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PACING STRATEGY DURING SIMULATED MOUNTAIN BIKE RACING

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ABSTRACT

Cross-country mountain biking (XCO) is a popular high-intensity cycling endurance event, however, XCO pacing strategy has not been fully examined. This study examined the pacing strategies of different XCO athletes, during a laboratory-simulated XCO performance test. Brazilian cyclists classified as performance cohort level three (PL3-trained) performed an XCO race simulation. The simulation consisted of four 10 km laps with a gradient of 0-10%. No group vs. time interaction was found in lap time (P = 0.169), absolute (P = 0.719) and relative (P = 0.607) power output, ratings of perceived exertion (P = 0.182) and heart rate (P = 0.125). There was a time main effect, as athletes decreased the power output by 0.3 $W \cdot kg^{-1}$ throughout the XCO simulation, thereby resulting in a 1.6 min decrement per lap. The power output corresponding to the *onset blood lactate accumulation* adequately represented the mean power of the first lap. These results showed that cyclists with different training status adopted similar pacing strategies during a XCO race simulation, as they both used a fast starting pacing strategy, followed by positive pacing that resulted in a linear decrease in power output at every lap.

Keywords: Pacing strategy, exercise performance, mountain biking, fast start

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INTRODUCTION

Cross-country mountain biking (XCO) is a high-intensity, endurance sporting event (F. Impellizzeri, Sassi, Rodriguez-Alonso, Mognoni, & Marcora, 2002; F. M. Impellizzeri & Marcora, 2007), so that athletes are required to generate power output values ranging from ~ 50 to 400 watts. In fact, mean power output values has been shown to be around 208 watts, while peak power output values has been shown to be as high as 1000 watts at the outset of a XCO race (Stapelfeldt, Schwirtz, Schumacher, & Hillebrecht, 2004), thus supporting the suggestion that a fast start pacing strategy is the most used strategy in XCO races (F. M. Impellizzeri & Marcora, 2007; Macdermid & Morton, 2012). Because of this fast start pacing, XCO athletes usually decrease the power output as the race progresses so that the time to complete each lap increases (F. Impellizzeri et al., 2002; Wingo et al., 2004).

Athletes with faster start pacing strategies may gain advantages over other opponents during the initial phases of a XCO race (Macdermid & Morton, 2012), thereby playing a critical and decisive role for the race outcome (Viana, Inoue, & Santos, 2013). In this regard, the fast start pacing strategy used in a XCO race may depend on the performance level of the athlete, as athletes with different performance levels would adopt different pacing strategies (Lima-Silva et al., 2010). In fact, previous study with runners observed that higher-performing (HP) runners showed a more aggressive pacing strategy, with a faster start pacing during a 10-km running time trial, when compared to lower-performing (LP) runners. Furthermore, not only HP runners elicited greater mean velocity during the initial 400 m of the race, but also throughout the race. Therefore, it would be plausible to expect that HP XCO cyclists may further use a more aggressive pacing strategy in a XCO race, with a remarkable faster start pacing when compared to LP XCO cyclists.

Interesting finding in that running pacing study was that pacing strategy obtained at different parts of the race was well correlated with traditional parameters derived from a

laboratory maximal incremental test (MIT), thus suggesting that a cycling MIT may further predict pacing strategy in XCO athletes with different performance levels. As suggested elsewhere with runners, the peak power output (PPO) could be associated with initial XCO performance, while PPO and lactate thresholds intensity may be associated with the mean velocity and power output in a XCO race (Lima-Silva et al., 2010).

Initial evidences of pacing strategy in XCO events should be preferably obtained in a controlled, laboratory cycling set-up rather than real races. According to a pacing strategy model based on the perception of effort, proposed by Tucker & Noakes (2009), pacing may change according to variations in environment (Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks, 2012), presence of other competitors (St Clair Gibson et al., 2006) and context information such as performance feedback (Mauger, Jones, & Williams, 2009; Albertus et al., 2005). Therefore, to make inferences possible, the study of pacing strategy of XCO cyclists with different training status may be initially preferable in a laboratory, controlled cycling set-up. For example, higher correlations between MIT parameters and XCO pacing and performance could be observable in a controlled environment, rather than in a real race with variations in environment and presence of competitors. Thus, the aim of this study was to investigate the pacing strategy adopted by HP and LP XCO cyclists during a laboratory, XCO race simulation. We hypothesized that HP XCO cyclists would use aggressive start pacing strategies, more than LP cyclists. Thus, as a result of a remarkable faster start pacing strategy, HP XCO cyclists would elicit a decreasing pace as the race progressed. We further expected that traditional parameters of laboratory MIT such as PPO and lactate thresholds intensity would be correlated with performance in a XCO race simulation.

