Journal of Physical Education and Sport ® (JPES), 17(1), Art 53, pp. 361 - 366., 2017
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Air ventilation effects during the stationary roller bicycle test

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Published online: March 31, 2017
(Accepted for publication February 26, 2017)
DOI:10.7752/jpes.2017.01053

Abstract:
Problem Statement: The aim of our study was to analyse the influence of body cooling through fan airflow, in acute physiological responses of elite cyclists during a maximal progressive exercise with four stages. Approach: Nine male cyclists, from the sub-23 and elite category (average age, 26.11 ± 5.11 years-old; average weight, 68.69 ± 7.28 kg; average height, 172.87 ± 3.53 cm) performed, in random order, two discontinued maximum cycling tests with progressive increments: one with fan airflow ~10km/h-1 (~3m.s-1), and the other without it, with an initial load of 150 Watts (W), and an increase of 50 Wevery 6-minute long stage, until exhaustion. In both test conditions, the heart rate (HR), oxygen consumption (VO2), blood lactate concentration [La], tympanic temperature (TT), and rating of perceived exertion (RPE), were measured. Results: When the test conditions were compared, no significant differences were found between the stages for HR and RPE. Significant differences were noted for La, only at the 4th stage of the test (p=0.008). The VO2max was significantly different between the protocols (p=0.004), with significant variations at stage 2 (p=0.033), and 3 (p=0.028). TT was significantly lower (p<0.05) during all the four stages of the protocol. With the exception of HR, all the registered maximum values were significantly different (p>0.05) between the two test conditions and were achieved in the stage in which each subject reached VO2max. Conclusions: The speed of airflow at ~10 km.h-1 does seem to induce significant variations in the acute physiological responses of elite cyclists, as seen during a discontinued maximal progressive cycling test.
Key words: cycling, body temperature, performance, oxygen consumption..

Introduction

Athletic performance results from the influence of multiple individual characteristics that in a greater or lesser degree, are required to excel in a given sport. Many of such traits (e.g. aerobic power, explosive strength or anaerobic capacity), apart from the effects of genes,' inevitably require a rigorous training and control regimen, particularly the selection of the best training load for a specific sport or activity (Costa et al., 2012).

Nowadays, sports training professionals use different devices for training control in an increasingly widespread way (Gardner, Martin, Martin, Barras, & Jenkins, 2007; Halson, 2014; Mroczek, Kawczynski, Superlak, & Chmura, 2013), particularly the portable and easy-to-use ones. The development and improvement of practical and accessible evaluation methods to accurately measure performance are thus issues of high interest for creating individual workout plans. However, training intensities are mostly determined under highly controlled conditions of laboratory testing with low ecological validity. As it comes to cycling, there are multiple real-time factors that interact with the performance. Weather conditions (Hayes, Castle, Ross, & Maxwell, 2014), road surface (Martin, Milliken, Cobb, McFadden, & Coggan, 1998) and altimetry (Menaspà. Abbiss, & Martin, 2012 are a few examples of variables that can limit performance and endanger the reliability of the parameters recorded. Furthermore, the absence of air-flow in the laboratory evaluation can probably affect the body thermoregulatory effectiveness, the heart rate response and, may lead to an inaccurate performance evaluation (Júnior & Denadai, 1996).

It has been well-established that more than 75% of the metabolic energy released during exercise by active muscles is converted into heat (Wenger, 2003). Thus, an air conditioner is crucial to maintain an ambient temperature around 19şC to 23şC, suitable to ensure good body core temperature. Nevertheless, even with a suitable room temperature, the effective control of body core temperature is considerably more complicated when performing a stationary exercise (such as for stationary rollers) (Van Schuylenbergh, Vanden Eynde, & Hespel, 2004a). In fact, in 15 to 20 minutes of intense exercise, the body's core temperature can reach values of

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concern, imposing a hyperthermia state, which can trigger fatigue symptoms and the early discontinuation of exercise (Gleeson, 2002). As in outdoor exercise, an inappropriate temperature along with high relative humidity may further exacerbate the problem. High humidity and dehydration are linked to a reduction of heat loss by sweat evaporation, which consequently causes an increase of body's core temperature and a rapid decline in performance (Galloway & Maughan, 1997; Wendt, van Loon, & Lichtenbelt, 2007). Périard et al. (2011) stated that a thermal strain on cardiovascular function is associated with reductions in sustainable power output and peak oxygen uptake during self-paced exercise in the heat. Thus, heat dissipation mechanisms are essential to permit good athletic performance.

