RESEARCH ARTICLE

Psycho-physiological responses of mountain bike riders during anaerobic and aerobic testing

Ana C. Paludo[1]✉, Christian J. Cook[2], Julian A. Owen[2], Tim Woodman[2], Steffan Owen[2] and Blair T. Crewther[2]

Abstract

The study objective was to compare the psycho-physiological responses of mountain bike riders to anaerobic and aerobic cycle testing. Nineteen male mountain bike riders were separated into high (n = 6), moderate (n = 6) and low experienced group (n = 7). The athletes were assessed for their psychological state (i.e. state-anxiety and perceived exertion), physiological responses (i.e. heart rate variability, salivary testosterone and cortisol) and performance (i.e. maximal oxygen consumption, power output) during a single bout of anaerobic and aerobic cycle testing. No group differences in state-anxiety or exercise-induced hormones were found (P >0.05). The high experienced group produced greater power outputs in both tests and they reported a higher level of perceived exertion during the aerobic test compared to low experienced (P <0.05). Also, pre-test heart rate variability in the high experienced group was significantly higher than that of the moderate and low experienced groups (P <0.001). In conclusion, greater experience with mountain bike training and competition was associated with elevated cardiac autonomic activity and higher perceived physical exertion in male riders, thereby potentially contributing to (or reflecting) better cycling performance.

Keywords: mountain bike; performance; athletes; cycling; psycho-physiology

✉ anacarolinapaludo@usp.br (AC. Paludo)

[1] Sao Paulo University, Sao Paulo, Brazil
[2] Bangor University, Bangor, United Kingdom

Introduction

Mountain biking is a popular cycling sport throughout the world. Conceived in the late 1970's, it now receives wide engagement by non-competitive individuals for leisure and recreational purposes, and also competitive athletes (Berto, 1999). According to the International Cycling Union (UCI) rules, mountain biking can be broken down into 4 separate disciplines: cross-country, downhill, four cross, and enduro specialities. Mountain bike races are conducted on off-road terrain with repeated climbs and descents over challenging and undulating race courses.
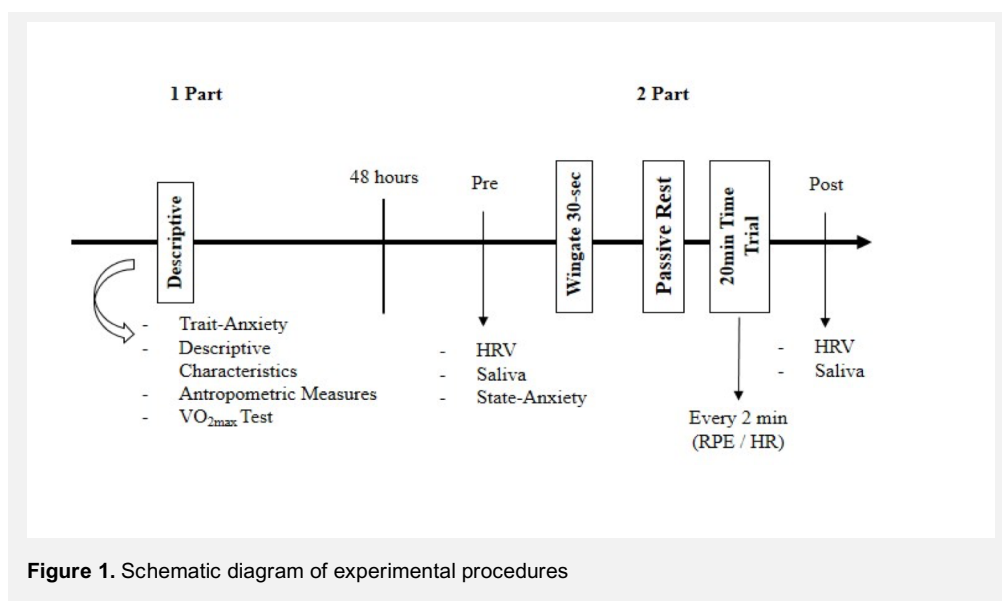
New insight has been gained over the last 10 years regarding the physiological capabilities of mountain bike riders. It has been demonstrated that these athletes have higher workload demands when compared to road cycling athletes (Hamilton et al. 2002; Lee et al. 2002; Stapelfeldt et al. 2004), which might be attributed to a strong focus on hill-based training, coupled with intense and repeated isometric contractions of arms and leg musculature during training and competition (Impellizzeri et al. 2005a,b; Impellizzeri and Marcora

2007; Macdermid et al. 2014; Novak and Dasmbe 2014). Physiological testing has also identified possible predictors of riding performance, for example, peak power output obtained during a cycle test was associated with actual racing times (Hurst and Atkins 2005; Impellizzeri et al., 2005a,b).

