider could no longer perform a pedal cadence of 50 rpm. From these tests, we determined peak W (W_{peak}), peak HR (HR_{peak}), and peak oxygen uptake ($\dot{V}O_{2\text{peak}}$). W_{peak} was defined as the highest W achieved for 1 complete minute of a given stage. $\dot{V}O_{2\text{peak}}$ was recorded as the highest average $\dot{V}O_2$ obtained for any 1-minute period during the tests that met the criteria that respiratory exchange ratio ≥ 1.15 (6). During the test, subjects adopted a conventional (upright) seated cycling posture for the duration of the tests. This posture was characterized by a trunk inclination of approximately 75° with the cyclists placing their hands on the handlebars with elbows slightly bent (flexion approximately 10°). During the Computrainer test, we placed a fan near the braking unit (Figure 1) in an effort to provide cooling to the braking unit because of its small size.

Cardiorespiratory Assessment

Prior to each individual test, we calibrated each ergometer according to the manufacturer's instructions. This calibration procedure also included calibration of our metabolic cart to standardized calibration gases. The gas analyzer was calibrated using room air and a single gas tank (16.01% O_2 , 4.00% CO_2 , nitrogen balanced). We calibrated the computerized metabolic systems with a 5-stroke calibration using a 3.00-L Hans Rudolf 5530 series syringe. We also measured ambient temperature (Ta) and barometric pressure (PB) at the start of each test and entered this information into the computer. We collected gas exchange data continuously using an automated computerized Parvomedics Truemax Metabolic System (Sandy, UT). Expired gases were collected in breath-by-breath fashion using a pneumotachometer and a paramagnetic O_2 analyzer and infrared CO_2 analyzer to perform O_2 and CO_2 analyses, respectively. This system has been shown to be accurate as compared to Douglas bag criteria (2). After each test, we exported all gas exchange data into a report detailing the test in 60-second intervals. We used the final minute of each stage for our analyses. The following variables were measured during each test: $\dot{V}O_2$, pulmonary ventilation (VE), ventilatory equivalents for oxygen ($VE \cdot \dot{V}O_2^{-1}$) and carbon dioxide ($VE \cdot \dot{V}CO_2^{-1}$), and end-tidal partial pressure of oxygen (PET_{O_2}) and carbon dioxide (PET_{CO_2}).

We subsequently used these parameters to examine the PO where ventilatory threshold (VT) and respiratory compensation point (RCP) occurred. The VT was determined using the criterion of an increase in both $VE \cdot \dot{V}O_2^{-1}$ and PET_{O_2} with no concomitant increase in $VE \cdot \dot{V}CO_2^{-1}$, whereas the RCP was determined using the criterion of an increase in both the $VE \cdot \dot{V}O_2^{-1}$ and $VE \cdot \dot{V}CO_2^{-1}$ and a decrease in PET_{CO_2} (5).

Statistical Analyses

We began our analysis using an analysis of variance (ANOVA) to examine the relationship for each ergometer with respect to TTE, PO_{peak} , HR_{peak} , $\dot{V}O_{2\text{peak}}$, and the PO associated with VT and RCP. Individual stage data were analyzed by using a repeated measure ANOVA. Post hoc tests were also employed using a Tukey-Kramer analysis.

