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Differences in physiological variables of U23 cyclists between normoxia and hypoxia

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1. Introduction

For elite cyclists, the effect of altitude on physiological parameters and thus on endurance performance involves a complex interplay of training, physiological adaptation, and recovery[1–3]. Since the summer Olympic games 1968 in Mexico City extensive research[4] was conducted to study the effects of altitude training on the human body, as the physiological response to the altitude stimulus can have a legal performance enhancing effect for altitude and sea level endurance performance[5,6].

2. Materials and Methods

The participants of the study were twelve U23 cyclists (N=12) from a UCI continental team. (Mean ±SD: age 20.4 ±1.20 years; height 182.2 ±4.7 cm; body mass 68.4 ±6.6 kg; Pmax 6.6 ±0.4 $W.kg^{-1}$; VO_{2max} 72.6 ±5.1 $ml.kg^{-1}.min^{-1}$). The subjects were asked to avoid any exhaustive activities and refrain from caffeine and alcohol for the last 24 hours before the graded incremental exercise test (GXT). Participants were informed adequately of the purpose and procedures of the investigation. A written consent was additionally obtained as set out in the Declaration of Helsinki.

Experimental Design - The experimental design included two GXT within two days. The first GXT was conducted in normoxia at 574m above sea-level and the second GXT in a custom build altitude chamber (GAIRRIT, Gerrit Glomser GmbH, Kitzbühel, Austria) corresponding to a simulated altitude of 1800m above sea-level. Both GXTs were performed on the participants' individual road bike mounted on an electromagnetically braked ergometer (Cyclus2, RBM elektronik-automation GmbH, Germany) starting at an initial load of 100 watts with an increment of 20W every minute until volitional exhaustion. Peak power output (Pmax) in uncompleted stages was calculated according to Kuipers et al.[7].

Measurements – Open circuit spiro ergometry with a breath-by-breath technique (Cortex Metalyzer 3B, Cortex Biophysik GmbH, Germany) was continuously measuring respiratory flow, volume, and the volume fractions of oxygen (O_2) and carbon dioxide (CO_2) from expired air. The volume and flow were calibrated with a 3l syringe, gas analyzer calibration was performed before each measurement as recommended by the manufacturer (4.9 Vol% CO_2, 15.9 Vol% O_2, 79.2 Vol% N_2). Continuous recordings of heart rate (HR) (Polar H9, Polar Electro Austria GmbH, Austria) and oxygen saturation (SpO_2) (Nonin® Pulse Oximeter, Nonin Medical Inc, US) were measured at a 1Hz sampling rate. Measured variables involved oxygen uptake (VO_2), carbon dioxide release (VCO_2), minute ventilation (VE), breathing frequency (BF) and tidal volume (TV). The GXTs were performed in a controlled environment (temperature approx. 20°C, humidity approx.. 48%).

Statistical Analysis – All data are represented as mean ± standard deviation (SD) and checked for normality using Shapiro Wilk (p>.05). Paired sample t-test analyzed differences in physiological variables between normoxia and hypoxia conditions. The magnitude of the effect was interpreted according to Cohen's d[8] for small (.2 to .5), moderate (.5 to .8) and large (>.8) effects. Statistical analysis was conducted using a free available software package (JASP, JASP Team, the Netherlands) and graphs and figures were created with Prism8 (Graphpad software, US).

3. Results

Absolute VO_{2max} was significantly lower (d=1.21, p=.002) in hypoxia (4.59±0.36 L.min^{-1}) than normoxia (4.95±0.36 L.min^{-1}) – see figure 1 A and B. Absolute Pmax was significantly lower (d= 1.18, p=.003) in hypoxia (424±27 W) than normoxia (447±27 W) – see figure 1 C. Due to no significant changes in body mass (p>.05) relative values for VO_{2max} and Pmax were also significantly different between conditions. Peak SpO_2 was significantly lower (d=1.19, p=.003) in hypoxia (82.0±4.3 %) than normoxia (88.0±3.4 %) – see figure 1 D.

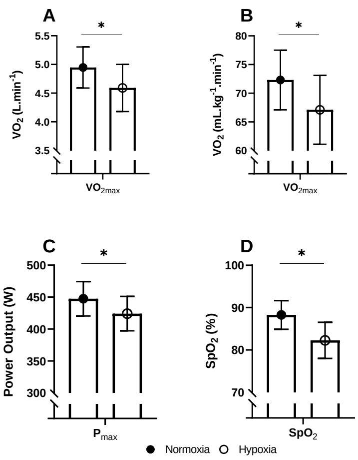

Figure 1: differences in absolute and relative VO_{2max} – maximum oxygen uptake, Pmax – peak power and SpO_2 between normoxia and hypoxia; *significantly different

No significant differences were found in the other physiological variables including VE, VT, BF and HR_{max} between normoxia and hypoxia (p>.05).

4. Discussion

The present study investigated physiological responses in normoxia at 574 m above sea-level and in hypoxia at simulated 1.800 m above sea-level to better understand the immediate impact of altitude on physiology determinants during cycling exercise.
The findings of the present study regarding lower VO_{2max} values in hypoxia than normoxia are in accordance with with previous studies[1,5,9].
Lower Pmax and decreased SpO_2 values in hypoxia were also found by Gore et al. studying elite cyclists.
Non-significant changes in VE were also reported from Benoit et al.[10] between hypoxia and normoxia.
Although statistically analysis revealed no differences in VE, VT and BF between normoxia and hypoxia, inter-individual differences might involve valuable information about the altitude response of the individual athlete. Combining information from HR and ventilatory responses across the whole intensity spectrum[6,11] might be beneficial to evaluate immediate altitude effects on the human body.

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

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