Original Article

Fatigue level after maximal exercise test (laboratory and road) in cyclists

ALFREDO CÓRDOVA[1] ✉, JULIÁN SAINZ[2], MANUEL CUERVAS-MONS[3], JOSEP A. TUR[4], ANTONI PONS[4]

[1]Department of Biochemistry, Molecular Biology and Physiology, University School of Physiotherapy, University of Valladolid, Soria, Spain.

[2]Department of Statistics, University School of Physiotherapy, University of Valladolid, Soria, Spain.

[3]Department of Cellular Biology, Histology and Pharmacology, University School of Physiotherapy, University of Valladolid, Soria, Spain.

[4]Research Group on Community Nutrition and Oxidative Stress, Research Institute of Health Sciences, University of the Balearic Islands, Palma de Mallorca, Spain.

ABSTRACT

Córdova A, Sainz J, Cuervas-Mons M, Tur JA, Pons A. Fatigue level after maximal exercise test (laboratory and road) in cyclists. *J. Hum. Sport Exerc.* Vol. 5, No. 3, pp. 358-369, 2010. Despite the importance of uphill cycling performance during cycling competitions, there is very little research investigating uphill cycling, particularly concerning field studies. The lack of research is partly due to the difficulties in obtaining data in the field. The aim of this study was analyze the fatigue after a maximal exercise test and the maximal blood lactate in elite cyclists after two maximal exercises, one on laboratory and other in field. In this study 14 semi-professional cyclists have participated. The trials consisted in a laboratory incremental test (LIT) to exhaustion, and a maximal individual uphill time trial test on road (UTT) (5.85±0.24% slope) during 12-minute. The results showed that in LIT the maximal heart rate (HR_{max}) (beats·min^{-1}) was 188±9.8, with a maximum of blood lactate (LA_{max}) (mmol·L^{-1}) of 13.9±2.5. Similar data were obtained in the 12 min maximal UTT (LA_{max} 15.2±3.1 mmol·L^{-1}, and HR_{max} 188±6.5 beats·min^{-1}). A high correlation of LA_{max} (0.70) and HR_{max} (0.86) was obtained from both trials. No differences were observed with respect the fatigue data (psychological and dynamometric) between both test LIT vs UTT.We conclude that UTT test on road as a useful test to evaluate the cyclist's physical condition. We think that is perfectly valid, reliable and reproducible, and is possible to carried by the made for the own cyclist or for the trainers. On the other hand, is important because we can obtain information about of performance as well as power feeling of cyclist. These results may be significant in physiological terms to monitor the training and for recommendation of exercise or performance prediction. **Key words**: FATIGUE, CYCLING, PHYSICAL TEST, HEART RATE, LACTATE.

✉ **Corresponding author.** Departamento de Bioquímica, Biología Molecular y Fisiología. E.U. Fisioterapia. Campus Universitario "Los Pajaritos". 42004-Soria (Spain).
E-mail: a.cordova@bio.uva.es
Submitted for publication March 2010.
Accepted for publication September 2010.
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.4100/jhse.2010.53.06

INTRODUCTION

The laboratory tests to measurements of oxygen consumption, analysis of lactate, etc, in cyclists are made using a cycloergometer. However though this method is useful does not reflect the sensation and way of acting which cyclists develop on the road (Paton & Hopkins, 2001). Usually the tests to do a good measure of cyclists' power with their own bicycle need portable oxygen consumption analyzers. Nevertheless, most cyclists do not have access to these new methods (Paton & Hopkins, 2001). Other research groups have studied the performance and the body response of cyclist in time trials on road cycling stages (Lucia et al., 2002; Rodriguez-Marroyo et al., 2003; Faria et al., 2005a; Faria et al., 2005b; Billat et al., 2003; Jones et al., 2003).

Several tests are available to measure the power that a cyclist can develop. In field tests there is a lot of supply to choose from, 10 second to 6 hour tests (Hopkins et al., 2001; Paton & Hopkins, 2001; Reiser et al., 2000; Schabort et al., 1998). Conconi's test is one of the most used tests to evaluate cyclists, and it is usually developed on the cyclist's own bicycle (Bodner & Rhodes, 2000; Conconi et al., 1996; Lucia et al., 2002; Paton & Hopkins, 2001). Some authors (Jeukendrup & Diemen, 1998) point out that to measure the cyclist power via SRM (system to know continuously power developed by cyclist) training could be the most direct indicator of exercise intensity. This method is commonly not very useful when applied to most professional cyclists, but it shows the effort intensity as being a function of the length and uphill of the mountain passes, and also of the heart rate. However, in studies on professional cyclists it has been shown that power is more variable than heart rate (Jeukendrup & Diemen, 1998), and that its usage may be restricted on professional cycling training (Lucia et al., 2000).