Methods

Participants

Twenty Brazilian male XCO cyclists participated in this study. Based on their PPO and VO_{2max} values, the participants were classified as performance level three (PL3-trained), according to cohort analysis as suggested elsewhere (De Pauw et al., 2013)

Athletes were unconsidered as subjects if they had been recently injured or presented potential limitation to perform competitive mountain biking. The athletes were informed about the experimental procedures, their risks and benefits when they signed the consent form. All procedures were approved by the local Human Research Ethics Committee and were conducted in accordance with the Helsinki declaration (Harriss & Atkinson, 2011). The athletes' characteristics are presented in Table 1.

Experimental design

The athletes visited the laboratory at three different sessions. The first session consisted of anthropometric measurements and a cycling MIT. In the second session athletes were familiarised with the simulated XCO test (XCO test) (Inoue et al., 2016). Then, they performed the XCO test in a competitive fashion in the third session. All the tests, including the XCO test were performed on different days interspersed by 48 h minimum interval, in a controlled laboratory (21º ± 1°C) at the same time of day (≈ 2 h). The cyclists were asked to avoid solid food during the three hours preceding the tests and avoid high-intensity exercise for the 24 h before the tests. Water was ingested *ad libitum* during the XCO test (Rose & Peters-Futre, 2010).

Procedures

Maximal incremental test (MIT). After warming up at 100 W for 10 min, the power output was increased by 30 W/5 min until exhaustion, which was defined as an incapacity to maintain the pedal cadence > 70 rpm (Inoue, A., et al., 2016). The test was performed on a bike

equipped with specific MTB cycling pedals saddle, fixed by the rear wheel (100 psi) to an ergometer electromagnetically braked (Computrainer™ Lab 3D, RacerMate, Seattle, WA, USA) (Peveler, 2013; Sparks et al., 2016) which was calibrated before each test according to manufacturer's specifications. Gas exchange was assessed throughout the MIT through an open circuit gas analyser (Vacumed Vista-Mini CPX metabolic analyser, Ventura, CA, USA) (Paulucio, Nogueira, Velasques, Ribeiro, & Pompeu, 2015) calibrated before each test, according to manufacturer's specification. The peak of oxygen uptake (VO_{2peak}) was determined at the highest 30 s value reached during the last stage of the MIT. The PPO was determined at the last stage fully completed, corrected by the time spent in incomplete stage (Kuipers, Verstappen, Keizer, Geurten, & van Kranenburg, 1985).

The heart rate (HR) was monitored throughout the MIT (Polar® RS 800 CX [Polar Electro, Oy, Finland]), blood samples (25 µL) and ratings of perceived exertion (RPE), quantified according to the CR100 Borg scale (Borg & Borg, 2002; Borg & Kaijser, 2006), were obtained at the end of each stage.

Determination of lactate thresholds. Blood samples were collected from the earlobe and immediately analysed for blood lactate concentrations with an automatic analyser (YSI 1500; Yellow Springs Instruments, Yellow Springs, OH, USA) (Medbo, Mamen, Holt Olsen, & Evertsen, 2000), calibrated before each test according to manufacturer's guidelines. Then, blood lactate concentrations were plotted as a function of the power output, so that two thresholds were determined as: (a) the lactate threshold (LT) corresponding to the power output that elicited a 1 $mmol \cdot L^{-1}$ increase in blood lactate concentrations above values measured at 40-60% VO_{2peak} (Hagberg & Coyle, 1983); (b) the onset of blood lactate accumulation (OBLA), which corresponded to the power output associated with a 4 $mmol \cdot L^{-1}$ blood lactate concentration (Sjodin & Jacobs, 1981).

Simulated XCO test (XCO TEST). The integrated 3D software version 1.0 (RacerMate Inc.) created a XCO course in order to simulate a XCO race. The software uses the individual's body weight and gradient when estimating speed and power output during the trial, similar to that reported in a recent XCO study (Inoue et al., 2016). After a 10 min warming up at 100 W, the cyclists started the XCO test. The XCO test consisted of four laps with 10 km distance (Figure 1), and gradient varying stochastically between 0% and 10%. Distance and elevation were set in order to allow the XCO test completion within ~100 min (i.e. ~25 min per lap). To simulate a real XCO competition, athletes were free to pace themselves throughout the race, therefore they were free to change gears, pedal cadence and body position while cycling (i.e. change from seat to stand position). They were oriented to complete the SPT as fast as possible, as in a real XCO competition. With exception of the elapsed time, no other feedback was made available during the trial. Unpublished data from our group have suggested this XCO test is a valid and reliable protocol to measure performance in XCO cyclists, as we have observed high correlation between XCO test performance and outcome in real XCO competition ($r = -0.84$; $P < 0.001$). Additionally, this XCO test has further shown high intraclass correlation coefficient (ICC = 0.96) and low standard error of measurement (1.4%).