The hormonal and psychological responses of athletes during a competition are closely related to physical performance in different sports, particularly those involving individual modalities such as tennis (Filaire et al. 2009), golf (Kim et al. 2009) and hockey (Aguilar et al. 2013). These studies suggested that higher cortisol and/or lower testosterone levels, along with greater anxiety, can lead to (or reflect) poor performance. Sperlich et al. (2012) monitored the salivary cortisol, heart rate and blood lactate responses of elite mountain-bike riders during a downhill event. They reported higher heart rate and blood lactate during this event compared to a qualification day. However, no performance data were collected. Recently, Arslan and Aras (2016) compared the cardiac autonomic response between cyclist and triathletes before exercise, and no significant difference in any index was found. To our knowledge, no other data are available to characterise the psycho-physiological responses of mountain bike riders, whilst also linking these profiles to actual cycling performance.

In many sports, athletes that differ in training experience and/or competitive background often present different physiological and psychological profiles (Kim et al.,

Figure 1. Schematic diagram of experimental procedures

2009; Ooi et al. 2009; Torres-Unda et al. 2013). To our knowledge, only one study has evaluated the physiological profile of downhill mountain bike riders from this perspective (Burr et al. 2012). The authors found a higher oxygen consumption (VO_2) and rating perceived exertion (RPE) during an incremental exercise test in those athletes with more training experience. To explain their findings, the authors suggested that more experienced and thus skilful riders might exhibit a stronger willingness (and ability) to seek out more difficult cycling terrains.

Therefore, the present study was undertaken to describe the performance and psycho-physiological responses of mountain bike riders during aerobic and anaerobic cycle testing. To further evaluate the influence of training and competitive experience, the groups were separated into high, moderate, and low experienced riders. We hypothesized that the high experienced riders would exhibit superior performance abilities during anaerobic (i.e. higher power peak) and aerobic (i.e. higher power average) testing, accompanied by different psychological and physiological responses (i.e. lower anxiety and cortisol, higher cardiac modulation), than the moderated and low experienced groups.

Materials and methods
Participants
Nineteen male bike riders, competing in cross-country (n = 7), downhill (n = 7) and enduro (n = 5) disciplines were recruited for this study. Based on self-reported training and competitive experience, the participants were broadly separated into 3 groups: high, moderate and low experienced. The high experienced group (n = 6) were racing in professional categories at a national and/or international events, whilst the moderate experienced group (n = 6) were competing only at local events. Both high and moderate experienced riders had more than 3 years experience on mountain bike race. The low experienced group (n = 7) had less than 3 years experience on mountain bike and were racing at local events. The descriptive characteristics of each group are outlined in the Table 1. After ethics approval by the local

University Research Ethics Committee in accordance with the Helsinki Declaration, the experimental protocols were explained and consent was obtained from each participant.

Experimental design
This study was conducted in 2 parts, each performed on separate days (Figure 1). In the first visit, anthropometric data were taken and trait anxiety assessed, followed by exercise testing to evaluate the rider's maximal oxygen consumption (VO2max). They returned to laboratory after 48-72 hours of recovery to complete a 30 s anaerobic test (Wingate test) and a 20 min aerobic time trial test. These tests were separated by 30 min rest period. Heart rate variability (HRV), state-anxiety and salivary testosterone and cortisol were measured before Wingate testing, with HRV and hormones reassessed after 20 min time trial test. Measures of cycling power and ratings of perceived of effort (RPE) were also taken. All testing was performed between 5 pm and 7 pm to minimise the influence of circadian variation (Armstrong et al. 2011; Hayes et al. 2010). The participants were instructed to refrain from caffeine, alcohol and any strenuous exercise in the previous 24 hours (Martin and Pangborn 1971). Food intake was not strictly monitored, but the participants were instructed to avoid eating at least 1h before the second visit, to reduce the effect of food intake on salivary hormones (Papacosta and Nassis 2011).

