



ORIGINAL ARTICLE

## Determining the ventilatory inter-threshold area in individuals with different endurance capacities

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Received 14 June 2017; accepted 6 November 2017

### KEYWORDS

Anaerobic threshold;  
Aerobic-anaerobic  
transition;  
Ventilatory  
thresholds;  
Inter-threshold area

**Abstract** There is a general consensus in the literature regarding the existence of two ventilation break points during incremental exercise, i.e., Ventilatory Threshold 1 (VT<sub>1</sub>) and Ventilatory Threshold 2 (VT<sub>2</sub>), which mark the boundaries of the aerobic-anaerobic transition. The Inter-Threshold Area (ITA) has been defined as a parameter that connects the ventilatory thresholds. The main aim of the present study was to examine the ITA i.e., the expressed area between VT<sub>1</sub> and VT<sub>2</sub> for the function: ventilation ÷ oxygen uptake (VE/VO<sub>2</sub> in L<sup>2</sup> min<sup>-2</sup>) in individuals with various endurance capacities. Six hundred and six men with different levels of endurance completed an incremental exercise test and their ventilatory thresholds were recorded. The ITA is a trapezoid whose area is calculated as the sum of the area of the triangle and rectangle that form it between VT<sub>1</sub> and VT<sub>2</sub> below the VO<sub>2</sub>/V<sub>E</sub> function. The mean ITA for the function VO<sub>2</sub>-V<sub>E</sub> was greater in cyclists, as the main representatives for endurance athletes, than the mean corresponding to physical education students, who averaged a lower endurance level (120 ± 34 vs. 86 ± 40 L<sup>2</sup>/min<sup>2</sup>). The results suggest that the determination of the ITA can reflect metabolic status throughout the aerobic-anaerobic transition during maximal incremental exercise tests. © 2017 Published by Elsevier España, S.L.U. on behalf of FC Barcelona.

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## PALABRAS CLAVE

Umbral anaeróbico;  
Transición  
aeróbica-anaeróbica;  
Umbral ventilatorio;  
Área interumbral

## Determinación del área ventilatoria interumbral en individuos con diferentes capacidades de resistencia

**Resumen** Existe un consenso general de que hay dos puntos de ruptura de la ventilación durante el ejercicio incremental, el umbral ventilatorio 1 (VT1) y el umbral ventilatorio 2 (VT2), que marcan los límites de la transición aeróbica-anaeróbica. El área interumbral se ha definido como un parámetro que relaciona los umbrales ventilatorios. El objetivo principal del presente estudio fue examinar el área entre los umbrales (ITA), es decir, el área entre VT1 y VT2 para la función ventilación/absorción de oxígeno. Seiscientos seis varones con diferentes estados de condición física, desarrollaron una prueba de esfuerzo incremental y se registraron los umbrales ventilatorios. EL ITA es un trapecio cuya área se calcula como la suma del área del triángulo y rectángulo que lo forman, tal como se muestra en la figura entre VT1 y VT2 y que permanecen por debajo de la función VO<sub>2</sub>/VE. La media de ITA para la función VO<sub>2</sub>-VE fue mayor en los ciclistas, como representantes de deportistas de resistencia, frente al área correspondiente a los estudiantes de educación física con menores niveles de resistencia (120 ± 34 vs. 86 ± 40 L<sup>2</sup>/min<sup>2</sup>). Estos resultados sugieren que la determinación del ITA puede reflejar adecuadamente el estado metabólico durante el proceso de transición aeróbico-anaeróbico durante las pruebas de esfuerzo incrementales.

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## Introduction

The term 'anaerobic threshold' was initially coined by Wasserman and McIlroy (1964) using the respiratory exchange ratio (RER) to detect the beginning of anaerobic metabolism in patients with cardiac problems performing stress tests.<sup>1</sup> Later, Wasserman, Whipp, Koyl and Beaver (1973), defined the anaerobic threshold as: (1) a non-linear increase in ventilation (V<sub>E</sub>), (2) a non-linear increase in the removal of CO<sub>2</sub> (VCO<sub>2</sub>), (3) an increase in the partial pressure of O<sub>2</sub> during a series of breaths (PetO<sub>2</sub>), with no corresponding drop in the partial pressure of CO<sub>2</sub> (PetCO<sub>2</sub>), (4) an increase in the RER, positively correlating to work load (all during an incremental exercise test). In contrast, Skinner and McLellan (1980) developed the triphasic model which uses gaseous exchange (breathing) variables, thus distinguishing the two thresholds: the Ventilatory Threshold 1 (VT<sub>1</sub>) and the Ventilatory Threshold 2 (VT<sub>2</sub>). Unfortunately, in the literature, VT<sub>1</sub> and VT<sub>2</sub> are known by different names which has led to much ambiguity.<sup>2</sup>

It is assumed that VT<sub>1</sub> and VT<sub>2</sub> are influenced by changes in the concentration of lactic acid in the blood.<sup>3-5</sup> Ideally, the ventilatory thresholds (VTs), which mark the boundaries of the aerobic-anaerobic transition, should be as close as possible to the maximum oxygen consumption value (VO<sub>2max</sub>). This is so the body may experience conditions where oxygen can be used efficiently for as long as possible. Acidosis begins when VT<sub>1</sub> is surpassed, and at this stage compensatory hyperventilation facilitates the continuation of exercise as lactic acid builds up.

Several studies have provided descriptive data for VT<sub>1</sub> and VT<sub>2</sub> in different groups of athletes<sup>6-11</sup>; however, the literature appears to contain no reports referring to the relationship between these thresholds, nor does it suggest if there is an ideal relationship between the VTs. As suggested in a review article<sup>12</sup> the VT<sub>1</sub> can vary between 0.5%

and 22% in relation to VO<sub>2max</sub>, while the variation of the VT<sub>2</sub> ranges from 2.5% to 12.8%, and with specific reference to this review, these variations occur over one or more competitive seasons. Furthermore, a parameter known as the Inter-Threshold Area (ITA) has been said to connect the VTs.<sup>13</sup> The ITA is expressed as the area between VT<sub>1</sub> and VT<sub>2</sub> for the function: ventilation/oxygen uptake (VE/VO<sub>2</sub> in L<sup>2</sup> min<sup>2</sup>).

According to this rationale, the general aim of this study was to examine the ITA, and to report the values of inter-ventilatory threshold in a large sample of male athletes who specialize in different sports. The data was collected through subject completion of a maximal incremental exercise test until exhaustion. Our investigation followed a verified protocol proposed by Peinado et al. (2014). We hypothesized that athletes who participate in typical endurance-dominant sports, e.g., cycling and athletics (track), will display higher VT<sub>1</sub> and VT<sub>2</sub> values; as well as the ITA being a suitable variable to indicate metabolic status during a maximal incremental exercise test.

## Material and methods

### Participants

606 men completed a maximal incremental exercise test until exhaustion using a cycloergometer (Jaeger ER 800, Germany) or a treadmill (H/P/COSMOS 3PW 4.0, H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany): 251 cyclists, 104 triathletes, 53 swimmers, 51 track athletes, 17 basketball players, 26 football players, 12 gymnasts and 92 physical education (PE) students. All tests were performed under similar atmospheric conditions (temperature 22.8 ± 0.6 °C; relative humidity 62.5 ± 4.4%; barometric pressure 703.54 ± 7.41 mmHg). All subjects were informed about the nature of the study and gave their signed consent

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