Statistical Analysis

Similar to previous study (Lima-Silva et al., 2010) we used percentiles to split the sample into two different groups with distinct performance status. Then, XCO athletes (n = 20) were initially categorized into percentiles based on the time to complete the XCO test (time). Thereafter, athletes dropping within the first 45th percentile (i.e. time > 104.6 min) or the last 45th percentile (i.e. cyclists dropping from 55th to 100th percentiles, time < 100.3 min) were ranked as LP (n = 9) and HP group (n = 9), respectively. Two athletes were excluded from analysis as they were out of the LP and HP groups range (i.e. time < 100.3 min and > 104.6 min). This method ensured that cyclists were allocated into two groups significantly different

in terms of performance level, without leading to a substantial sample loss due to the split process, yet.

Alterations in pacing strategy were detected through a 4 x 2 two-way repeated-design ANOVA (laps x group), having the Bonferroni's test corrected results in multiple comparisons. Thus, time to complete the XCO test (1, 2, 3 and 4 laps) by performance level (HP and LP) interaction was checked for the following dependent variables: time to complete each lap (lap_{time}), mean power output ($W_{absolute}$, expressed as W and $W_{relative}$, expressed as $W \cdot kg^{-1}$), HR and RPE. Furthermore, correlations between $W_{absolute}$ and parameters derived from MIT (i.e. PPO and OBLA) in ungrouped and grouped data (HP *vs* LP group), were calculated as Pearson product-moment coefficient. The 95% confidence limits were reported for all results, having been the significant results set at $P < 0.05$ (SPSS Inc., Chicago, IL, USA version 17.0).

RESULTS

Characterization of XCO cyclists was reported in Table 1. HP and LP cyclists were significantly different in terms of performance, as the time to complete the XCO test was significantly lower in HP ($P < 0.001$) than in LP XCO cyclists. In addition, significant differences between groups were also found in body mass (kg), height (cm), PPO, LT, and OBLA.

We did not observe laps by group interaction effect in lap_{time} ($P = 0.169$), $W_{absolute}$ (W) ($P = 0.719$) and $W_{relative}$ ($W \cdot kg^{-1}$) ($P = 0.607$), thus suggesting that HP and LP XCO groups used similar pacing strategies to complete the XCO test. In fact, both the HP and LP group showed a fast start pacing strategy, with a decreasing pacing as XCO test progressed. A time main effect was observed in lap_{time}, $W_{absolute}$ and $W_{relative}$, reflecting a positive pacing strategy throughout the XCO test (Figure 2). In this regard, significant differences were observed between lap 1 and lap 4 for lap_{time} (3.6 ± 0.4 min; [$CI_{95\%}$ 2.1,5.1]; $P < 0.001$) and $W_{absolute}$ (-46.5 ± 5.9 W; [$CI_{95\%}$-64.3, -28.7]; $P < 0.001$). Interestingly, we found decreases of 5 % (r =

0.75 p = 0.019) and 7% (r = 0.44 p = 0.233) in HP and LP groups, respectively, when power output responses were analysed relative to OBLA intensity. Accordingly, there was a 5% (r = 0.48 p = 0.187) and 6% (r = 0.64 p = 0.058) decrease in HP and LP groups, respectively, when power output was analysed relative to PPO (figure 3).

Regarding HR and RPE responses, there was no lap by group interaction effect in HR (P = 0.125) and RPE (P = 0.182), despite a time main effect has been detected for both (Figure 2D and 2C). Additionally, there was a main time effect in RPE so that RPE increased throughout the SPT (29.44± 3.67; [$CI_{95\%}$18.39, 40.49]; $P < 0.001$).

When analysing ungrouped data we observed significant correlation ($P < 0.001$) between $W_{absolute}$ and indexes derived from MIT, for example PPO (r = 0.87) and OBLA (r = 0.86). In contrast, grouped data analysis revealed significant correlation ($P < 0.05$) between $W_{absolute}$ and OBLA (r = 0.75) in HP group, but not in LP group ($P > 0.05$).

DISCUSSION

The present study showed that XCO athletes adopted a fast start pacing strategy in a XCO test, regardless of the athletes' performance level. Thus, both HP and LP groups used an aggressive pacing strategy design, eliciting a fast start followed by a linear decrease in performance as the trial progressed. This suggests that training schedule could be orientated to reinforce this pacing strategy shape in athletes with different performance levels.