Visit 1: Baseline testing
Anthropometric measures
Height was measured to the nearest 0.1 cm with a wall stadiometer, whilst the participant stood barefoot with their heels touching the wall. Body mass was measured to the nearest 0.1 kg, with a minimum of clothing, using a digital calibrated scale (Mersey Weight Ltd, Ellesmere Port, UK). Body fat percentage was estimated from 7 skinfold measures (i.e. triceps, subscapular, chest, abdominal, suprailiac, thigh and calf) using the Jackson and Pollock (1978) equation.

Trait-Anxiety
The Sport Anxiety Scale (SAS-2; Smith et al. 2006) was used to evaluate the stress state of the athletes. This instrument has 3 subscales (i.e. somatic anxiety, worry and concentration disruption) and each one consists of 5 items. The athletes answered questions such as: "I lose focus on the game"; "I worry that I will not play well". Previously, was explained that the word game should be undertaken as a mountain bike competition. For each

item, participants indicated how typically they felt based on a 4-point Likert scale, ranging from 1 = not at all to 4 = very much. Subscales scores were derived calculating sum of scores on the individual items for each subscale with a total ranging from 15 to 60 points.

Maximal Oxygen Consumption
The VO_{2max} of subjects was evaluated using an incremental ramp test on a cycle ergometer (Lode Excalibur, Groningen, The Netherlands). The protocol started with 5 min cycling warm-up without load. Work-rate increased by 25Watts each minute until the participant was unable to continue the test. The participants cycled at a self-selected pedal rate, which remained constant throughout the test (60-90 revolution per min). Expired gas was measured breath-by-breath throughout the test by a spirometry system (MetaLyzer 3B, Cortex, Leipzing, Germany). The VO2max was expressed as oxygen uptake per kilogram of body mass each minute (ml/kg/min).

Visit 2: Anaerobic and Aerobic cycle testing
Anaerobic test
The 30-s Wingate test is widely used to determine anaerobic peak power and anaerobic capacity (Coppin et al. 2012). This test was performed on an air-braked ergometer with a fan resistance level and magnetic brake (Wattbike Ltd, Nottingham, UK), presenting a high reliability in cyclists (Bellinger and Minahan, 2014). The participants were instructed to pedal as fast as possible against no resistance whilst remaining seated. Verbal encouragement was provided throughout the test. Before the measured trial, a 5 min warm-up with a frictional load equal to 1.kg using a self-selected cadence was performed, with an additional 5 min cool-down after the sprint trial. The software recorded mean peak power during the test period.
Aerobic test
The aerobic time trial test was performed on the same ergometer used for anaerobic testing. This test involved a 20 min continuous time trial whilst trying to maintain the highest possible power output (PO) relative their body weight (i.e. functional power threshold). This test was chosen because it closely resembles a normal training session for mountain-bike riders (Inoue et al. 2016). The ergometer was interfaced with a software to calculate the average power and cadence every second. For both tests, the ergometer settings were individually adjusted to allow each cyclist to replicate the position they typically assume on their personal bike.

Psycho-physiological measures
Heart rate variability
Participants were fitted with a heart rate monitor (Polar ® RS800CX, Kempele, Finland) and after a 2 min customisation period, beat-to-beat heart rate was continuously recorded during a 10 min period, as they rested in a seated position (Leicht and Allen 2008). All time series (R-R) were extracted on a Microsoft ® Windows compatible computer with a processing software (Polar Precision Performance, Polar Electro, Kempele, Finland). Text files were then analysed in the

time and frequency-domains after automatic removal of occasional ectopic beats (Kubios, BSAMIG, Kuopio, Finland). The validity of this equipment for assessing R-R intervals has been reported previously (Gamelin et al. 2006). Heart rate data were collected for 10 min before testing (pre-test) and 10 min after exercise (post-test). The 10-min sampling time is a recommended standardised protocol for assessing resting HRV (Young and Leicht 2011). The time domain measures were analysed, based on the root mean-square of successive RR intervals difference (RMSSD), using the last 5 min of data in each period of monitoring. The RMSSD index was chosen as it represents short-term HRV variability, especially vagal modulation (Task Force, 1996; Buchheit et al. 2007) and is widely used in exercise physiology (e.g. Oliveira et al. 2013; Plews et al. 2014).