The data presented by Ganio, Wingo, Carroll, Thomas, and Cureton (2006) are also in agreement, showing that exercising in high ambient temperatures (30şC) leads to a reasonable stage of dehydration and cause a decrease of around 9% in VO_{2max}. Testing at higher room temperatures (30°C) with no air ventilation around the body impairs evaporative and convective heat dissipation, which can lead to significant changes in the physiological responses.

How physiological performance varies as the environment shifts between suitable environment-ventilation and none air ventilation during a maximal isometric exercise is not clarified by the literature. Ventilation appears to be crucial in cycling stationary indoor exercises to secure proper heart rate training thresholds and metabolic load. Van Schuylenbergh, Vanden Eynde, and Hespel (2004b). also demonstrated that it is difficult to predict thresholds during a stationary progressive cycling test indoor without ventilation. Other study reported that at 24şC room temperature, an airflow at 32km.h-1 can deeply affect many thermoregulation variables, but an airflow of less than 16 km.h-1 didn´t seem to have a significant impact on heart rate response (Buono & Wilson, 1999).

Therefore, we aimed to compare the acute physiological (cardio-respiratory, lactate accumulation and tympanic temperature) and perceptual responses of elite cyclists when performing a maximal progressive exercise in two different environment-related conditions to thermoregulation effectiveness (with and without body cooling through fan airflow).

Materials & methods

Subjects

The study sample consisted of nine elite male triathletes (26.11 ± 5.11 years-old; 68.69 ± 7.28 kg; 172.87 ± 3.53 cm), who participate regularly in National and International level competitions. All individuals were warned about the risks and benefits of graded cycling test, and signed a term of informed consent that had been approved by local sport sciences research ethics committee and carried out according to the Helsinki Declaration. It was also cautioned not to participate in high intensity training or competitions at least two days before the stationary cycling tests, in order to avoid accumulated fatigue. Likewise, drugs and alcohol intake were restricted, and the ingestion of food and caffeine was not allowed three hours before testing. The athletes were also instructed to maintain their regular diet routine.

Testing procedures

Each subject participated, while hydrated, in two testing sessions (with and without body cooling through fan airflow), in random order, conducted with one-week interval from each one. All tested triathletes used the same classic racing bicycle (Swork´s, Specialized Bicycle Components, USA) positioned over a stationary roller (Tacx Flow, Wassenaar, Netherlands), equipped with a potentiometer SRM Training System (Schoberer Rad Messtechnik, SRM GmbH, Hauptniederlassung, Germany). Room temperature was kept between 21 and 23°C and humidity between 50% and 60%, to enable a proper heat dissipation (Kunduracioglu, Guner, Ulkar, & Erdogan, 2007).

For the testing session with air ventilation, a portable anemometer was placed on the handlebar (brand Xplorer, model SkywatchXplorer 3, JDC Electronic, Yverddon-les-Bains, Switzerland) to control wind speed. To create cooling, a 360 W fan (Equation, model VAP-905, LM-Maya Yapi Marketler A.S, Besiktas, Istambul, Turkey) was used with the following characteristics: 0.765 meters (m) of high, 0.77 m of width, 0.21 m of deep, 22.247 Kg of weight. The air-flow speed was set to $10Km.h^{-1}$ ($\sim 3m.s^{-1}$) (Van Schuylenbergh, Vanden Eynde, & Hespel (2004b).

Subjects were provided water ad libitum throughout the trials with the total volume consumed recorded for each experiment. Fluid ingestion did not differ when comparing trials.

The tympanic temperature (bilateral) was assessed in both testing situations (twice before warm-up, one right after the end of each test stage and another one minute after testing) with a digital thermometer Omron Gentle Temp 510 (Omron Healthcare Corporation LTD, Kyoto, Japan)[17]. For hygienic and equipment precision reasons, the protection layer was changed after every use (Moran, 2002). According to Heusch & McCarthy[20], the head's position seems to effect data acquisition, thus TT was measured with the athlete sitting down and with his head in neutral position (Frankfurt plane), while the evaluator, whose task was placing the thermometer in the most profitable position, was obliged to do an otoscopic manoeuvre, which consisted on pushing the athlete's ear upwards and backwards (Heusch & McCarthy, 2005).