In contrast to our initial hypothesis, results of the present study suggested that XCO athletes with different performance levels adopt similar aggressive pacing strategy, at least in a laboratory XCO test. Thus, as a result of a fast start pacing there was a greater psychophysiological stress during the initial phase of the trial, as suggested by a higher HR and RPE in lap 1. Similar results have been reported elsewhere (Sandals, Wood, Draper, & James, 2006) (Thompson, MacLaren, Lees, & Atkinson, 2003), perhaps indicating a greater fatigue occurrence in the earlier phase of the event (Thompson et al., 2003; Thompson, MacLaren,

Lees, & Atkinson, 2004), which could lead to a performance impairment in the later stages (Foster et al., 1993).

The maintenance of the first positions in the earlier phases of a XCO race is important, because athletes can avoid a slow-down in pacing imposed by presence of slower riders, mainly in single-track racing (F. Impellizzeri et al., 2002; F. M. Impellizzeri & Marcora, 2007). Actually, longitudinal data from the XCO World Cup over the last 10 years provided a significant, positive association (R^2 = 0.64) between the position at the beginning of the race start and the race outcome (Macdermid & Morton, 2012). These authors showed that for most men and women elite competitors, variations between positions at the beginning and at the end of the race would tax about 15 and 10 positions, respectively. Consequently, it is unlikely to finish the race well placed, having been started it in the back positions.

In contrast to our and others results (F. Impellizzeri et al., 2002; F. M. Impellizzeri & Marcora, 2007; Stapelfeldt et al., 2004; Wingo et al., 2004), a previous study (Martin et al., 2012) identified an even pacing strategy in XCO race. However, that study used a GPS system to provide speed data, making difficult the analysis of the real pacing strategy used throughout the race. In this regard, it should be highlighted that the dissociation between speed and power output in a cycling trial may have produced the different pacing strategies reported in these studies.

As reported elsewhere, XCO athletes are frequently required to generate OBLA power output values for prolonged periods in XCO competitions (F. M. Impellizzeri & Marcora, 2007). Our results showed that regardless of the performance level (HP and LP groups), athletes performed every lap with HR values greater than 90% of maximal HR, thus corroborating previous findings (Impellizzeri et al., 2002; Inoue, Sa Filho, Mello, & Santos, 2012). In addition, the $W_{absolute}$ in lap 1 was similar to OBLA intensity in both HP and LP groups, but decreased 5-7% relative to OBLA as the XCO test progressed, thereby suggesting

that the capacity to sustain the OBLA may be important in XCO performance (F. M. Impellizzeri & Marcora, 2007). Importantly, although the significant correlation observed between $W_{absolute}$ and OBLA power output in ungrouped data, only the HP group showed significant correlation between XCO test performance (as indicated by $W_{absolute}$ values) and OBLA intensity when data was grouped as HP and LP groups. Therefore, these results may suggest that improvements in OBLA intensity may be required for a better XCO performance.

Some limitations should be pointed out here. We used a laboratory XCO test to determine the athletes' pacing strategies, thereafter we inferred results to a real XCO race. Despite assuming a logical limitation when inferring laboratory test outcomes to a real world competition, we believe that our XCO test was suitable to study pacing strategy of real XCO competitions. First, even though using a gradient range from 0% to 10%, therefore missing negative gradients usually observed in real XCO competitions, we found mean HR values around 90% of the maximal HR, and these values were close to HR values reported in XCO real competitions (Impellizzeri et al., 2002). Consequenly, it could be argued that our XCO test induced a similar physiological demand when compared to a real XCO race. In fact, we observed a strong correlation ($r = -0.84$) between $W_{relative}$ in XCO test and time to complete a real XCO race (unpublished data from our lab). Moreover, we are unaware of a controlled-laboratoty experimental set-up simulating XCO pacing strategies with a greater ecological validity.

An important direction for future studies considers the power output data sampling. Instead of recording power output data set with low resolution, as we did in the present study, high-resolution data set may be preferable when investigating power output data variability and dynamic control of exercise relationships (Angus & Waterhouse, 2011; Tucker et al., 2006). In this sense, future studies should consider higher-resolution power output data set to investigate XCO pacing strategy and exercise regulation relationships.

PRACTICAL APPLICATIONS

The results of the present study have practical implications, as they suggested that the improvements in OBLA power output could be a good strategy to improve performance in XCO competitions, as XCO test performance in HP group (as indicated by $W_{absolute}$) was strongly correlated with OBLA intensity.

CONCLUSION

Regardless of the performance level, XCO athletes adopted a similar aggressive pacing strategy design, thus eliciting a fast start followed by a decreasing pacing strategy as the XCO test progressed. Furthermore, although the similar pacing strategy between HP and LP XCO athletes, HP athletes showed greater OBLA intensity and lower time to complete the XCO test. Therefore, training programs designed to increase the OBLA power output may be insightful to improve XCO performance.