Salivary hormones
Saliva samples were collected with participants seated, with their head tilted slightly forward. Unstimulated samples were provided by passive drool 5 min before the 30 s Wingate test and 5 min after 20 min time trial test, equalling a sampling period of approximately 60 min. These were collected in 5-mL sterile containers and stored at -80°C until assay. After thawing and centrifugation, testosterone and cortisol concentrations were measured in duplicate using a commercial assay kit (Salimetrics). All samples were tested within a single assay plate. The testosterone assay had a detection limit of 6 pg/ml with intra-assay coefficients of variation (CV) of 6.3%. The cortisol assay had a detection limit of 0.12 ng/ml with intra-assay CV of 7.7%.

Perceived exertion
A rating of perceived effort (RPE) (Borg, 1982) was taken before the 20 min time trial test and during exercise at 2 min intervals. The RPE values ranged from 6 to 20 corresponding to the perception of "very, very light intensity" (RPE= 6) up to "very, very hard intensity" (RPE=20). These data were taken verbally by the lead investigator.

State-Anxiety
The revised competitive state anxiety inventory-2 (CSAI-2R; Cox et al. 2003) was administered before the testing session to estimate the athletes' cognitive and somatic anxiety, as well as self-confidence levels. The CSAI-2R contains 17 items scored on a 4-point Likert scale (1 = not at all and 4 = very much so) that corresponds to how the athlete feels at that particular pointing time. Cognitive anxiety was assessed from 5 items (intensity range: 5-20), somatic anxiety with 7 items (intensity range: 7-28) and self-confidence from 5 items (intensity range: 5-20).

Statistical analysis
The Kolmogorov-Smirnov test was applied to ensure a Gaussian distribution and all variables presented a normal distribution. Subsequently, One-Way analysis of variance (ANOVA) was used to compare the group effect on each measured variables. Where appropriate,

Bonferroni test was employed as a post-hoc procedure. For HRV and salivary hormones, a one-way ANOVA was first conducted on the pre-test values. If no significant difference was found, we conducted a one-way ANOVA on the pre-post change scores. Otherwise, a one-way ANCOVA was employed with pre-test values as a covariate. All data were analysed with SPSS 22.0 statistical software. Significance was set at $P \leq 0.05$. The results are expressed as mean ± standard deviation (SD).

Results

The descriptive, physiological and psychological results are displayed in Table 1. We found no group differences in mean age, anthropometric measures, VO_{2max} or trait anxiety. However, practice time was significantly lower in low experienced group than the high and moderate experienced group (Table 1). The 20 min time trial test performance was higher in high and moderate than low experienced group, whilst 30 s Wingate test performance was higher in the high experienced compared to low experienced ($P < 0.05$). We found no significant group differences in competitive state anxiety, or any of the somatic, cognitive and self-confidence subscales.

Table 2 shows the RMSSD and hormonal responses. We found a significant negative shift in RMSSD within each group tested ($P < 0.05$). ANCOVA testing revealed a significant group effect with the high experienced cyclists producing greater withdrawal of vagal activity indicated by RMSSD response than moderate and low experienced riders ($P < 0.001$). A positive pre- to post-test change in testosterone and cortisol levels was noted in the high and moderate experienced groups, respectively ($P < 0.05$). Following ANOVA testing, we found no significant group differences in the testosterone ($P = 0.994$) and cortisol ($P = 0.343$) responses.

As expected, HR during the 20 min time trial test significantly increased ($P < 0.05$) over time compared to baseline measurements in each group (Figure 2a), but no group differences in HR were identified at any time point ($P > 0.05$). Likewise, RPE significantly increased in each group over time when compared to baseline ($P < 0.05$) (Figure 2b). Significant group differences in RPE were noted from the 10 min period up to 20 min, with higher values reported by high experienced compared to low experienced riders ($P < 0.05$). The mean cadence during the 20 min time trial are reported in Figure 3. The low experienced group presented a significant lower cadence than high and moderate experienced groups ($P < 0.05$).

Table 1. Descriptive and cycle testing profiles of mountain bike riders groups (mean ±SD).