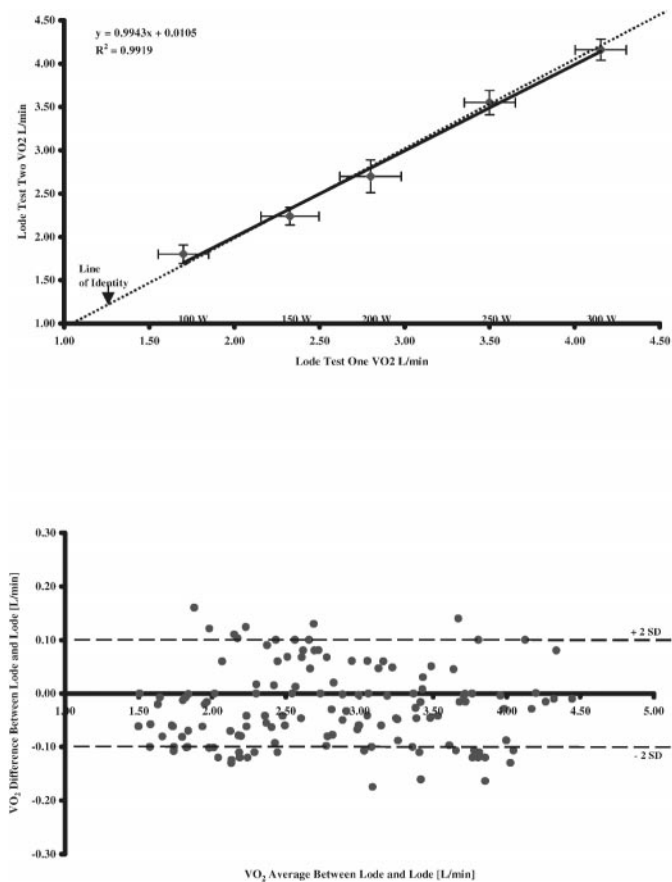


FIGURE 2. Panel A represents mean $\dot{V}O_2$ ($L \cdot \text{min}^{-1}$) for the final minute of each 50-W stage increment beginning at 100 W and culminating at 300 W. The x-axis and horizontal error bars (*SD*) represent results of the Lode testing condition number 1. The y-axis and vertical error bars (*SD*) represent results of the Lode testing condition 2. Panel B represents the Bland-Altman plot of the average $\dot{V}O_2$ ($L \cdot \text{min}^{-1}$; x-axis) and difference scores ($L \cdot \text{min}^{-1}$; y-axis) for the end of each completed minute of testing for the Lode versus Lode ergometer testing conditions.

All data are presented as mean \pm *SD*. To gain the greatest appreciation for our investigation, we examined the relationship of our data in 3 different ways. First, we used a basic regression analysis to examine the relationship for the $\dot{V}O_2$ obtained for each comparative ergometer during each stage of the test. We subsequently plotted each plot against a line of identity to compare the “gross equality” of each test or deviance from a linear/identical relationship. However, we consider this to be a gross analysis with the understanding that data may be strongly related, yet not yield the correct relationship conclusion regarding the accuracy of the instrument being examined. To elucidate this analysis, we compared the $\dot{V}O_2$ of each completed minute of the exercise protocol for the Lode and Computrainer using Bland and Altman’s 95% limits of agreement (3). Lastly, we calculated the coefficient of variation (CV) for each data point.

RESULTS

During phase I, we found no significant difference for any peak or submaximal variable, good repeatability between trials (Figure 2a), and a minimal dispersion of $\dot{V}O_2$ via the Bland-Altman plot (Figure 2b). The CV for TTE (8%), $\dot{V}O_{2\text{peak}}$ (7%), PO_{peak} (6%), HR_{peak} (6%), VT (10%), and RCP (8%) was also low. The mean and CV data for these variables are presented in Table 1. In addition, no significant difference was noted for $\dot{V}O_2$ during any individual stage. In addition, the CV for each stage was small and ranged from 4–6% (Figure 4).

During phase II, we found a significant difference for TTE and PO_{peak} , as well as the PO associated with VT and RCP when comparing the Lode to the Computrainer ($p < 0.001$) (Table 1). The CV for TTE (16%), $\dot{V}O_{2\text{peak}}$ (8%), PO_{peak} (17%), HR_{peak} (4%), VT (51%), and RCP (24%) was higher than the phase I comparison. We also observed that $\dot{V}O_2$ uptake was significantly higher during the Computrainer riding condition at 200, 250, and 300 W ($p < 0.05$). Though the 2 tests showed a strong relationship when using the gross estimate of the regression analysis (Figure 2a), the dispersion of Bland-Altman data showed a gradual increase in the $\dot{V}O_2$ uptake difference with increasing PO during the trial (Figure 3b). This finding sup-

TABLE 1. Data represent the physiologic characteristics of study subjects during exercise testing to exhaustion on a Lode and Computrainer bicycle ergometer. Values are mean \pm *SD*.†

	TTE [min:sec]	Peak $\dot{V}O_2$ (L/min)	Peak PO (W)	HR peak (B/min)	VT PO [W]	RCP PO [W]
Lode vs. Lode (<i>n</i> = 12)						
Lode test 1	19:54 \pm 3:12	4.18 \pm 0.4	303 \pm 19.5	184 \pm 11.7	191 \pm 24.9	269 \pm 24.3
Lode test 2	20:08 \pm 3:24	4.12 \pm 0.3	308 \pm 21.7	186 \pm 11.7	186 \pm 32.9	267 \pm 24.8
Difference between conditions (%)	1	1.5	2.0	1.0	3.0	1.0
Coefficient of variation (%)	8.2	7.1	6.3	6.2	10.1	8.2
Lode vs. Computrainer (<i>n</i> = 16)						
Lode	21:12 \pm 3:12*	4.10 \pm 0.8	335 \pm 57.8*	179 \pm 9.2	137 \pm 17.5*	275 \pm 58.9*
Computrainer	19:09 \pm 2:36	4.13 \pm 0.8	300 \pm 47.1	178 \pm 6.7	110 \pm 88.4	230 \pm 58.7
Difference between conditions (%)	10	1.0	15.0	1.0	20.0	16.0
Coefficient of variation (%)	15.6	8.0	17.1	4.4	51.4	24.4

* $p < 0.001$.
 † TTE = time to exhaustion; PO = power output; HR = heart rate; VT PO = ventilatory threshold power output; RCP PO = respiratory compensation threshold power output; B = beats.