REFERENCES

Albertus, Y., Tucker, R., St Clair Gibson, A., Lambert, E. V., Hampson, D. B., & Noakes, T. D. (2005). Effect of distance feedback on pacing strategy and perceived exertion during cycling. *Med Sci Sports Exerc, 37*(3), 461-468.

Angus, S. D., & Waterhouse, B. J. (2011). Pacing strategy from high-frequency field data: more evidence for neural regulation? *Med Sci Sports Exerc, 43*(12), 2405-2411. doi: 10.1249/MSS.0b013e3182245367

Borg, E., & Borg, G. (2002). A comparison of AME and CR100 for scaling perceived exertion. *Acta Psychol (Amst), 109*(2), 157-175.

Borg, E., & Kaijser, L. (2006). A comparison between three rating scales for perceived exertion and two different work tests. *Scand J Med Sci Sports, 16*(1), 57-69. doi: 10.1111/j.1600-0838.2005.00448.x

Corbett, J., Barwood, M. J., Ouzounoglou, A., Thelwell, R., & Dicks, M. (2012). Influence of competition on performance and pacing during cycling exercise. *Med Sci Sports Exerc, 44*(3), 509-515. doi: 10.1249/MSS.0b013e31823378b1

De Pauw, K., Roelands, B., Cheung, S. S., de Geus, B., Rietjens, G., & Meeusen, R. (2013). Guidelines to classify subject groups in sport-science research. *Int J Sports Physiol Perform, 8*(2), 111-122.

Foster, C., Snyder, A. C., Thompson, N. N., Green, M. A., Foley, M., & Schrager, M. (1993). Effect of pacing strategy on cycle time trial performance. *Med Sci Sports Exerc, 25*(3), 383-388.

Hagberg, J. M., & Coyle, E. F. (1983). Physiological determinants of endurance performance as studied in competitive racewalkers. *Med Sci Sports Exerc, 15*(4), 287-289.

Harriss, D. J., & Atkinson, G. (2011). Update--Ethical standards in sport and exercise science research. *Int J Sports Med, 32*(11), 819-821. doi: 10.1055/s-0031-1287829

Impellizzeri, F., Sassi, A., Rodriguez-Alonso, M., Mognoni, P., & Marcora, S. (2002). Exercise intensity during off-road cycling competitions. *Med Sci Sports Exerc, 34*(11), 1808-1813. doi: 10.1249/01.MSS.0000036690.39627.F7

Impellizzeri, F. M., & Marcora, S. M. (2007). The physiology of mountain biking. *Sports Med, 37*(1), 59-71.

Inoue, A., Impellizzeri, F. M., Pires, F. O., Pompeu, F. A., Deslandes, A. C., & Santos, T. M. (2016). Effects of Sprint versus High-Intensity Aerobic Interval Training on Cross-Country Mountain Biking Performance: A Randomized Controlled Trial. *PLoS One, 11*(1), e0145298. doi: 10.1371/journal.pone.0145298

Inoue, A., Sa Filho, A. S., Mello, F. C., & Santos, T. M. (2012). Relationship between anaerobic cycling tests and mountain bike cross-country performance. *J Strength Cond Res, 26*(6), 1589-1593. doi: 10.1519/JSC.0b013e318234eb89

Kuipers, H., Verstappen, F. T., Keizer, H. A., Geurten, P., & van Kranenburg, G. (1985). Variability of aerobic performance in the laboratory and its physiologic correlates. *Int J Sports Med, 6*(4), 197-201. doi: 10.1055/s-2008-1025839

Lima-Silva, A. E., Bertuzzi, R. C., Pires, F. O., Barros, R. V., Gagliardi, J. F., Hammond, J., . . . Bishop, D. J. (2010). Effect of performance level on pacing strategy during a 10-km running race. *Eur J Appl Physiol, 108*(5), 1045-1053. doi: 10.1007/s00421-009-1300-6

Macdermid, P. W., & Morton, R. H. (2012). A longitudinal analysis of start position and the outcome of World Cup cross-country mountain bike racing. *J Sports Sci, 30*(2), 175-182. doi: 10.1080/02640414.2011.627368

Martin, L., Lambeth-Mansell, A., Beretta-Azevedo, L., Holmes, L. A., Wright, R., & St Clair Gibson, A. (2012). Even between-lap pacing despite high within-lap variation during mountain biking. *Int J Sports Physiol Perform, 7*(3), 261-270.

Mauger, A. R., Jones, A. M., & Williams, C. A. (2009). Influence of feedback and prior experience on pacing during a 4-km cycle time trial. *Med Sci Sports Exerc, 41*(2), 451-458. doi: 10.1249/MSS.0b013e3181854957

Medbo, J. I., Mamen, A., Holt Olsen, O., & Evertsen, F. (2000). Examination of four different instruments for measuring blood lactate concentration. Scand J Clin Lab Invest, 60(5), 367-380.