	High (n =6)	Moderate (n = 6)	Low (n =7)	P
Descriptive				
Training (years)	13.6 ± 8.7	8.5 ± 6.6	1.7 ± 0.7[a]	0.012
Age (years)	29.5± 8.7	30.2 ± 8.9	26.3 ± 8.5	0.693
Height (cm)	1.78 ± 0.1	1.78 ± 0.01	1.81 ± 0.1	0.755
Body mass (kg)	77.4 ± 11	81.4 ± 7.6	68.1 ± 10.8	0.074
Body fat (%)	15.8 ± 5.2	18.8 ± 4.7	12.2 ± 5.6	0.104
VO_{2max} (ml/kg/min)	52.5 ± 7.1	52.2 ± 5.7	45.4 ± 8.2	0.121
Trait anxiety (score)	28.2 ±4.6	26.2±6.2	30.1 ± 6.2	0.478
Cycle testing				
Somatic anxiety	11.3 ± 2.8	9.17 ± 3.4	12.7 ± 4.1	0.201
Cognitive anxiety	9.17 ± 1.7	9.17 ± 3.6	11.4 ± 3.4	0.328
Self- confidence	14.7 ± 3.0	13.5 ± 2.1	12.1 ± 1.1	0.138
Wingate peak power (W)	1283 ± 223	1071 ± 249	791 ± 203[a]	0.004
Time trial mean power (W/kg)	272 ± 29	239 ± 50	146 ± 45[a,b]	0.000

Note: [a]Significantly different from the high experienced group P <0.05; [b]Significantly different from the moderate experienced group P <0.05.

Table 2. Autonomic and hormonal profiles of mountain bike riders groups before and after the cycle testing (mean ± SD).

|	High (n = 6)	Moderate (n = 6)	Low (n = 7)
RMSSD			
Pre (ms)	67.2 ± 26.4	34 ± 11.5[a]	32.1± 11.1[a]
Post (ms)	9.2 ± 3.6*	9.6 ± 3.7*	13.2 ± 8.4*
Change (ms)	58.05 ± 25.3	24.4 ± 10.1[a]	18.9 ± 10.5[a]
Testosterone			
Pre (pg/ml)	402 ± 92	372 ±96.2	493 ± 283
Post (pg/ml)	620 ± 130*	591 ± 292	727 ± 574
Change (pg/ml)	217.4 ± 172.5	224.8 ± 261.9	233.3 ± 305. 7
Cortisol			
Pre (ng/ml)	9.0 ± 4.6	4.9 ± 1.9	8.1 ± 2.7
Post (ng/ml)	11.6 ± 3.3	11.6 ± 5.1*	10.1 ± 7.0
Change (ng/ml)	2.6 ± 5.5	6.6. ± 5.1	3.6 ± 5.3

Note: RMSSD= root mean-square of successive RR intervals difference. [a]Significantly different from the high experienced group P <0.05, *Significantly different from pre-test P <0.05

cadence than high and moderate experienced groups ($P < 0.05$).

Discussion

The main finding of this study was that high experienced mountain bike riders presented elevated autonomic cardiac activity compared to low experienced riders. We identified differences between the high and low experienced riders in terms of cycling power and perceived exertion. No group differences in the remaining measures variables (e.g. anthropometric, oxygen consumption, trait and state anxiety, salivary hormone response) were identified.
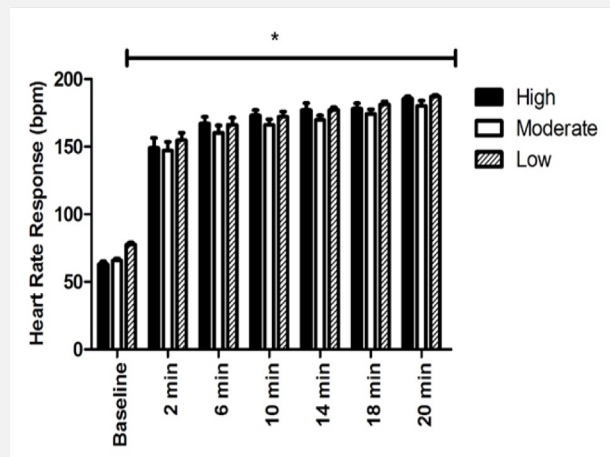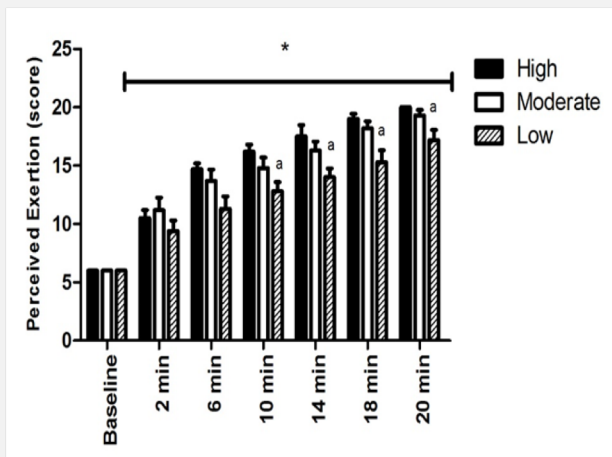
Figure 2. Heart rate response (2a) and perceived exertion (2b) across the time trial test. Note: bpm= beat per minute. [a]Significantly different from the high experienced group P <0.05. *Significantly different from baseline condition P <0.05.

