ARTICLE IN PRESS

Physiology & Behavior xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/physbeh

A comprehensive integrative perspective of the anaerobic threshold engine

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1. Introduction

Recently, Sales et al. [1] proposed an integrative perspective of the anaerobic threshold (AT), highlighting peripheral stimuli and autonomic adjustments during exercise. According to their engine [1], the central nervous system (CNS) progressively increases the cardiac output through a complex feedforward coupling response of peripheral organs and muscles in order to meet the increased metabolic requirement during maximal incremental test (MIT). They argued that the increased sympathetic activity and complete parasympathetic withdrawn at ~60–80% VO_{2MAX} would match an exponential increase in blood catecholamine concentrations and progressively impaired blood and O_2 supply to organs and skeletal muscles. This intensity would be coincident with electromyography (EMG) and ventilatory (VT) thresholds.

Although the authors are commended for this integrative perspective, it is needed to adequately consider the CNS to provide a comprehensive understanding of the AT puzzle. The role of the prefrontal cortex (PFC) should be highlighted, as PFC is involved in a cascade of integrated physiological events and connects physiological to psychological responses. The present commentary advances Sales' et al. approach [1], expanding their perspective to cerebral and psychological responses.

1.1. Anaerobic threshold engine: the driver

The AT engine needs a driver. We argue that Sales et al. [1] approached only a part of the complex regulation. Every planned-motor output starts at the PFC, as PFC is connected to premotor cortex areas to regulate primary motor cortex (MC) and motor output [2,3] while integrating sensory afferents during exercise [4,5]. MIT is a controlled-paced exercise so that exercisers have to enhance motor output according to externally increased exercise intensities [6]. Thus, PFC activation increases during MIT in order to increase the MC-derived motor command toward motor units of primary muscles [4,7]. Hence, together with external information provided by experimenter and devices (i.e. power output, workload, time, etc.), the feedforward system composed of peripheral III and IV afferent fibers informs to the CNS [8] about the necessity to continuously increase motor output [9], so that PFC and MC activation increases as MIT progresses [4,10].

The increasing intensity triggers a cascade of responses throughout the MIT (increased sympathetic activity, parasympathetic withdrawn, blood catecholamine elevation, etc.), thereby leading to a reduced O_2 delivery to organs and skeletal muscles mainly from the AT intensity [1]. The muscle deoxygenation threshold (MOX) at ~70–80% VO_{2MAX} [10,11] reflects a mismatch between muscle O_2 delivery (and extraction) and increased muscle acidosis that results in loss of muscle contractility. Consequently, there is a remarkable increase in motor command to peripheral muscles in order to compensate for the loss of contractility of fatigued motor units [12,13], thereby producing an increased type II fibers recruitment and an EMG threshold at ~80–90% VO_{2MAX} [11] that matches a remarkable metabolic acidosis-driven hyperventilation [14] and exercise-induced hypocapnia (i.e. a lowered blood $PeTCO_2$). Importantly, the exercise-induced hypocapnia from ~80% VO_{2MAX} is related to a cerebral hypoperfusion and PFC deoxygenation, as the lowered blood $PeTCO_2$ induces a pronounced vasoconstriction of cerebrovascular arteries [15] and reduces the cerebral blood flow and O_2 delivery to cortical regions involved with motor planning and command [16]. In this regard, the PFC deoxygenation threshold suggested at ~80% MIT [10] is likely related to a compromised PFC and MC activation [4], perhaps reflecting a change on the individuals' emotions and a pleasure-displeasure turn point during exercise [17,18].

1.2. Anaerobic threshold engine: the emotion-driven driver

The PFC is connected to limbic structures such as amygdala, thalamus, and hypothalamus, involved in body interoceptive representations of a variety of physiological conditions [19]. Physiological responses including acidic pH, hypoxia, hypercapnia, etc., are projected to the limbic motor cortex through the III and IV afferent fibers that innervate most body tissues [19]. It has been suggested that amygdala is a key structure to decompose these representations into sensations such as tension, distress, and fatigue [5], while PFC translates these sensations to emotionally relevant messages to exercise such as

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https://doi.org/10.1016/j.physbeh.2019.01.019