Blood lactate concentration and the lactate threshold are suggested as a superior method for identifying appropriate exercise intensities (Weltman, 1995). Also, the heart rate (HR) corresponding to lactate threshold (LT) during exercise has commonly been accepted as a tool for predicting endurance performance, designing training programs (Craig et al., 1993; Steed et al., 1994; Bentley et al., 2007). However, is common the utilization of complex instrumental to evaluate cyclist, and therefore it needs to carry out the test in the laboratory (Reiser et al., 2000) indicated that cycling tests need take into account different variables (distance, time, aerobic and anaerobic capacities, heart rate, etc.). These authors emphasized that the most important consideration at the moment of choosing a test is that the measurement of physical capacities during the test should be closely related to the cyclist's capacities developed on a race.

On the other hand, fatigue, defined as an exercise-induced reduction in maximal voluntary force produced with the locomotor muscles and limit exercise performance. It is difficult to isolate a reduction in muscle force from other physiological effects of fatigue. The fatigue affects cardiorespiratory responses, performance, and accumulation of various metabolites, such as lactic acid. Performance tests allow for a controlled simulation of sports and exercise performance for research or applied science purposes (Currel & Jeukendrup, 2008).

The aim of this study was analyze the fatigue after a maximal exercise test and the maximal blood lactate in elite cyclists after two maximal exercises, one on laboratory and other in field. We analyze the physiological response (maximal power, maximal heart rate and maximal blood lactate) through two maximal tests, i.e. a classical incremental test until exhaustion (on laboratory (LIT) with time and power controlled) and a road field test (uphill time trial (UTT)). Therefore, we can say if the field test may be considered by cyclists and trainers, considering that the cost and material employed to develop the UTT is insignificant compared with the necessary means for carry out the LIT test. On the other hand, we can know the real fatigue sensations and the feeling of cyclist in the both test, contrasted with dynamometric measures. The practical application of this field test is the possibility to evaluate the cyclists in a real condition on the field (UTT), because the cyclist might adapt pedalling movements to field being less uniform that on laboratory test

MATERIAL AND METHODS

Subjects and conditions

The study participants were fourteen elite semi-professional cyclists (25.7±2.9 years old), and with an average of a 5-year experience in cycling competitions (Table 1). Prior to any testing, all subjects were informed about the risks involved and were required to sign an informed consent form in accordance with the Human Rights Code followed by the institutional Human Rights Committee. Two weeks before starting the physical tests for the study, cyclists were submitted to clinical exams and blood tests according to the International Cycling Union (ICU) protocols, and they showed to be in good health.

Cyclists followed a controlled diet, and took a polyvitamin mineral complex (Rochevit ®, Spain) and aminoacids supplementation (Novodieta ®, Spain) after training sessions were finished. Subjects were instructed to refrain from strenuous exercise training, and to ingest a standardized food and fluid plan based on individual body mass during the 48 h preceding each laboratory test. Compliance with these requirements was assessed through training and nutritional logs. Food intake was not allowed during the 3 h prior to testing. Body fat was measured by the Bioelectrical Impedance (BI) method with an Omron® Body Fat Analyzer (HBF-306).

In order to avoid in the results, cyclists were divided in two randomized groups, n=7 each. Seven subjects performed the laboratory test (LIT) before the field test (UTT) and the other six subjects performed the field test. That is, each fourteen cyclist have the two tests on different days, having regenerative physical exercise the day before each test. Both tests were conducted on the same time on two follow days to reduce any circadian variation that may have affected the measurements. Cyclist followed the recommendation to have a light training session and to be sure that their diet was high in carbohydrates the day before tests.

Assessment of initial performance status of cyclists: Maximal oxygen uptake test

Two weeks before the beginning of start the investigation, each cyclist reported to the laboratory and took part in an incremental maximal cycling test. A mechanically braked cycle ergometer (Monark 818 E, Varberg, Sweden) adapted with a racing saddle, drop handlebars and clip-in pedals were used. The test started with an initial resistance of 150 W, with further increments of 35 W every 3 min. Subjects kept a constant 75 rpm pedal cadence with the help of a metronome. Testing concluded when the required pedal cadence was no longer maintained by the cyclist. Heart rate was recorded at 5-s intervals during the entire test (Polar S720i, Polar Electro Oy, Finland). Gas-exchange data were continuously monitored with a breath-by-breath metabolic cart (CPX-Plus, Medical Graphics Corporation, St. Paul, Minnesota, USA). W_{max} was determined as the highest workload a cyclist could maintain for a complete 3-min period. When the last workload was not maintained 4 full minutes, Wmax was computed as follows (Hopkins et al., 2001): W_{max} = Wf + [(t/240 x 35] where Wf is the value of the last complete workload (in W), t is the time the last uncompleted workload was maintained (in seconds), and 35 is the power output difference between the last two workloads.