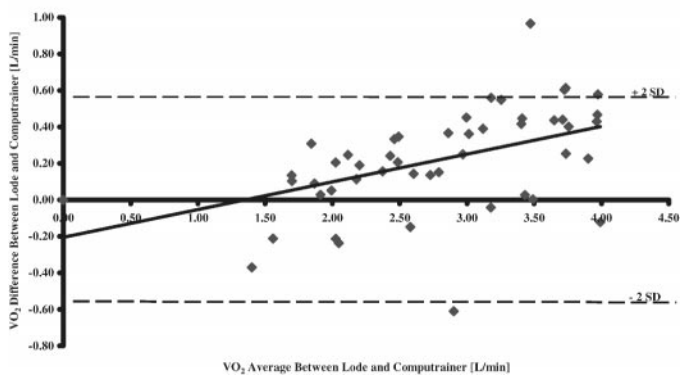
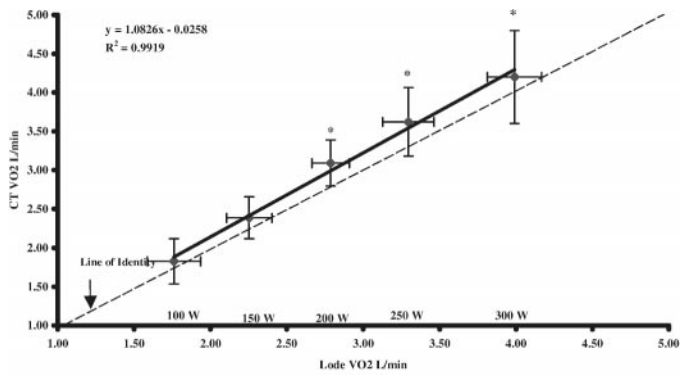


FIGURE 3. Panel A represents mean $\dot{V}O_2$ ($L \cdot \text{min}^{-1}$) for the final minute of each 50-W stage increment beginning at 100 W and culminating at 300 W. The x-axis and horizontal error bars (*SD*) represent results of the Lode testing condition. The y-axis and vertical error bars (*SD*) represent results of the Computrainer testing condition. Panel B represents the Bland-Altman plot of the average $\dot{V}O_2$ ($L \cdot \text{min}^{-1}$; x-axis) and difference scores ($L \cdot \text{min}^{-1}$; y-axis) for the end of each completed minute of testing for the 2 ergometer testing conditions.

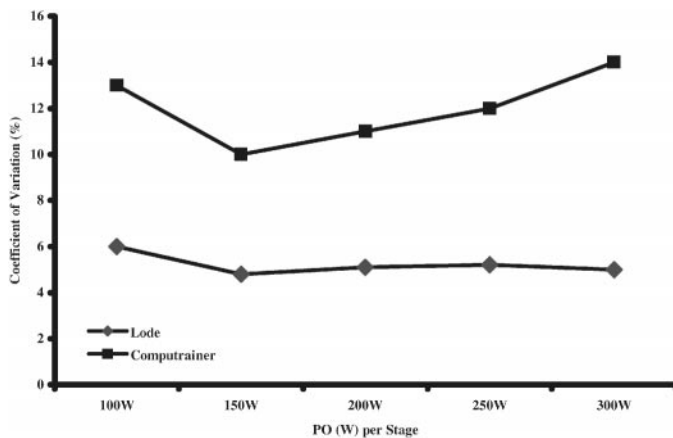


FIGURE 4. Figure represents the coefficient of variation for each 50-W stage for the Lode versus Lode testing condition and Lode versus Computrainer testing condition.

ports the increase in the mean $\dot{V}O_2$ observed during the repeated measure ANOVA. These findings were further confirmed by an accompanying increase in the CV, which suggests a greater degree of inaccuracy with higher PO, as individual stage data ranged from 13–15% CV for each stage (Figure 4).

DISCUSSION

The primary finding from this investigation is twofold. First, there is strong agreement between cardiorespiratory variables obtained during testing and retesting on the Lode ergometer when testing conditions are similar. Secondly, however, a similar comparison using the Computrainer training device designed to facilitate training for cyclists yields substantial differences when comparing the energy cost of supposedly identical workloads. Though the data associated with peak values such as HR_{peak} and $\dot{V}O_{2\text{peak}}$ appear to be reasonably agreeable, the same cannot be said for PO_{peak} , TTE, and VT and RCP thresholds. To this end, our data show that the transferability from the Lode to the Computrainer may be tenuous and that coaches and athletes should take note of this disparity when taking the physiologic variables obtained in the laboratory and applying them to training in the field.