Paulucio, D., Nogueira, F., Velasques, B., Ribeiro, P., & Pompeu, F. (2015). Day-to-Day Variation of Cardiopulmonary Variables Obtained During an Incremental Cycling Test to Volitional Exhaustion. . JEPonline, 18(3), 81-90.

Peveler, W. W. (2013). The accuracy of simulated indoor time trials utilizing a CompuTrainer and GPS data. J Strength Cond Res, 27(10), 2823-2827. doi: 10.1519/JSC.0b013e318280ce76

Sparks, S. A., Williams, E., Jones, H., Bridge, C., Marchant, D., & McNaughton, L. (2016). Test-retest reliability of a 16.1 km time trial in trained cyclists using the CompuTrainer ergometer *J Sci Cycling*, 5(3), 35-41, 2016.

Rose, S., & Peters-Futre, E. M. (2010). Ad libitum adjustments to fluid intake during cool environmental conditions maintain hydration status during a 3-day mountain bike race. *Br J Sports Med, 44*(6), 430-436. doi: 10.1136/bjsm.2008.049551

Sandals, L. E., Wood, D. M., Draper, S. B., & James, D. V. (2006). Influence of pacing strategy on oxygen uptake during treadmill middle-distance running. *Int J Sports Med, 27*(1), 37-42. doi: 10.1055/s-2005-837468

Sjodin, B., & Jacobs, I. (1981). Onset of blood lactate accumulation and marathon running performance. *Int J Sports Med, 2*(1), 23-26. doi: 10.1055/s-2008-1034579

St Clair Gibson, A., Lambert, E. V., Rauch, L. H., Tucker, R., Baden, D. A., Foster, C., & Noakes, T. D. (2006). The role of information processing between the brain and peripheral physiological systems in pacing and perception of effort. *Sports Med, 36*(8), 705-722.

Stapelfeldt, B., Schwirtz, A., Schumacher, Y. O., & Hillebrecht, M. (2004). Workload demands in mountain bike racing. *Int J Sports Med, 25*(4), 294-300. doi: 10.1055/s-2004-819937

Thompson, K. G., MacLaren, D. P., Lees, A., & Atkinson, G. (2003). The effect of even, positive and negative pacing on metabolic, kinematic and temporal variables during breaststroke swimming. *Eur J Appl Physiol, 88*(4-5), 438-443. doi: 10.1007/s00421-002-0715-0

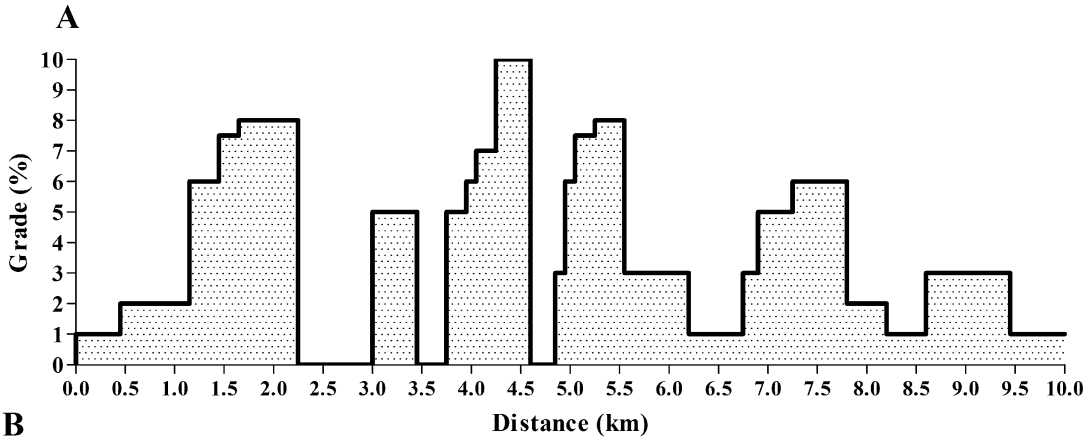
Thompson, K. G., MacLaren, D. P., Lees, A., & Atkinson, G. (2004). The effects of changing pace on metabolism and stroke characteristics during high-speed breaststroke swimming. *J Sports Sci, 22*(2), 149-157. doi: 10.1080/02640410310001641467

Tucker, R., Bester, A., Lambert, E. V., Noakes, T. D., Vaughan, C. L., & St Clair Gibson, A. (2006). Non-random fluctuations in power output during self-paced exercise. *Br J Sports Med, 40*(11), 912-917; discussion 917. doi: 10.1136/bjsm.2006.026435

Tucker, R., & Noakes, T. D. (2009). The physiological regulation of pacing strategy during exercise: a critical review. *Br J Sports Med, 43*(6), e1. doi: 10.1136/bjsm.2009.057562

Viana, B. F., Inoue, A., & Santos, T. M. (2013). The influence of start position on even-pacing strategy in mountain bike racing. *Int J Sports Physiol Perform, 8*(4), 351.