Laboratory Incremental Test (LIT) and Uphill Time Trial (UTT) Road Field Test

Although on LIT we permit to finish the test to exhaustion, in general (as average) both tests have duration around of 12 minutes. Our experience evaluating cyclists along of the years, has led us to conclude that they need around 12 minutes to up exhausted and finish the test. By this we have chosen 12 minutes on field test, similar to Cooper's test (Cooper & Storer, 2001).

For the aim our study, two tests were carried out: A laboratory incremental test (LIT) until volitional exhaustion with their own bicycle, and a 12-minute uphill time trial road field test (UTT) with a mean incline of 5.85±0.24% slope. The uphill road was obtained taking into account the information provided by topographic cards and contrasted with the measures made with a Polar S720i. The altimetry was measured 20 times along the distance of test.

Both tests were developed between 8:00h and 12:00h a.m., and warm up conditions were controlled. On laboratory, cyclists underwent a continuous and progressive maximal test up to exhaustion on a cycle stimulator (Cateye CS-1000, Cateye CO. LTD. Japan), upon which their own competition bicycle was fixed. The test started at 34 $km \cdot h^{-1}$, keeping a constant 75 rpm pedal cadence, and increased 2 $km \cdot h^{-1} \cdot min^{-1}$ to arrive at 48 $km \cdot h^{-1}$, the gear was fixed at 53x16 maintaining constant the speed corresponding to different workload. When cyclists passed the steep corresponding to 48$km \cdot h^{-1}$, the gear and pedalling cadence was elicited freely. During the tests, Cyclists' heart rate (HR) was measured with a HR monitor (Polar S720i, Polar Electro Oy, Finland).

The heart response was monitored telemetrically during the length of the test using the cyclists' own pulsometer. Then, maximum oxygen consumption (VO_{2max}) and heart rate were measured in each of the stages of the effort. Blood lactate evolution and anaerobic threshold (AT) (4 $mmol \cdot L^{-1}$), were calculated with the seven times blood samples withdrawn along the test and 30 seconds after the test ended (LA_{max}) ($mmol \cdot L^{-1}$). The exercise intensity corresponding to the onset of blood lactate accumulation (OBLA) was identified on the [La]-power output curve by straight line interpolation between the two closest points as the power output eliciting a blood lactate concentration of 4 $mmol \cdot L^{-1}$ (35). The anaerobic threshold was calculated drawing a curve putting the points of lactate (LA $mmol \cdot L^{-1}$) on abscises axis and the heart rate (HR, $beats \cdot min^{-1}$) on ordinates axis.

The individual uphill time trial test (UTT) on road was 12 min (same time that the "Cooper test") continuous pedalling effort (freely selected gear and pedalling cadence, but trying for a constant 75 rpm pedal cadence), with a mean incline approximately of 6 % average slope, using the cyclist own bicycle. By our experience, we have chosen this slope because it permits to maintain a big variety of changes in the gear and position of cyclists along the test. Also, this test was elicited because the incremental laboratory test has an average duration around 12 minutes, similar to Cooper test (Cooper & Storer, 2001). Three days before the test, cyclists supervised the route. The test was carried out at 900m of altitude and controlled climatic conditions: outside temperature was 20-22°C, and there was no appreciable wind during the experimental period (Climatic Anemometer AVM 2000, Kestrel). The test started after 25 min warm-up on a mechanical break. Cyclists were free to pace themselves as to complete the maximum possible distance in 12 minutes. At the end of the test (12 min) capillary blood samples were extracted. Also, 30 seconds after the test ended and on recovery period (3 min at rest), capillary blood samples were obtained from hyperemic outer ear, and whole blood lactate (LA) ($mmol \cdot L^{-1}$).

Capillary blood samples (25 μl) were withdrawn from a previously hyperemized ear lobe (Finalgon, Laboratorios FHER, Barcelona, Spain) immediately after completion of each workload. Blood lactate concentration (La) was determined electroenzymatically with an automatic analyzer (YSI1 1500 Sport, Yellow Springs Instruments, Yellow Springs, OH, USA). The analyzer was calibrated before each test with standard solutions of known lactate concentrations (0, 5 and 15 $mmol·L^{-1}$), as recommended by the manufacturer.

Both maximal test (LIT and UTT) generate stress and consequently fatigue and cyclist's feeling can be different. At the end of each exercise test, psychological test was applied to evaluate the fatigue. To physiological measures we have used the Borg scale. The control of physical fatigue was analyzed by means dynamometry.

