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Effects of acute hypoxia at rest exposure on time trial performance of national category cyclists.

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Abstract: *The aim of this study was to analyze the effects of rest exposure to hypoxia at performance on a simulated cycling time trial (TT) in normoxia cycling. Nine cyclists of national class participated in the study. A single blind, cross-over randomised study in which participants performed two test sessions on two different days in the laboratory was conducted. First, they were exposed to normobaric hypoxia simulating an altitude of 4500 m above sea level (FiO_2=0.09) or normoxia for 30 min. After hypoxia or normoxia exposure, participants performed a 20-min simulated TT. Mechanical performance variables, perceived exertion and economy and gross efficiency (GE) amongs other physiological variables were measured. The results showed that hypoxia exposure did not provoke any changes neither in physiological variables, mechanical performance variables and perception of effort ($p > 0.05$, ES = -0.03 – -0.25, trivial to small), nor in economy and GE ($p > 0.05$, ES = 0.450, small, -0.139, trivial, respectively). The results suggest that a 30-min rest hypoxia exposure does not affect performance in a 20-min simulated TT in a cycle ergometer under normoxic conditions.*

Keywords: Altitude; Hypoxia; Cycling; Physiology; Hypocapnia; Performance.

1. Introduction

Improvements in cycling performance have been found through exposure to hypoxia and training (Garvican et al., 2012; Hahn & Gore, 2001; Hamlin et al., 2010; Mattila & Rusko, 1996; McLean et al., 2014). One of the methods that seem to produce improvements in performance is called "living high-training low" (LHTL) (Levine & Stray-Gundersen, 1997). This technique involves repeated exposure to hypobaric hypoxia while at rest, coupled with training at sea level (Garvican et al., 2012; Hamlin et al., 2010; Mattila & Rusko, 1996; McLean et al., 2014). However, it requires significant logistical and economic resources. The effects of exposure to resting normobaric hypoxia on cycling performance have been analyzed, this method is less expensive and easier to apply by coaches and athletes (Bonetti et al., 2009; Mattila & Rusko, 1996; Mekjavic et al., 2012) . However, there is little scientific evidence on the effects of acute normobaric hypoxia exposure on immediate cycling performance. It has been observed that acute exposure to hypoxia (FiO_2=0.16) can lead to an acute decrease in performance resulting in lower mean power output (11% ± 3%) during a 10 km time trial under these hypoxic conditions (Constantini et al., 2021). Therefore, more studies are needed in this regard with different protocols applications. The aim of the present study was to analyze the effects of 30-minute rest normobaric hypoxia on the physiological, performance, perceived effort, economy and efficiency variables during a simulated cycling time trial.

2. Materials and Methods

The study involved nine national-class cyclists (7 men and 2 women, age: 26.0 ± 3.4 yr). None of the participants had prior exposure to normobaric hypoxia. The study was approved by the Ethics Committee for Research with Human Beings (CEISH) of the University of the Basque Country (UPV/EHU) (NoRefCEid: M10/2017/200). The present study followed the ethical standards set out in the Declaration of Helsinki in 2013.

Design: A cross-blind study was conducted in which all participants performed 2 test sessions on 2 different days in the laboratory. In the first session, participants were exposed to either a protocol of normobaric hypoxia (FiO_2=0.09) or a placebo protocol in normoxia (FiO_2=0.21) for 30 min. Subsequently, participants warmed up for 5 min, after which they performed a 20 min time trial (TT) on a cycle ergometer (Lode Escalibur, Lode®, Groningen, Netherlands). Physiological variables, mechanical performance variables and perceived effort were measured. The laboratory procedure was conducted at an altitude of 539 m, under environmental conditions of 20-22 ºC temperature and 30-35% humidity.

Methodology:

Hypoxia/normoxia exposure protocol

Exposure to hypoxia or normoxia was performed in two sessions. Participants were seated in a chair and fitted with a no-return breathing mask (Hypoxico Biolaster, Biolaster®, Andoain, Spain), connected to a normoxic altitude generator (Hypoxico, Hypoxico, Inc.®, New York, USA) (Wilber, 2001). Participants were exposed to normobaric hypoxia for 30 minutes (Larsen et al., 2014), simulating an altitude of 4500 m above sea level, corresponding to a FiO_2 of 0.09. In the normoxia (placebo) session, FiO_2 was 0.21.

Simulated time trial (TT) in cycle ergometer

Participants performed a 20 min simulated time trial test (Bentley et al., 2001) on cycle ergometer (Lode Escalibur, Lode®, Groningen, Netherlands) in the two sessions (hypoxia session and normoxia session). The power (W) was hidden from the participants to avoid the self-regulation using power in the TT; they were only shown the elapsed time (Borszcz et al., 2018). The average power developed in 20 min was recorded (Bentley et al., 2001). The gas analysis system was calibrated before each test with reference gases using a 1 L syringe (nSpire Koko, nSpire Health Inc.®, Longmont, CO, USA). Values of oxygen consumption (VO_2, L/min) and relative oxygen consumption (VO_2r, mL/kg/min) were obtained. The subjective perception of effort was recorded using the Borg scale "CR10" during the warm-up at minutes 10 and 20 of the TT (Borg & Löllgen, 1998).

Economy and efficiency values

The calculation of the economy variable was calculated as the ratio of average power produced (W) to the mean value of VO_2 during the TT, expressed in liters per minutes (L/min).