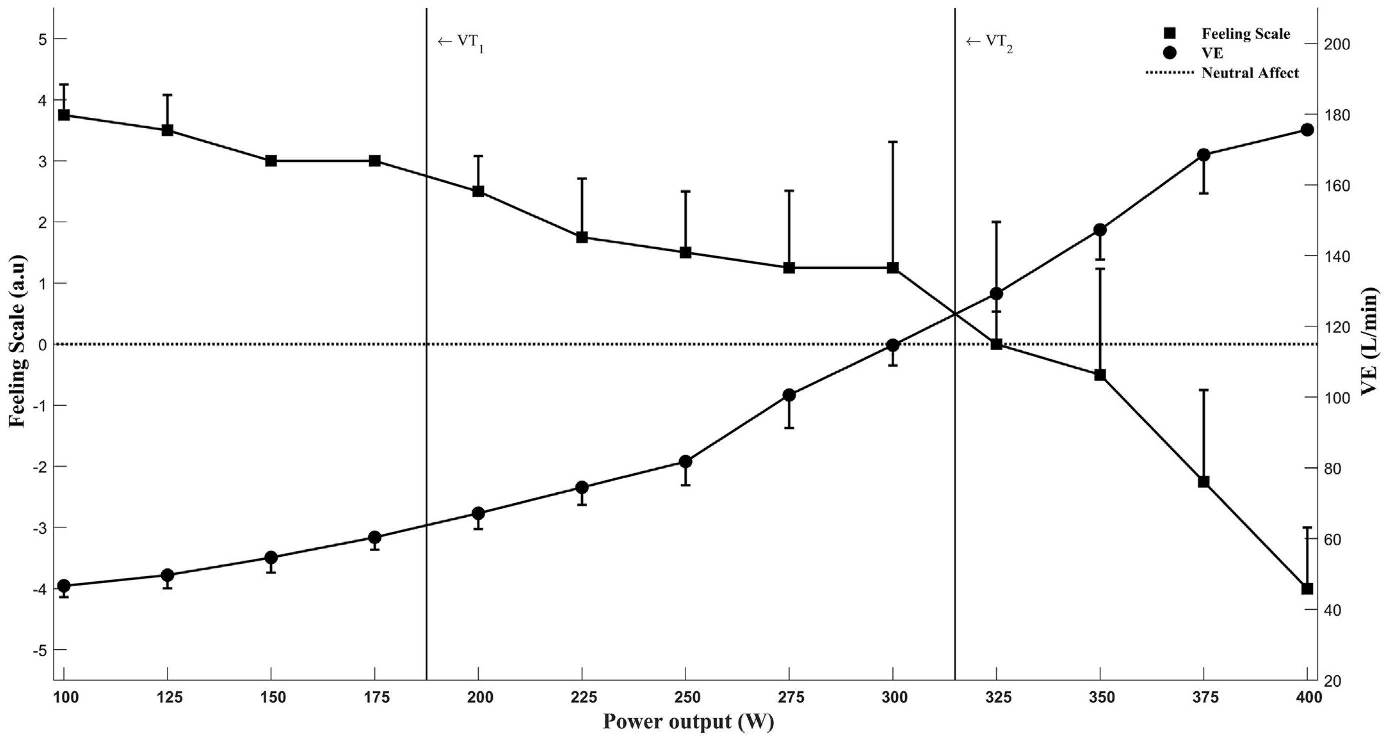

Fig. 1. Unpublished data of five healthy participants in a cycling maximal incremental test. VT_1 and VT_2 are first and second ventilatory threshold, respectively. Affect responses were obtained by using a feeling scale.

pleasure/displeasure [4,17,20,21]. PFC plays a key role to guide exercise, as PFC inhibits the amygdala-mediated negative sensations [5,19].

Assuming a direct tissue oxygenation-activation relationship [5] one may argue that the PFC deoxygenation threshold [7,22] indicates a progressively reduced PFC capability to inhibit the amygdala-mediated negative sensations during exercise. This reduced PFC oxygenation (after a progressive increase up to 80% MIT) may suggest a pleasure/displeasure turn point that indicates a likely closeness to exercise disengagement (i.e. exhaustion). Unpublished data from our group ($n = 5$) showed a VT_2-matched affect threshold (pleasure/displeasure) during MIT, with a change from positive to negative affective valence (Fig. 1). Hence, the VT_2 may highlight a change in a variety of physiological conditions that further reverberates in a pleasure/displeasure threshold. Actually, it has been proposed that VT_2 is the highest intensity that allows the maintenance of positive affective responses during exercise [17]. Perhaps, manipulations that change affective responses during exercise may be insightful in a performance and exercise adherence scenario [23].

In summary, we argue that the integrative perspective proposed by Sales et al. [1] needs to include the PFC for a comprehensive understanding on the AT puzzle, as PFC plays an important role when connecting a variety of physiological conditions to emotionally relevant messages during exercise.

Conflict of interest

None.

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