Dynamometry

A special bench with a dynamometer (leg-Jamar, USA) connected was used to measure the power. Previously, by means of a questionnaire, the dominant muscle was determined, the one to be used in the strength test. The subjects were seated on the bench, with a knee at a 90º angle and a belt surrounding the waist just on the line over the anterior suprailiac spine. An extensometer dynamometer gauge with a distal handle was placed, which opposes resistance at the level of the ankle. The maximum isometric force is measured with the knee at 90º. The subject was asked to make a maximum knee extension effort for 20 seconds. The subjects were then allowed a 60-second rest period. The process was repeated tree times [(3 × 20) + (3 × 60)]. The subjects were constantly stimulated and encouraged by means of sound and the time was meticulously monitored.

Haematological determinations

Immediately to final each exercise test haematological parameters were analyzed in an autoanalyzer (Coulter ACT-8, Beckman Coulter, Inc). Hematocrit (Hct) was also measured in duplicate by the microcentrifuge method.

Statistical analysis

Statistical analysis was carried out using a statistical package for social sciences (SPSS 12.0 (Chicago, IL) for windows). Results are expressed as means ± standard error of mean (SEM) and $p<0.05$ was considered statistically significant. All the data were tested for their normal distribution (Kolmogorov-Smirnov test). A Student's t test for paired data was applied to compare HR and LA data between laboratory and field tests. The effects of the exercise (E) and the test type (T) on the changes induced in the haematological parameters were tested by a two-way ANOVA with exercise (E) and the test (T) as ANOVA factors. When significant effects of exercise or test were found, a student t-test for paired data was used to determine the differences between the groups involved. Pearson product-moment correlation coefficients were calculated to determine whether there was a significant relationship between HR data, on one hand, and LA data, on the other obtained in the aforementioned two tests. A multiple regression analysis using a stepwise method was also used to determine correlations between field and laboratory data.

RESULTS AND DISCUSSION

Table 1 shows anthropometric and maximal exercise test data of cyclists: maximal oxygen uptake (VO_{2max}), anaerobic threshold (AT), and heart rate at the anaerobic threshold (HR AT) ($beats·min^{-1}$).

Table 1. *Physical characteristics of cyclists (n=14). Anthropometric and maximal exercise test data.*

Age (yr)	25.7±2.9
Weight (kg)	71.3±3.1
Height (cm)	176±2.8
Body fat (%)	8.3±0.2
$VO_{2\ max}$ (ml·kg^{-1}·min^{-1})	74.3±2.1
HR AT (beats·min^{-1})	172±2.1
W_{max} (wats)	396±34

$VO_{2\ max.}$, maximal oxygen uptake (ml·kg^{-1}·min^{-1}).
Heart rate at the anaerobic threshold (HR AT) (beats·min^{-1}).
Maximal power (W_{max})(wats). Values are mean ± SEM.

Exercise influence the haematocrit, the blood haemoglobin concentration and the red blood cells counts; however, the mean corpuscular haemoglobin, mean haemoglobin corpuscular concentration, and mean cellular volume were unaffected by exercise. The concentration of haemoglobin, the red cells counts and the haematocrit increase significantly after exercise, both in the incremental laboratory test and in the uphill time trial test. The test type did not influence the haematological parameters (Table 2).

Table 2. *Hematological parameters at rest and after Laboratory Incremental Test (LIT) and Uphill Time Trial Test (UTT).*

	REST	Laboratory Incremental Test (LIT)	REST	Uphill Time Trial Test (UTT)	ANOVA *E*	*T*	*E*T*
Hct (%)	44.4±2.4	**48.4±2.4***	44.6±1.84	**48.2±3.3***	#		
Hb (g/dl)	14.7±1.0	**16.1±1.0***	14.9±0.53	**16.0±1.0***	#		
RBC (10^6/µl)	4.9±0.3	**5.4±0.2***	4.96±0.24	**5.2±0.3***	#		
MCV (fl)	89.0±3.3	90.0±3.7	89.9±3.91	89.7±3.7			
MCH (pg)	30.6±1.5	30.7±1.5	30.9±2.69	30.2±1.4			
MCHC (g/dl)	34.5±1.0	34.2±1.2	33.7±0.66	33.6±0.8			

Hct= Hematocrit; Hb= Blood Haemoglobin; RBC= Red Blood Cells Counts; MCV= Mean Corpuscular Volume; MCH= Mean Corpuscular Haemoglobin and MCHC= Mean Corpuscular Haemoglobin Concentration.
Data expressed as means ±SEM
*ANOVA: E, exercise factor; T, test type factor, E*T, interaction of both factors.*
 # Significant effects of the ANOVA factor
**(p<0.05) LIT vs Rest or UTT vs REST, by Student's t-test for paired data.*