Gross efficiency (GE) was calculated as the ratio of the average power produced and the energy expenditure during the TT.

$$GE (\%) = (\text{Average power (w)} / \text{Energy expenditure (J/s)}) \times 100$$

Energy expenditure formule (Brouwer, 1957):

$$\text{Energy Expenditure (J/s)} = [3.869 \times VO_2) + (1.195 \times VCO_2)] \times (4.186/60) \times 1000$$

Statistical Analysis:

Results are shown as mean and standard deviation (SD). The normality and homogeneity of the variances were checked using, Shapiro-Wilk and Levene tests respectively. Student t-test for paired data was used to evaluate the difference in the TT after exposure to normoxia or hypoxia. The effect size (ES) was calculated (Cohen, 1988), and classified as: high (≥ 0.8), moderate (0.8-0.5), small (0.5-0.2), and trivial (< 0.2) (McDonald, 2014). Data analysis was performed using JASP statistical processing software (JASP, JASP Free Project, University of Amsterdam, Amsterdam, Netherlands). Statistical significance was fixed at $p < 0.05$.

3. Results

Table 1 shows the results of the variables collected during the TT after exposure to normoxia or hypoxia. No significant differences were observed in TT performance or in physiological variables ($p > 0.05$, ES = 0.10 to 0.13, trivial), in mechanical performance variables ($p > 0.05$, ES = -0.21, small) and in the perception of effort ($p > 0.05$, ES = -0.25 to 0.21, small) between the normoxia and hypoxia conditions.

The values of economy after exposure to normoxia and hypoxia were 4.4 ± 0.2 W/L/min and 4.5 ± 0.2 W/L/min, respectively, with no significant differences found ($p = 0.214$, ES = 0.45, small). The GE values during the TT after exposure to normoxia and hypoxia were 7.5 ± 1.0% and 7.4 ± 1.0%, respectively, and no significant differences were observed ($p = 0.689$, ES = -0.14, trivial).

Table 1. Results of physiological variables, mechanical performance variables and perceived effort after normoxia/hypoxia exposure.

	After normoxia exposure	After hypoxia exposure	ES	p
VO_2 (L/min)	3.6 ± 0.3	3.6 ± 0.4	0.10	0.770
VO_2r (ml/kg/min)	57.6 ± 4.2	56.8 ± 4.9	0.13	0.707
POWER (W)	273.2 ± 31.8	277.8 ± 33.3	-0.21	0.540
POWERr (W/kg)	4.2 ± 0.4	4.3 ± 0.3	-0.21	0.545
$CR10_{WUP}$	3.1 ± 1.5	2.7 ± 0.9	0.21	0.535
$CR10_{TT10}$	7.0 ± 0.9	7.3 ± 0.6	-0.25	0.464
$CR10_{TT20}$	9.0 ± 1.0	9.1 ± 0.8	-0.17	0.608
$CR10_{TTmean}$	6.3 ± 1.0	6.4 ± 0.6	-0.03	0.923

*VO_2: average values of oxygen consumption during the time trial. WUP: values in the warm-up prior to the time trial. VO_2r: average values of oxygen consumption relative to body mass during the time trial. **POWER**: average power of the time trial. **POWERr**: average relative power of the time trial. $CR10_{WUP}$: values of rate of perceived exertiondurnig warm up of TT. $CR10_{TT10}$: values of rate of perceived during min 0 and min 10 of TT. $CR10_{TT20}$: values of rate of perceived during min 10 and min 20 of TT. $CR10_{TTmean}$: average values of $CR10_{TT10}$ and $CR10_{TT20}$. **ES**: effect size.*

No significant differences were found in energy expenditure during the TT after exposure to normoxia or hypoxia (3613.8 ± 181.6 vs. 3750.3 ± 338.1 J/s, $p > 0.250$, ES =0.41, small).

4. Discussion

No significant differences were observed in the physiological, mechanical, perception exertion, economy, GE and energy expenditure variables in TT after exposure to hypoxia or normoxia in the present study. Some studies about hypoxia and performance impairment have shown that exposure to acute hypoxia leads to losses in performance in cycling TT under this conditions (Constantini et al., 2021; Płoszczyca et al., 2021) and GE values on hypoxia cycling performance (Clark et al., 2007; Noordhof et al., 2013). Therefore, it appears that acute hypoxia at rest did not affect immediate TT cycling performance under normoxic conditions. While previous studies have shown that exposure to hypoxia can influence factors related to VO_2 in athletes (Wehrlin & Hallén, 2006) and in cycling performance in TT under hypoxia conditions (Constantini et al., 2021; Płoszczyca et al., 2021)[redacted]the present study did not find any differences in VO_2 variables in TT in normoxia after exposure to hypoxia, despite methodological differences. This result may be explained by the "compensatory effect of exercise" on acute cardiorespiratory responses to hypoxia exposure (Constantini et al., 2021) . Hypoxia exposure has shown modifications in values of GE in cycling, explained mainly by the loss of power (van Erck et al., 2019), in the present study the absence of effects on these variables could be for the same values of POWER and VO_2 between TT in normoxia and hypoxia. Based on the results of this study, it can be concluded that exposure to hypoxia at rest (FiO_2= 0.09) for 30 minutes does not influence subsequent performance in 20-min TT under normoxic conditions.

.5. Practical Applications.

In the present study the methodology used does not show improvements or decreases in performance after exposure to acute hypoxia. Exposure at rest to acute hypoxia does not seem to influence performance values during subsequent cycle ergometer TT under normoxia. Additionally, the use of normobaric hypoxia in training may have potential for improving performance. Thus more studies are needed to evaluate the usefulness of acute exposure to hypoxia for the improvement of subsequent performance on a 20 min TT in cycling.

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Conflicts of Interest: The authors declare no conflict of interest.

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