Blood lactate concentrations were measured at rest and repeated at one, three and five minutes after the exercise protocol. Capillary blood samples were collected from the earlobe and the blood lactate concentration was determined using a handheld Lactate Pro meter (Lactate Pro, Arkray Factory, Inc, Shiga, Japan).

Ventilatory pattern was assessed with a portable gas analyser device (Cosmed® K4b2, Roma, Italy) (Duffield, Dawson, Pinnington, & Wong, 2004). The expired gases were collected breath-by-breath, and then averaged for 15 seconds intervals (Aisbettm & Le Rossignolm, 2003); then, the average values for each minute were calculated. The stabilization of the oxygen consumption (VO_2) was established when the variation in oxygen uptake was less than 2.1 ml.kg-1.min^{-1} in four consecutive values of 15 seconds (Whipp & Rossiter, 2005). Time delay and reference air calibration of the device was performed before each stationary cycling test using a gas sample with a 16% of O_2 concentration and 5% of CO_2 concentration. The flow meter was also calibrated before each testing with a 3000 ml syringe, according to the manufacture recommendation.

The heart rate was also continuously monitored and recorded by a wireless double electrode (Polar Electro, OY, Finland) (Millet, Tronche, Fuster, Bentley, & Candau, 2003). The data was obtained beat-by-beat and then averaged in 15 s intervals.

Rating of perceived exertion (RPE, Borg's CR-10 scale) was also used as a measure of intensity after each protocol stage during the maximal discontinuous cycling test protocol.

All anthropometric measurements were assessed according to international standards and prior to any physical performance test. Body weight was measured on subjects in light clothing and without shoes to the nearest 0.1 kg using a mechanical scale (SECA®, model 841, Germany) and height was measured to the nearest 0.1cm with a stadiometer (SECA®, model 214, Germany). The percentage of body fat was assessed using a bioelectrical impedance device (Omron, model HBF-303, Matsusaka, Japan), according to manufacture evaluation assumptions.

Maximal discontinuous cycling test protocol

The triathletes were submitted to a progressive cycling test, 6 minutes long for each stage, having 150 W as initial load and then increasing for 50 W each stage (Amann, Subudhi, & Foster, 2006; Kunduracioglu et al., 2007), until reaching volitional exhaustion. The tests were taken at random order. This cycling test was discontinuous, with recovery intervals individually defined according to VO_2 values measured in resting state before the test.

The pedaling cadence was freely chosen in the first lab test, because it does not interfere with the maintenance of power[27]_ENREF_20. However we advised the triathletes to maintain the same cadence for the second test (Van Schuylenbergh, Vanden Eynde, & Hespel, 2004b). Equally, the gear ratio was selected by each cyclist. The test was considered valid if one of the following criteria was met: (1) heart rate within 10% of the predicted maximum; (2) a clear plateau in oxygen uptake, (3) respiratory exchange ratio equal or above 1.15.

No unusual or regular physical efforts were performed for at least 12 hours before testing. Likewise, drugs and alcohol intake was restricted, and the ingestion of food and caffeine was not allowed three hours before testing.

Statistical analysis

All data was analysed using SPSS 19.0 (IBM©, USA). Standard statistical methods were used for the calculation of means, standard deviations, minimum and maximum values. The normality of all distributions was verified using Shapiro-Wilks tests, and non-parametric procedures were adopted because of the rejection of the null hypothesis (H0) and the very low value of the N (i.e., N < 30). To compare data obtained in the two tests, Wilcoxon signed rank test was used to compare the values obtained by each subject in both test situations. Statistical significance was accepted at $p \leq 0.05$ for all analysis.

Results

The anthropometric measurements and basal conditions of the triathletes evaluated before the stationary bicycle tests are described in Table 1.

Table 1. Age, weight, height, body fat percentage (%BF), body surface area (BSA) and baseline data of blood lactate concentration [La], tympanic temperature (TT) at rest in both testing conditions with (Fan) and without air ventilation (Fout) (n=9).