Physiological variables [speed ($km \cdot h^{-1}$), anaerobic threshold at 4 $mmol \cdot L^{-1}$ (AT), maximal heart rate (HR_{max}, $beats \cdot min^{-1}$), maximal lactate at the end of the test (LA_{max}, $mmol \cdot L^{-1}$)] obtained from incremental and uphill maximal road tests are shown in Table 3. No significant differences were found between HR_{max} and LA_{max} of both tests, which showed the same range. The continuous heart rate monitorization with pulsometer during the tests allowed determining that the cyclists arrived to the anaerobic threshold (AT) in different moments in both tests (results not shown). Whereas in laboratory test 2/3 of total time is used to developed aerobic metabolism, in the road test, from the first ¼ of time, the metabolism is mainly anaerobic. However, at the end of both tests and when the heart rate was maximal ($beats \cdot min^{-1}$), the obtained maximal blood lactate (LA_{max}) ($mmol \cdot L^{-1}$) data are similar after each test, which shows the maximal anaerobic capacity. The time used to complete both test was similar, however the speed was different, reason for which the covered distance was different. Obviously the distance obtained in each test was different, and the protocol is different for each test also. The LIT is a progressive test and UTT is a maintained test.

Table 3. *Comparison of data of Laboratory Incremental Test and Uphill Time Trial Test.*

Variable	Laboratory Incremental Test (LIT)	Uphill Time Trial Test (UTT)
Maximal Speed ($Km \cdot h^{-1}$)	57.6±1.5	
AT (4 $mmol \cdot L^{-1}$)	172±2	
HR_{max} ($beats \cdot min^{-1}$)	188±3	189±2
LA_{max} ($mmol \cdot L^{-1}$)	13.9±0.9	15.2±1.0
Time (min)	12.8±0.8	12
Distance (m)		4698±152

Mean±SEM for Speed ($Km \cdot h^{-1}$), anaerobic threshold (AT) (4 $mmol \cdot L^{-1}$), maximal Heart rate (HR_{max}) ($beats \cdot min^{-1}$), maximal lactate (LA_{max}) ($mmol \cdot L^{-1}$), and distance (m) after Laboratory Incremental Test (LIT) and Uphill Time Trial Test (UTT). No significant differences were found between HR_{max} and LA_{max} of both tests.

Pearson correlation between variables in the different tests is showed in Table 4. A high correlation was obtained between LA ($r=0.70$; $p<0.05$) and HR values ($r=0.856$; $p<0.01$) obtained in both trials.

Table 4. *Correlation between maximal blood lactate (LA_{max}) ($mmol \cdot L^{-1}$) and maximal heart rate (HR_{max}) ($beats \cdot min^{-1}$), at the end in both tests, LIT and UTT.*

Variables	Pearson r	Signification
LA_{max} (LIT) / LA_{max} (UTT)	0.701	$P<0.05$
HR_{max} (LIT) / HR_{max} (UTT)	0.856	$P<0.01$

With respect the fatigue state by means psychological test (Borg scale), cyclists indicated that as well as the laboratory test (LIT) was softer at the beginning and very hard at the end. However in the test of road (UTT) they indicated that the test was hard from the first moment. With regard to the dynamometer data (Table 5), the generated force did not change immediately after the both test in the subjects when carried out the exercise on laboratory (LIT) with respect to the field test (UTT).

Table 5 *Average of maximum power (kg) obtained on dynamometer after 3 consecutive measures immediately after both test: UTT and LIT.*

		After training
LIT	contraction-1	62.0
	contraction-2	57.0
	contraction-3	57.6
	Mean ± SD	**58.9 ± 2.73**
UTT	contraction-1	60.1
	contraction-2	60.0
	contraction-3	58.8
	Mean ± SD	**59.6 ± 0.72**

Data are expressed as mean ± SD. No significant differences were found.

Performance protocols allow researchers to simulate sporting performance or aspects thereof in a controlled scientific manner. The UTT can be a useful test to evaluate the cyclist's physical condition because we thing that is a protocol valid, reliable and sensitive. In our study we compare two maximal tests, and we have obtained a practical application of UTT test to evaluate the cyclists in a real condition on the field without special technology. In this test (UTT) the cyclist might adapt pedalling movements to field and observe the real sensations, because the cyclist informs not only about of fatigue, also about his power sensation, which is depending on the gear used.