As expected, the performance outputs during 30 s Wingate and 20 min time trial testing were generally higher in those athletes with greater training experience in mountain biking (high and moderate experienced group) than those with lesser experienced (low experienced group). In the 20 min time trial test, the highest PO produced by the high experienced riders (272 Watts) was however much lower than that PO reported previously for mountain bike riders (Impellizzeri et al. 2005a,b; Lee et al. 2002). In the cited work, the athletes produced a peak PO of 392 ± 35 Watts during an incremental maximal cycling test (Impellizzeri et al. 2005b), with another value of 360 ± 29 Watts reported elsewhere (Impellizzeri et al. 2005a). In work by Lee et al. (2002), cross-country athletes also reported higher PO (358±34 Watts) during a 30 min lab-based time trial. Macdermid et al. (2006) demonstrated a higher PO (398 ±27 Watts) taken by self-paced time trial in seven competitive endurance trained cyclists. Recently, Novak et al. (2017) tested cross-country riders in an incremental exercise test until exhaustion; and the riders produced a maximal aerobic output (MAP) 351±35 Watts. The divergent results might be explained by differences in the cycling protocols, the ergometer used, and overall training experience.

In support of the current study, Baron (2001) compared anaerobic and aerobic PO of national-international mountain bikers and sport science students. In terms of aerobic power (normalized by body mass), the athlete groups produced higher maximal power (5.5 ± 0.4 W/kg) than the control group (4.3 ± 0.7 W/kg). In addition, the average PO during a 10-sec cycle test was higher in the athletes ($IsoW_{peak}$ = 14.9 ± 1.1) than the controls ($IsoW_{peak}$ = 13.3 ± 1.4). Although these results
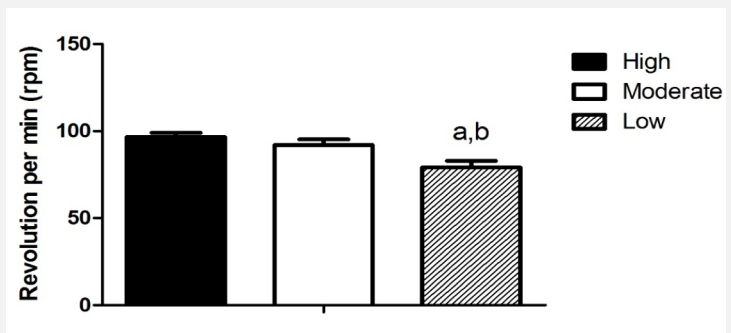

Figure 3. Mean cadence during the 20-min time trial testing. [a]Significantly different from the high experienced group; [b]Significantly different from the moderate experienced group P<0.05.

cannot be compared directly with the current study, they do confirm that those individuals with more training exercise also produce greater PO when assessed in a sport-specific exercise. In agreement with Baron (2001), the high experienced athletes in this work also produced greater anaerobic PO (1283.2 Watts) than the low experienced group (791 Watts).

The high experienced group in the current study presented a lower sympathetic tone demonstrated by a higher RMSSD value at rest and pre- test (67.2 ms) than both moderate (34 ms) and low experienced group (32.1 ms). These results are consistent with previous studies demonstrating that high-level athletes show enhanced vagal and sympathetic modulation of the atrial node (Furlan et al. 1993; Iellamo et al. 2002). This enhancement of vagal activity at rest appears to be related to an increase in aerobic power and actual sporting performance (Iellamo et al. 2002; Oliveira et al. 2013). Our results corroborate these findings, whereby the high experienced athletes presented both higher

vagal activity and better performance during the aerobic cycling test.