Wingo, J. E., Casa, D. J., Berger, E. M., Dellis, W. O., Knight, J. C., & McClung, J. M. (2004). Influence of a Pre-Exercise Glycerol Hydration Beverage on Performance and Physiologic Function During Mountain-Bike Races in the Heat. *J Athl Train, 39*(2), 169-175.



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Distance (Km)	0.4	0.5	0.5	0.1	0.3	0.9	0.6	0.3	0.3	0.1	0.1	0.3	0.4	0.1	0.1	0.1	0.3	0.3	1.0	0.1	0.2	0.5	0.6	0.2	0.6	1.1
Grade (%)	1.0	2.0	6.0	7.5	8.0	0.0	5.0	0.0	5.0	6.0	7.0	10	0.0	3.0	6.0	7.5	8.0	3.0	1.0	3.0	5.0	6.0	2.0	1.0	3.0	1.0

Figure 1: Gradient profiles of the simulation performance test.

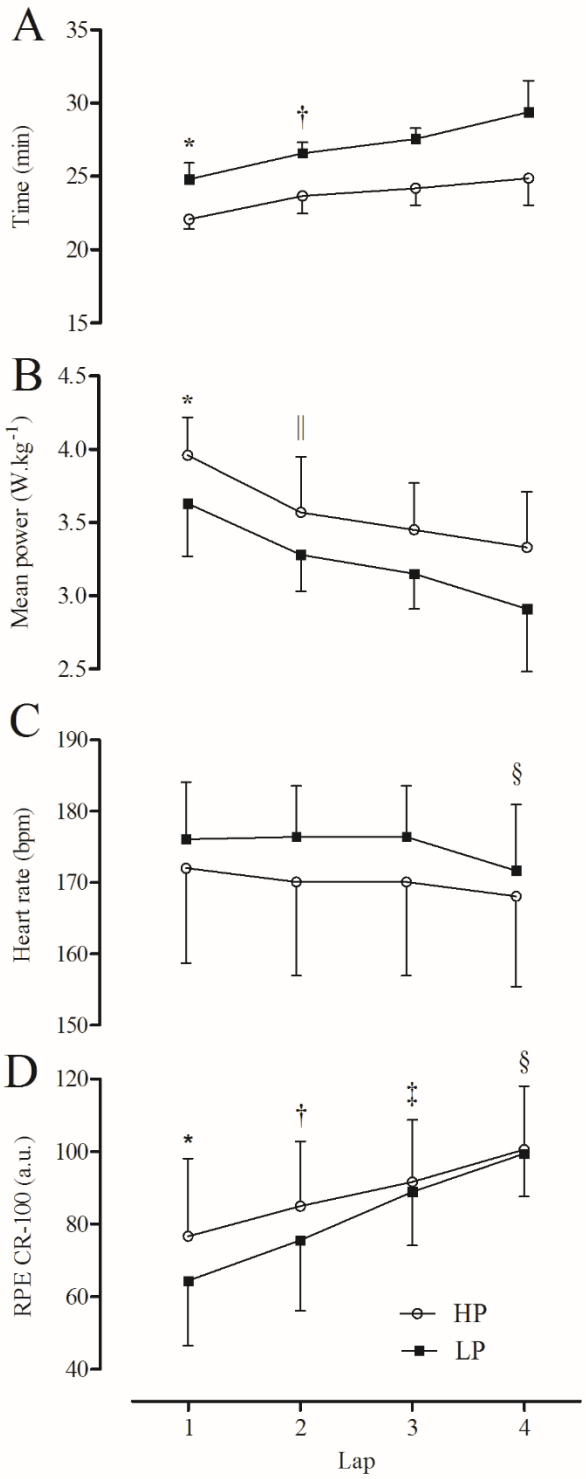

Figure 2: time main effect for the: (A) laptime, (B) Wrelative ($W \cdot kg^{-1}$), (C) Heart rate (bpm) and (D) RPE (CR100). All significant differences were set at $P \leq 0.05$. *significant differences among laps 2, 3 and 4; †significant differences among laps 1, 3 and 4; ‡ significant differences among laps 1, 2 and 4; § significant differences among laps 1, 2 and 3; || significant differences between laps 1 and 4.