	Age (years)	Weight (Kg)	Height (cm)	BF (%)	BSA (m^2)	[La] (mmol/L)		TT (şC)	
						Fan	Fout	Fan	Fout
$\bar{x}$ ± sd	26.1±5.1	68.23± 7.23	172.87± 3.53	11.66± 2.50	1.81±0.09	1.61±0.37	1.6±0.20	36.34± 0.55	36.33±0.47
min-max	21-29	55.0-78.8	168.4-179	7.0-14.9	1.6-1.9	1-2.1	1.3-1.9	35.4-36.9	35.6-37.1

$\bar{x}$ ±sd, mean and standard deviation

All registered variables during both testing conditions are presented in table 2. Significant differences were noted for VO_2 uptake at stages 2 ($p=0.033$) and 3 ($p=0.028$). The tympanic temperature was significantly higher ($p<0.05$) during all non-ventilated protocol stages. No significant differences were noted for perceived exertion between both testing conditions. With exception of HR, significant differences ($p>0.05$) were found between both testing conditions for all obtained maximum values; these values were achieved in the stage in which each subject reached VO_{2max}.

Table 2. Oxygen consumption (VO_2), heart rate (HR), blood lactate concentration [La], tympanic temperature (TT) and rating of perceived exertion (RPE) in both testing conditions, with (Fan) and without (Fout) air ventilation for each protocol stage (values are the mean±sd) (n=9).

	Stage 1		**Stage 2**		**Stage 3**		**Stage 4**		**Max. values**	
	Fan	Fout	Fan	Fout	Fan	Fout	Fan	Fout	Fan	Fout
VO_2 (ml/kg/min)	42.26 ±5.38	43.62 ±4.16	50.75 ±4.24	53.55 ±4.32	58.12 ±5.27	62.37 ±5.07	64.99 ±5.53	67.87 ±6.75	70.55 ±8.70	64.36 ±6.23
	p=0.305		p=0.033*		p=0.028*		p=0.144		p=0.004*	
HR (bpm/min)	140.48 ±14.95	141.74 ±12.74	160.81 ±14.86	160.30 ±14.03	177.59 ±12.09	176.33 ±11.20	183.28 ±10.12	185.50 ±7.05	190.56 ±9.00	190.89 ±7.18
	p=0.644		p=0.831		p=0.379		p=0.347		p=0.061	
[La] (mmol/L)	1.41 ±0.21	1.46 ±0.73	2.31 ±2.25	2.52 ±1.69	6.64 ±2.84	6.88 ±2.74	9.59 ±2.38	10.40 ±2.15	11.19 ±2.08	11.92 ±1.94
	p=0.330		p=0.168		p=0.111		p=0.023*		p=0.008*	
TT (şC)	36.47 ±0.37	36.50 ±0.32	36.70 ±0.30	37.17 ±0.36	37.02 ±0.35	37.49 ±0.24	37.31 ±0.38	37.69 ±0.27	37.49 ±0.37	37.82 ±0.23
	p=0.001*		p=0.005*		p=0.023*		p=0.045*		p=0.001*	
RPE	1.22 ±0.61	1.44 ±0.53	3.11 ±0.93	3.67 ±0.87	6.56 ±1.24	7.33 ±1.02	9.22 ±0.97	9.44 ±0.53	10 ±0.00	10 ±0.00
	p=0.137		p=0.139		p=0.214		p=0.200			

* significant differences ($p<0.05$).

Discussion

This study aimed to compare the acute physiological and perception responses of elite cyclists during a maximal progressive stationary bicycle exercise in two different laboratory-testing conditions -with and without air ventilation. In summary our results showed that an air ventilation apparatus, set to induce airflow at ~10 $km.h^{-1}$, seems sufficient to cause significant changes at most of the physiological parameters assessed. Indeed, the VO_2 values were significantly higher in the non-ventilated test at stage 2 (50.75 ± 4.24 ml/kg/min; p= 0.033), stage 3 (58.12 ± 5.27 ml/kg/min; p= 0.028), and on the ventilated test at the stage, where VO_2max was achieved (70.55 ± 8.70 ml/kg/min; p=0.004). The VO_2 was always lower while testing with air ventilation (except for the last level) (table 2) although it was not significantly different at all stages, perhaps due to the small sample size. With the exception of the HR, all maximum values were achieved in the stage where each subject reached VO_{2max}. The data presented (Ganio et al., 2006; Périard et al., 2011) are somewhat consistent with our results, which shows a significant impact of ventilation over VO_{2max}, [La] and TT. However, our data seem to disagree with the results present by Van Schuylenbergh, Vanden Eynde, & Hespel (2004b) who reported no impact of air ventilation on VO_2 during a constant-load test. It is therefore possible that variations in procedures may explain some of these differences between studies. During a continuous load test (15 to 20 minutes long) the VO_2 tends to decline along with power as the exercise progresses (Ganio et al., 2006). While performing a maximal discontinuous exercise test, VO_2 always increases with the increment of power until the athlete reach exhaustion. We couldn’t found significant changes regarding the heart rate responses between tests, which also does not support the results presented by Van Schuylenbergh, Vanden Eynde, & Hespel (2004b) excepted for the results regarding the maximal lactate threshold on stationary discontinuous cycling exercise.