Specific to our findings is the relative consistency of our data when examining the phase I portion of our trial. Though some “error” or variance does exist, the small degree of variation that we did observe can easily be accounted for by the day-to-day physiologic differences of humans. Considering the additional potential variances associated with day-to-day equipment use, we believe that our phase I data demonstrate good consistency with the Lode system when the testing parameters are controlled. Given the success of this portion of our trial, we are confident in extrapolating our findings to the phase II portion of our investigation comparing the Lode to the Computrainer.

One of the more remarkable features that we observed during the phase II portion of our trial relates to the consistently increasing variance associated with higher PO. This is clearly seen by examining the data presented in Figures 3 and 4, which show a distinctive pattern for dispersion from linearity and agreement given (a) the statistically higher $\dot{V}O_2$ cost at 200, 250, and 300 W (Figure 3a), (b) the continual dispersion from agreement associated with Bland-Altman plot limits of agreement (Figure 3b), and (c) the increasing CV as compared to the Lode (Figure 4). Further, riders were not able to complete the same TTE or same maximal PO as during laboratory conditions. Though this was not an investigation to determine the laboratory utility of such a training device, per se, it does point to the need for riders wishing to train via wattage to exercise some caution when transferring the results of laboratory testing to their personal training programs when using such a training device. Specifically, riders who wish to use training programs involving the manipulation of wattage surrounding various physiologic “thresholds” or HR zones will likely need to modify the wattage used with the Computrainer device to provide appropriate training stimuli relative to their training needs (10).

When examining the various thresholds associated with this trial, we observed about a 10% and 8% CV when determining the PO accompanying VT and RCP, respec-

tively, during phase I of our testing procedure. However, the CV when considering the Lode versus Computrainer for the PO associated with VT and RCP was 51% (27 W) and 24% (45 W), respectively. More specifically, the PO for VT and RCP only varied by 5–6 W during phase I. For those who are unfamiliar with cycling research, this finding may not seem significant. However, the issues relative to training specificity, application, and the transferability of laboratory findings may indeed prove otherwise. A classic example of this discrepancy is eloquently demonstrated by Lucia et al., who examined the physiological differences between professional and elite road cyclists (5).

In the study by Lucia et al., professional cyclists were compared to a group of elite amateur cyclists. A striking finding from this study that is relative to our current investigation is the observation that in amateur elite cyclists, 300 W elicited a physiologic value that was distributed between the rider's VT and RCP (i.e., VT2). In contrast, riding at a slightly higher wattage (e.g., 323 W) was sufficient to move the cyclists above their RCP (often associated with "anaerobic threshold"). In this latter phase, pulmonary ventilation significantly increases in an attempt to buffer increasing acidosis, and a significant recruitment of inefficient type II fibers is required to maintain power output as efficient type I fibers start to fatigue. Similar results by the same group confirm this observation (4). Further, the wattage difference observed in our current trial falls easily within this range, as the PO at RCP during the Lode test is only 25 W shy of the maximal PO observed during the Computrainer condition. Furthermore, the PO associated with RCP during the Computrainer is a full 45 W lower than those values associated with the Lode testing condition. In essence, a cyclist asked to train below RCP (e.g., 275 W) according to Lode testing would indeed be over RCP by simply applying 230 W while training on the Computrainer.

PRACTICAL APPLICATIONS

In practical terms, these differences may cause a conundrum for any cyclist or coach who is familiar with the utility of wattage-based training and lab testing. Though we do not know why this disparity between the Lode and Computrainer modalities exists, we hypothesize that the smaller braking device of the Computrainer unit may overheat during higher PO. This is one of the reasons that we placed a fan over the braking device during our investigation. This phenomenon may be particularly puzzling to the user, as the advent of a wattage-based training device enables the rider and coach to perform more frequent "self-testing" during and in preparation for the

racing season without having to return to the lab to assess the athlete's training progress.

Nonetheless, these findings do not preclude the use of such a device during training. Rather, they point out the need to make adjustments accordingly following laboratory testing. It may also be beneficial for athletes to actually test on the Computrainer apparatus itself, if wattage-based training is their goal. Overall, the unit is relatively portable and can be used both with and without a computer interface and provides the means for cyclists to compete via a computer interface either on the same computer or across the Internet. Indeed, such a training device is helpful for the cyclist seeking quality-training stimuli sans HR. However, this latter point is offered cautiously to the reader, as the consistency of testing with such an apparatus has not yet been examined and the need for attending to the consistent details of rolling resistance, calibration, and tire pressure would be paramount to such an undertaking.

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