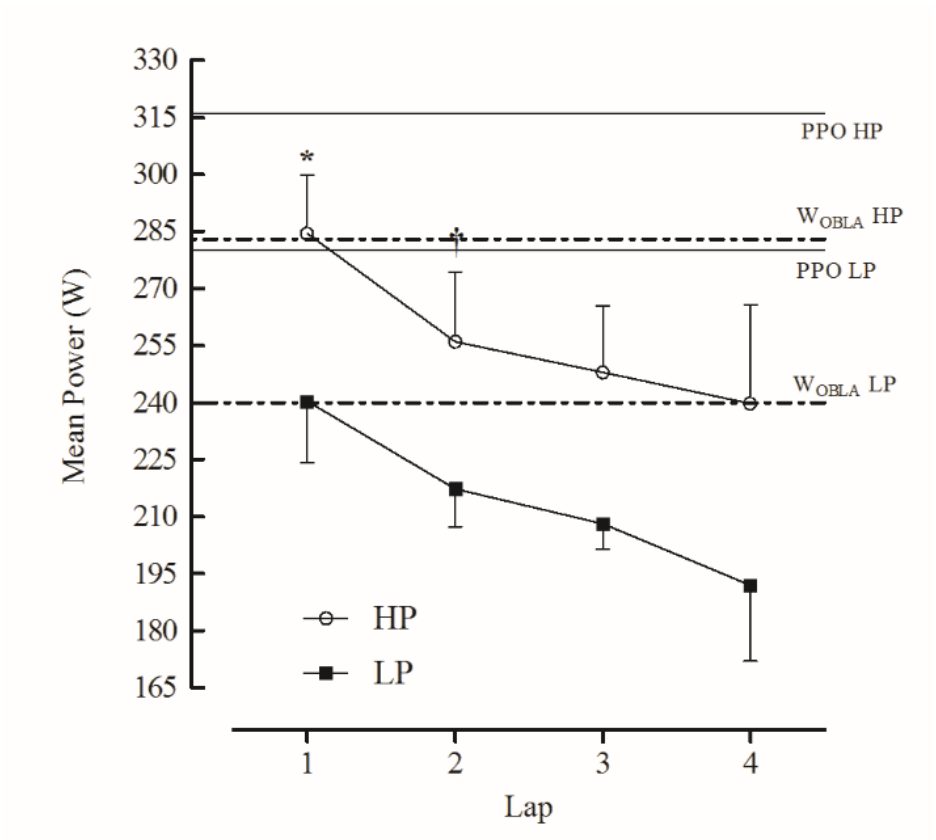

Figure 3: Time main effect for Wabsolute. Significant differences were set as $P \leq 0.05$. *significant differences among laps 2, 3 and 4; † significant differences among laps 1, 3 and 4; WOBLA HP – Power output associated with the OBLA in the HP group; WOBLA LP – Power output associated with the OBLA in the LP group. PPO HP – Peak power output achieved on the MIT for HP group; PPO LP – Peak power output achieved on the MIT for LP group.

Table 1: Anthropometric and physiological characteristics of the cyclists.

Variables	LP (n = 9)	HP (n = 9)	Sig.
	Mean ± SD	Mean ± SD	P
$Time_{spt}$ (min)	108.9 ± 2.5	95.5 ± 3.3	< 0.001
Age (years)	29.7 ± 2.0	35 ± 8.4	0.104
Body mass (kg)	66.4 ± 4.9	72.0 ± 4.9	0.029
Height (cm)	172.5 ± 4.0	179.0 ± 5.9	0.017
BMI	22.8 ± 0.9	22.5 ± 1.1	0.678
Body fat (%)	7.2 ± 2.7	7.9 ± 2.7	0.586
Wpeak (W)	279.6 ± 13.4	315.5 ± 10.3	< 0.001
Wpeak ($W.kg^{-1}$)	4.2 ± 0.3	4.4 ± 0.3	0.360
VO_{2peak} ($L.min^{-1}$)	4.3 ± 0.4	4.6 ± 0.2	0.145
VO_{2peak} ($mL.kg^{-1}.min^{-1}$)	65.7 ± 5,4	64.1 ± 4.3	0.515
LT (W)	198.6 ± 15.1	230.4 ± 22.8	< 0.001
LT ($W.kg^{-1}$)	3.0 ± 0.3	3.2 ± 0.3	0.268
OBLA (W)	240.2 ± 19.1	283.3 ± 19.1	< 0.001
OBLA ($W.kg^{-1}$)	3.6 ± 0.4	3.9 ± 0.2	0.079

LP Low performance group, *HP* High performance group, *BMI* body mass index, *Wpeak (W)* Power output at VO_{2peak}, *LT (W)* Power output at the Lactate Threshold, *OBLA (W)* Power output at the onset of blood lactate accumulation.