The blood lactate response to exercise is a commonly accepted tool for performance assessment and training prescription (Lehman, 1999). Laboratory tests are very common on professional road cyclists, but field tests are often used to express the performance of elite cyclists. In this way Klika et al. (2007), have indicated that the field test is a valid measure of fitness and changes in fitness, and it provided data for the establishment of training ranges. The exercise induces the answer of the whole body together with a heart rate increase proportional to the load and physical time required, which is accompanied by a blood lactate increase (Lucia et al., 2002; Mcardle et al., 2001; Mujika & Padilla, 2001). An increase of maximal heart rate is correlated to an increase on blood lactate that will be greater or smaller (greater or smaller anaerobic capacity) based on the athlete training degree (Coyle, 1999; Mcardle et al., 2001; Paton & Hopkins, 2001). The whole blood lactate (LA) ($mmol \cdot L^{-1}$) accumulation decreases the performance capacity, which is accompanied by an increase of the subjective and objective muscular fatigue (Coyle, 1999; Harmer et al., 2000). However, as the mechanisms of fatigue and recovery within the muscles are likely to be multifactorial, it appears that the cycling strategy employed does not alter the oxygen cost.

It is widely accepted that heart rate and blood lactate are good indicators of the effort intensity (Coyle, 1999; Kenefick et al., 2002; Mujika & Padilla, 2001; Paton & Hopkins, 2001). In our study the two tests have similar time duration: 12 min exactly on road test and lightly less than 13 min on LIT test. So, the observed similar values of HR_{max} ($beats \cdot min^{-1}$) and LA_{max} ($mmol \cdot L^{-1}$) from the two tests showed that body demands were similar in both cases. However exits some differences. Three minutes after the road field test began; cyclists remained over the AT, contrary to the laboratory test that showed HR increases proportional to the power developed. On the laboratory incremental test (LIT), cyclists exceed AT when they have surpassed the 2/3 of total time. However, on road and laboratory tests, maximal power has been liked to be developed, and although firstly the effort developed on road test was higher than on laboratory test, the HR_{max} (beats·min^{-1}) (188.3±3.3 and 188.4±2.2) and LA_{max} (mmol·L-1) (13.9±0.8 and 15.2±1.0) were in the same level and correlated after the tests ended. However, the uphill road test (12 min at maximal capacity) reproduces conditions similar to a competition, and it allows a comparison with data obtained from the laboratory test. Linear multiple regression using the HR_{max} (the average) (beats·min^{-1}) as dependent variable, and taking only into account the distance and the speed, a high correlation coefficient (r=0.714) was found. When more independent variables, as the maximal lactate level (LA_{max}) in both tests were considered, similar correlation coefficient (r=0.729) was obtained. This data suggest that both tests can be used to evaluate the performance of cyclists.

Earlier reports pointed out that exercise protocols of varying intensity and duration are usually associated with an increase in blood viscosity, mainly due to an increase in plasma viscosity and haematocrit (Córdova et al., 2006; Weltman, 1995; El-Sayed et al., 2005). The exercise-related increase in plasma viscosity and haematocrit is usually ascribed to fluid loss, conventionally known as hemoconcentration. In our data RBC, Hb concentrations and Hct increase after the exercise. In this same way, we have previously (Córdova & Escanero, 1992) observed that hemoconcentration after maximal exercises on laboratory may be explained by stress, which produces shifts on blood and, consequently, a decrease in plasma volume. The lack of change in the parameters specifics of red blood cells as are the mean cellular volume (MCV), the corpuscular haemoglobin concentration (MCHC) and the corpuscular haemoglobin (MCH) together to the increase in the concentration of haematocrit, blood haemoglobin concentration and red blood cells counts are in accordance with the existence of haemoconcentration as results of a decrease in plasma volume. This decrease in plasma volume is produced both in the uphill time trial test and in the incremental laboratory test in a similar quantity in the 12-13 minutes of duration of the tests.

The significant findings from the present study are the close relationship between HR_{max} (beats·min^{-1}) (r=0.86) and between LA_{max} (r=0.70) in both, laboratory and. uphill road tests (LIT and UTT). In the same way when consider the HR_{max} as dependent variable, and taking only into account the distance and the speed (r=0.714), and when was the maximal lactate level (LA_{max}) (r=0.729) consider in both tests.

We think that the UTT is a protocol valid, reliable and sensitive because it resembles the performance that is being simulated as closely as possible, provides a similar result from day to day when no intervention is used, and is able to detect small changes in performance. We consider that UTT is a useful test to evaluate the cyclist's physical condition in function of distance with respect the maximal heart rate. That is, maintaining constant the time and knowing the other parameters (maximal heart rate and distance) we can establish the cyclist performance level. An additional advantage may be to develop the test on the field in similar conditions to a competition and using the cyclist own bicycle. Therefore, the uphill road test may be considered by cyclists and trainers, and it yields complementary data to that obtained on the laboratory. Moreover, the cost and material employed to develop the UTT is insignificant compared with the necessary means for carry out the LIT test. On the other hand, is important because we can obtain information about of maximal performance as well as power feeling of cyclist. By last, we can say that this test (UTT) is useful to evaluate the performance level in well trained cyclist. Obviously, the test is not interesting on general people without an aim to follow a controlled training, hence the importance for the trainers. These results may be significant in physiological terms to monitor the training and for recommendation of exercise or performance prediction