Training experience was also associated with differences in cadence and RPE results during the 20 min time trial test. In regards to mean cadence, our results agree with other reports highlighting that more experienced cyclists tend to select higher cadence compared to less experienced and/or non-cyclists during laboratory testing (Marsh and Martin 1993, 1997). The more experienced riders (high and moderate experienced groups) reported greater physical exertion than less experienced (low experienced group), but only in the final 10 min of the 20 min time trial test. Similarly, Buur et al. (2012) found that training experience in downhill mountain bike riders was strongly associated with subjective demands (RPE) post a representative downhill ride.

The more experienced riders presented a higher PO, higher cadence and RPE results compared to novices, although the higher PO not reflected a higher HR response. Conversely, other studies found an association between higher cadence with an improvement in the cardiac response (Gotshall et al. 1996) and a lower RPE response (Löllgen et al. 1979). It is possible that the more experienced riders presented a willingness to push themselves harder that the less experienced riders, as suggested by Burr et al. (2011).

The hormonal changes in testosterone and cortisol concentrations play an important role regarding the metabolism over the recovery duration after exercise (Kramer et al. 2005). We found no hormonal differences between the 3 groups, either in baseline levels or session responses. In Hoogeveen and Zonderland (1996) study, both testosterone and cortisol levels were increased immediately post an incremental cycling test protocol in ten male road cyclists. No studies have compared the hormonal responses of different levels of experience in mountain bike riding across different tests. Training background (Ahtiainen et al. 2004) and experience (Kraemer et al. 1992) can both regulate the acute testosterone responses to exercise workouts. As an example, strength athletes had elevated testosterone concentrations after maximal and forced squats repetitions than non-athletes (Ahtiainen et al. 2004). Whereas subjects with more than 2 years of weightlifting experience had larger testosterone increases than subjects with less than 2 years experience (Kraemer et al. 1992). Similarly, highly-trained runners had a drop in testosterone levels following a 400 meter sprint, whereas regional runners had a rise in testosterone (Slowinska-Lisowska and Majda 2002). Athletes have also been shown to produce divergent hormonal responses to the same exercise stimulus (Beaven et al. 2008), perhaps explaining why no differences or changes were identified herein.

The anxiety sub-scales (cognitive, somatic and self-confidence) were similar for the 3 groups, which differs from other work. For instance, elite athletes in karate (Soltani and Reddy 2013) and soccer (Reilly et al. 2000) exhibited lower cognitive and somatic anxiety, and higher self-confidence, compared to non-elites in the pre-competition period. In junior male golfers (Kim et al. 2009), those athletes classified as elites exhibited lower cognitive anxiety and higher self-confidence compared to non-elites; however, no difference in somatic anxiety were found. These contradictory results might be due to factors such as the environmental conditions, the sport played and personality factors.

One limitation of this study is the collection of data that was not testing in the field setting, so comparisons with field studies are difficult. However, this approach did allow us some control over other confounding variables such as the hormonal and autonomic variables and the power outcomes. The groups were based by self-reported riding experience, a common tool used previously in cycling studies (Buur et al. 2012; Zabala et al. 2016), however the procedure can be a potential limitation. Other limitation include the small sample size (per group), the pooling of athletes across different mountain biking disciplines, and the self-reporting of cycling experience. Nevertheless, we are the first study to compare the psycho-physiological responses of mountain biker riders that differ in training experience and across 2 relevant tests of cycling performance.

In conclusion, more experienced mountain bike riders exhibited greater performance during 30 s Wingate and 20 min time trial testing, which was accompanied by higher perceived exertion and greater vagal activity than less experienced riders. Thus, the experience in training and competition may be expressed in terms of better cycling performance, along with corresponding changes in physiological (vagal activity) and psychological (perceived of exertion) response.

Practical Applications

Our results can assist researchers, coaches and athletes in terms to identifying key factors (trainable or non-trainable) that may discriminate between high and low experienced mountain bike riders. The information about the psycho-physiological measures can be used as part of training planning, especially with low experienced riders, as a purpose to achieve their best performance. The results of this study can also improve to update the literature regarding the mountain bike riders profile with different levels of experience.

Conflict of interest

The authors report no conflicts of interest.

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