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Thresholds in ventilation, cerebral and muscle oxygenation, and muscle activity during incremental cycling exercise

David Nichols¹✉, Sebastien Racinais¹, Martin Buchheit², Olivier Girard³

Abstract

Introduction: Cycle time-trial performance is a function of the highest sustainable power output. The first (VT-1) and second (VT-2) ventilatory thresholds are practical tools for coaches and athletes to set training zones and exercise intensity. Specifically, VT-2 is closely linked to critical power, a primary determinant of endurance performance. The cascade of physiological events in the organs responsible for power production accompanying these respiratory thresholds remains contentious and yet to be fully characterized. Electromyographic (EMG) thresholds have been identified in leg muscles during incremental exercise while near infrared spectroscopy (NIRS) has revealed thresholds in both muscle deoxygenation and cerebral oxygenation towards the end of an incremental exercise test. However, the relative timing of the different muscle and brain oxygenation and muscle electrical activity responses to each other is unclear.

Purpose: The aim of the present study was to examine the thresholds of cerebral and muscle oxygenation, along with muscle electrical activity during a ramp exercise test in relation to VT-1 and VT-2.

Methods: Twenty-five recreational cyclists (mean±SD: age 37±8yrs, body mass 78±13kg, height 178±8cm, VO₂max 53±8mL/kg/min) completed a ramp exercise test to exhaustion on an electromagnetically braked cycle-ergometer with a work rate increment of 25 W/min. Throughout the test, continuous measures of expired gas (breath-by-breath), prefrontal cortex and vastus lateralis (VL) oxygenation via NIRS, and EMG Root Mean Square activity for the VL, rectus femoris (RF), and biceps femoris (BF) muscles were recorded. Thresholds were defined by a double-linear model.

Results: The results are summarized in Figure 1. VT-1 and VT-2 occurred at 57 ± 6% and 81 ± 6% of the exercise, respectively. There was a threshold in both cerebral deoxyhaemoglobin and oxyhaemoglobin (56±13% and 56±8% of exercise, respectively) which were not significantly different from VT-1 ($P>0.05$, cohens $d<0.1$). Cerebral deoxyhaemoglobin further increased (87 ± 10% of exercise) while oxyhaemoglobin reached a plateau (86±8% of exercise) both significantly after VT-2 ($P<0.05$, $d>0.8$). Only one threshold could be identified for muscle parameters with a threshold in muscle oxyhaemoglobin (78±9% of exercise), attenuation in muscle deoxyhaemoglobin (80±8% of exercise), and increase in EMG activity of VL, RF and BF (89±5%, 82±14% and 85±9% of exercise, respectively). The thresholds in BF and VL EMG activity occurred after VT-2 ($P<0.05$, $d>0.6$).

Conclusion: The threshold in cerebral oxygenation parameters occurred at both VT-1 and VT-2. Conversely, the present investigation failed to support a role for VL muscle oxygenation and electrical activity at VT-1, but did display a threshold at or after VT-2. The changes in cerebral oxygenation and in BF and VL electrical activity occurred after VT-2, suggesting that the metabolic and ventilatory events characterizing this latter cardiorespiratory threshold may affect both cerebral and muscle oxygenation levels and subsequent muscle recruitment responses. These physiological mechanisms are important factors in describing key training concepts and performance capability; for instance critical power. Any marked rise in muscle recruitment above VT-2 or critical power will result in early onset of fatigue and limit exercise performance.

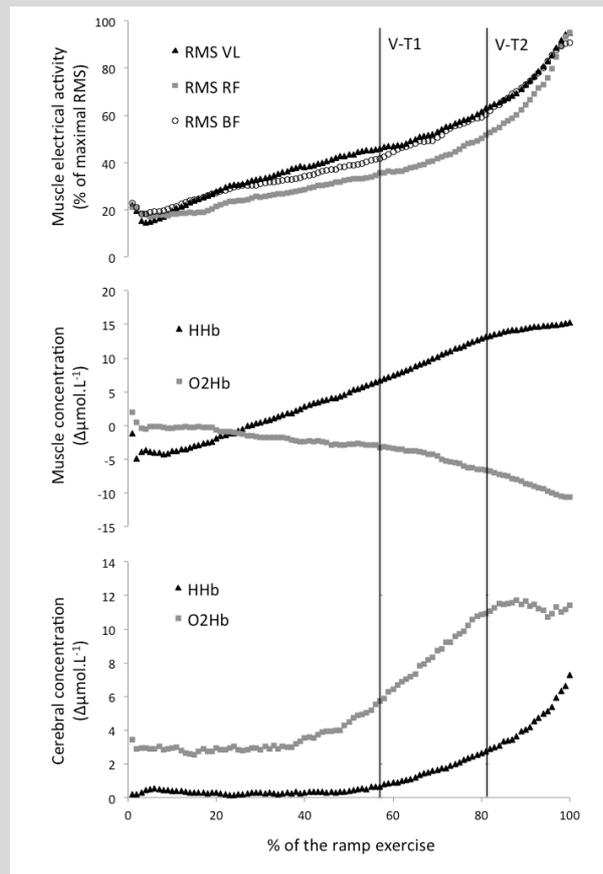


Figure 1: A) Mean EMG, B) NIRS muscle, C) NIRS cerebral parameters during an incremental ramp exercise. VT-1 and VT-2 first and secondary ventilatory thresholds. RMS, root mean square; VL, vastus lateralis; RF, rectus femoris; BF, biceps femoris; HHb, deoxyhaemoglobin; O2Hb. Oxyhaemoglobin. SD not included for clarity.

✉ **Contact email:** david.nichols@aspetar.com (D. Nichols)

¹ Research and Education Centre, Aspetar Qatar Orthopaedic and Sports Medicine Hospital, Doha, Qatar

² Sport Science Department, Myorobie Association, Montvalezan

³ Department of Physiology, Faculty of Biology and Medicine, Institute of Sport Sciences, University of Lausanne, Lausanne, Switzerland