ACKNOWLEDGMENTS

This study was granted by the Spanish Ministry of Education and Science (ref. DEP2005-00238-C04), and Junta Castilla y Leon (ref VA113A06)

REFERENCES

1. BENTLEY DJ, NEWELL J, BISHOP D. Incremental Exercise Test Design and Analysis: Implications for Performance Diagnostics in Endurance Athletes. *Sports Med*. 2007; 37:575-586. [Abstract] [Back to text]
2. BILLAT VL, SIRVENT P, PY G, KORALSZTEIN JP, MERCIER J. The concept of maximal lactate steady state: a bridge between biochemistry, physiology and sport science. *Sports Med.* 2003; 33:407-26. [Abstract] [Back to text]
3. BODNER ME, RHODES EC. A review of the concept of the heart rate deflection point. *Sports Med*. 2000; 30:31-46. [Abstract] [Back to text]
4. CONCONI F, GRAZZI G, CASONI I, GUGLIELMINI C, BORSETTO C, BALLARIN E, MAZZONI G, PATRACCHINI M, MANFREDINI F. The Conconi test: methodology after 12 years of application. *Int J Sports Med*. 1996; 17:509-519. [Abstract] [Back to text]
5. COOPER CB, STORER TW. *Exercise testing and interpretation. A practical approach*. Cambridge, England: Cambridge University Press; 2001. [Back to text]
6. CÓRDOVA A, ESCANERO JF. Iron, transferrin, and haptoglobin levels after a single bout of exercise in men. *Physiol. Behav.* 1992; 51:719-722. doi:10.1016/0031-9384(92)90107-D [Back to text]
7. CÓRDOVA A, VILLA G, AGUILO A, TUR JA, PONS A. Hand strike-induced hemolysis and adaptations in iron metabolism in Basque ball players. *An Nutr Metab*. 2006; 50:206-213. [Abstract] [Back to text]
8. CÓRDOVA A. Muscular fatigue and physical performance [in Spanish]. Madrid: Síntesis; 1997. [Back to text]
9. COYLE EF, FELTHER ME, KAUTZ SA, HAMILTON MT, MONTAIN SJ, BAYLOR AM, ABRAHAM LD, PETREK GW. Physiological and biomechanical factors associated with elite endurance cycling performance. *Med Sci Sports Exer.* 1991; 23:93-107. [Abstract] [Back to text]
10. COYLE EF. Physiological determinants of endurance exercise performance. *J Sci Med Sport*. 1999; 2:181-189. doi:10.1016/S1440-2440(99)80172-8 [Back to text]
11. CRAIG NP, NORTON KI, BOURDON PC, WOOLFORD SM, STANEF T, SQUIRES B, OLDS TS, CONYERS RA, WALSH CB. Aerobic and anaerobic indices contributing to track endurance cycling performance. *Eur J Appl Physiol Occup Physiol.* 1993; 67:150-158. [Abstract] [Back to text]
12. CURRELL K, JEUKENDRUP AE. Validity, reliability and sensitivity of measures of sporting performance. *Sports Med*. 2008; 38:297-316. [Abstract] [Back to text]
13. EL-SAYED MS, ALI N, EL-SAYED ALI Z. Haemorheology in exercise and training. *Sports Med*. 2005; 35:649-670. [Abstract] [Back to text]
14. FARIA EW, PARKER DL, FARIA IE. The science of cycling: factors affecting performance - part 2. *Sports Med.* 2005b; 35:313-337. [Abstract] [Back to text]
15. FARIA EW, PARKER DL, FARIA IE. The science of cycling: physiology and training - part 1. *Sports Med*. 2005a; 35:285-312. [Abstract] [Back to text]
16. FARRELL SW, IVY JL. Lactate acidosis and the increase in VE/VO_2 during incremental exercise. *J Appl Physio*. 1987; 62:1551-1555. [Abstract] [Back to text]