With induced air ventilation during the maximal cycling test the tympanic temperature was lower in almost all stages of effort. Despite the differences between study protocols, our data seem consistent with the results presented by several authors (Tatterson, Hahn, Martin, & Febbraio, 2002; Van Schuylenbergh, Vanden Eynde, & Hespel, 2004b). It seems that, during a discontinuous protocol cycling test in a stable ambient temperature, the body temperature (tympanic temperature), even slightly affected by the displacement of air caused by the fan, does not interfere significantly in the hearth rate response and in the lactate accumulation. It should be also noted that the tympanic temperature is no more than an average value obtained within the walls of the ear canal (Moran, 2002). As a result, the measurements are often lower than the actual core temperature (Lucia et al., 2004) despite being considered a reliable parameter during exercise even in extreme conditions (Amoateng-Adjepong, Del Mundo, & Manthous, 1999). Nevertheless, future research should seek to record core body temperature changes more accurately.

Regarding the lactate concentration, we can note a tendency to higher values in all stages of effort (particular at stage 4 and also the maximum obtained value, $p<0.05$) during the ventilated protocol. These results are consistent with the data reported by other authors (Périard et al., 2011; Tatterson, Hahn, Martin, & Febbraio, 2002) _ENREF_23showing lower lactate concentrations at fresher environments. An increase in exogenous heat load would have quantitatively less effects in lower power output stages than the greater endogenous heat production resulting from the high power outputs maintained in the last test stages.

Induced airflow during stationary exercise may reduce some discomfort feeling which in turn may positively influence triathletes to perform better. Nevertheless, no significant variation was found between both conditions, as reported by other authors (Van Schuylenbergh, Vanden Eynde, & Hespel, 2004). The reason for no lactate concentration variability with a reduced power output, lies in the fact that this parameter is highly associated with the heart rate response that in turn remains unaffected by air ventilation <16 km.h-1(Buono & Wilson, 1999). The same argument can be made for the RPE non-significant variation between both procedures. We speculate that, once RPE and heart rate are very similar in both tests, this may indicate an identical state of muscular fibers activation. Nevertheless, there seems to be very slight tendency to lower RPE in all protocol stages and a more abrupt arises during ventilated testing (Périard et al., 2011).

Galloway and Maughan (1997) reported that there is a clear effect of ambient temperature on exercise capacity which appears to follow an inverted U relationship (vertical-axis: exercise capacity; horizontal-axis: temperature). Our results are not strictly comparable since the room temperature was kept stable and we did not measure time to exhaustion. However, our results seem to support the hypothesis that mechanical ventilation during stationary exercise can improve the athlete's thermoregulation effectiveness and, consequently, induce lower energy expenditure. To study the effects of air ventilation on exercise capacity on different ambient temperatures appears to be an important subject for future studies.

Finally we should mention that the fact that our triathletes were adapted to train at warm weather might have caused several physiological adjustments aiming to minimize homeostasis' disturbances due to thermal stress (Fortney & Vroman, 1985). This could also be a strong reason why we did not found more significant variations between both exercise circumstances. For future studies would be very interesting to analyse the physiological responses during static exercise using different airflow velocities and for different ambient temperatures. We were unable to proceed with such study design, which is inevitably a limitation of this study, as well as its reduced sample.

Conclusions

The speed of airflow at ~10 km.h^{-1} seems to be insufficient and inconsistent to induce significant variations in acute physiological responses of elite cyclists during a discontinued maximal incremental cycling test. However, the maximal oxygen consumption reached by the triathletes is significantly higher at the air ventilation condition.

Acknowledgments

This study was supported by grants from the Project of Science and Technology Park of Alentejo - Laboratory of Research in Sport and Health (Alen-07-0262-FEDER-001883) funded by NSRF-INALENTEJO, included in the activity of the following units: "Unit of Sport Physiology and Biomechanics - Development of research activities in the area of Sports Physiology / Exercise" and "Unit for the Physiological assessment and training monitoring".

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