17. FERNANDEZ-GARCIA B, PEREZ-LANDALUCE J, RODRIGUEZ-ALONSO M, TERRADOS N. Intensity of exercise during road race pro-cycling competition. *Med Sci Sports Exerc*. 2000; 32:1002-1006. [Abstract] [Back to text]
18. HARMER AR, MCKENNA MJ, SUTTON RJ, RUELL PA, BOOTH J, THOMPSON MW, MACKAY NA, STATHIS CG, CRAMERI RM, CAREY MF, EAGER DM. Skeletal muscle metabolic and ionic adaptations during intense exercise following sprint training in humans. *J Appl Physiol.* 2000; 89:1793-1803. [Abstract] [Back to text]
19. HOPKINS SR, MCKENZIE DC. The laboratory assessment of endurance performance in cyclists. *Can J Appl Physiol*. 1994; 19:266- 274. [Abstract] [Back to text]
20. HOPKINS WG, SCHABORT EJ, HAWLEY JA. Reliability of power in physical performance tests. *Sports Med*. 2001; 31:211-234. [Abstract] [Back to text]
21. JEUKENDRUP A, VAN DIEMEN A. Heart rate monitoring during training and competition in cyclists. *J Sports Sci*. 1998; 16:91-99. [Abstract] [Back to text]
22. JONES AM, KOPPO K, BURNLEY M. Effects of prior exercise on metabolic and gas exchange responses to exercise. *Sports Med*. 2003; 933:949-71. [Abstract] [Back to text]
23. KENEFICK RW, MATTERN CO, MAHOOD NV, QUINN TJ. Physiological variables at lactate threshold under-represent cycling time-trial intensity. *J Sports Med Phys Fitness*. 2002; 42:396-402. [Abstract] [Back to text]
24. KLIKA RJ, ALDERDICE MS, KVALE JJ, KEARNEY JT. Efficacy of cycling training based on a power field test. *J Strength Cond Res*. 2007; 21:265-269. [Abstract] [Back to text]
25. KUIPERS H, VERSTAPPEN FT, KEIZER HA, GEURTEN P, VAN KRANENBURG G. Variability of aerobic performance in the laboratory and its physiologic correlates. *Int J Sports Med*. 1985; 6:197–201. [Abstract] [Back to text]
26. LEHMAN M. *Overload, performance incompetence, and regeneration in sport*. New York: Kluwer Academic/Plenum Publishers; 1999. [Back to text]
27. LUCIA A, HOYOS H, CHICHARRO JL. Physiological response to professional road cycling: climbers vs. time trialists. *Int J Sports Med*. 2000; 21:505-512. [Abstract] [Back to text]
28. LUCIA A, HOYOS J, CHICHARO JL. Physiology of professional road cycling. *Sports Med*. 2002; 31:325-337. [Abstract] [Back to text]
29. MCARDLE WD, KATCH FI, KATCH VL. *Exercise Physiology: energy, nutrition, and human performance* 5nd ed. Philadelphia: Lippincott Williams & Wilkins; 2001. [Back to text]
30. MUJIKA I, PADILLA S. Physiological and performance characteristics of male professional road cyclists. *Sports Med*. 2001; 31: 479-487. [Abstract] [Back to text]
31. PATON CD, HOPKINS WG. Tests of cycling performance. *Sports Med*. 2001; 31:489-496. [Back to text]
32. REISER M, MEYER T, KINDERMANN W, DAUGS R. Transferability of workload measurements between three different types of ergometer. *Eur J Appl Physio.* 2000; 82:245-249. [Abstract] [Back to text]
33. RODRIGUEZ-MARROYO JA, GARCIA-LOPEZ J, AVILA C, JIMÉNEZ F, CÓRDOVA A, VILLA JG. Intensity of exercise according to topography in professional cyclists. *Med Sci Sports Exerc*. 2003; 35:1209-1215. [Abstract] [Back to text]
34. SCHABORT EJ, HAWLEY JA, HOPKINS WG, MUJIKA I, NOAKES TD. A new reliable laboratory test of endurance performance for road cyclists. *Med Sci Sports Exerc*. 1998; 30:1744-1750. [Abstract] [Back to text]
35. SJODIN B, JACOBS I. Onset of blood lactate accumulation and marathon running performance. *Int J Sports Med*. 1981; 2:23-26. [Abstract] [Back to text]

36. STEED J, GAESSER GA, WELTMAN A. Rating of perceived exertion and blood lactate concentration during submaximal running. *Med Sci Sports Exerc.* 1994; 26:797-803. [Abstract] [Back to text]
37. SURIANO R, VERCRUYSSEN F, BISHOP D, BRISSWALTER J. Variable power output during cycling improves subsequent treadmill run time to exhaustion. *J Sci Med Sport*. 2007; 10:244-251. doi:10.1016/j.jsams.2006.06.019 [Back to text]
38. SZYGULA Z. Erythrocytic system under the influence of physical exercise and training. *Sports Med*. 1990; 10:181-197. [Abstract] [Back to text]
39. WELTMAN A. *The blood lactate response to exercise*. Champaign, IL: Human Kinetics; 1995. [Back to text]

