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Conference Abstract

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A simple and accurate wearable device to measure ventilatory threshold: principles and validation

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Abstract

Training zones are key for training and yet, there are only limited tools on the market to make accurate measurements. Coggan and CPxx tests lack accuracy, lactate tests require blood samples, are sensitive to food intake and require protocols with long steps, and ventilatory threshold require expensive, bulky and complex laboratory machines. In this paper, we present a novel device to make measurement of training zones based on ventilatory threshold easy and accessible. The measurement principle of the device is presented as well as a validation study.

Keywords

ventilatory threshold, training zones, breath, wearable

1 Introduction

In this paper, the principle and validation of ZoneX, a portable breath-analysis developed by PAIRFS to measure the training zones of athletes, is presented.

These training zones are at the core of training programs. Yet, no satisfactory method is available on the market for athletes. Methods based on threshold estimation (Coggan test, 30 minutes test) are exhausting and lack of accuracy [1], lactate-based methods require blood sampling and can be polluted by sweat, and respiration-based methods require expensive and complex equipment.

ZoneX addresses this problem by making lab grade measurement of training zones based on ventilatory thresholds simple and affordable. This paper is about the principle and the validation study that compares the performance - with respect to ventilatory threshold detection - of ZoneX technology versus the Cortex Metalyzer, an industry-standard metabolic cart. 9 Subjects have been tested with the device used in a row with the Cortex to evaluate signals.

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2 Material and Methods

Measurement of training zones is done according to Wasserman's method [2,3]. As illustrated on Figure 1, thresholds are measured by detecting changes in two respiratory metrics:

- VE: Minute Ventilation (L/min)
- VE/VCO_2: Ventilatory Equivalent for CO_2

ZoneX uses a state of the art ventilation sensor for the first metric, and a proprietary CO_2 sensor for the second one. This sensor has been developed using PAIRFS' technology and is protected by an 11 patents portfolio.

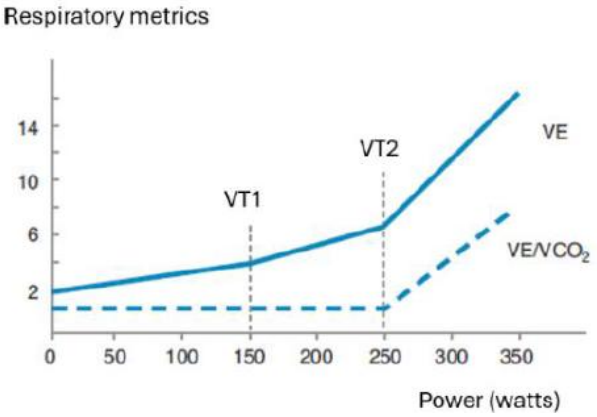


Figure 1. Detection of VT

Determining ventilatory threshold requires to analyze breath data and is operator dependent.

The validation of ZoneX is done therefore directly on the breath signals (VE and VE/VCO_2) to make sure a given operator would estimate the same training zones. As thresholds are defined by changing patterns in these signals, validation focuses on trend fidelity. It is assessed by the Pearson Correlation Coefficient (r). A coefficient approaching 1.0 confirms that ZoneX preserves the signal's shape and evolution, proving that an operator would measure the same training zones.

3 Results

The experiment involved 9 volunteers (8 male, 1 female) representing a range of fitness levels, from active amateurs to high-level endurance athletes. This diversity ensured that the system was tested against a broad spectrum of ventilatory patterns.

The validation uses a simultaneous recording protocol. To make sure both devices analyze identical air samples, a custom serial pneumatic rig was constructed. The flow path was configured as follows: exhaled air traveled from the athlete, through the Cortex Metalyzer (Reference), then into the ZoneX (Candidate), and finally out to the room.

Participants performed incremental ramp tests on a cycle ergometer. The experimental protocol consisted of a 4-minute initial warm-up, followed by a graded exercise test utilizing 2-minute incremental stages with a 25W increase per stage until exhaustion. As the systems operated on different computers, acquisitions synchronization was achieved during post-processing using Breath Frequency (BF).

An example of correlation between signals is illustrated on figure 2. For this acquisition, the Pearson coefficient on ventilation is r=0.979 and on VE/VCO_2 r=0.941. On figure 3, for the same acquisition, the temporal evolution of VE/VCO_2 of both systems is represented (at scale). Deformation can be observed but CO_2 increase (second threshold) around 980 s is visible on both systems.

The following results have been obtained:

- On ventilation (VE (L/min)), the average Pearson coefficient of the 9 acquisitions is r=0.982
- On $EqCO_2$, the average Pearson coefficient of the 9 acquisitions is r=0.89

These results show a high fit between systems for ventilatory threshold detection.

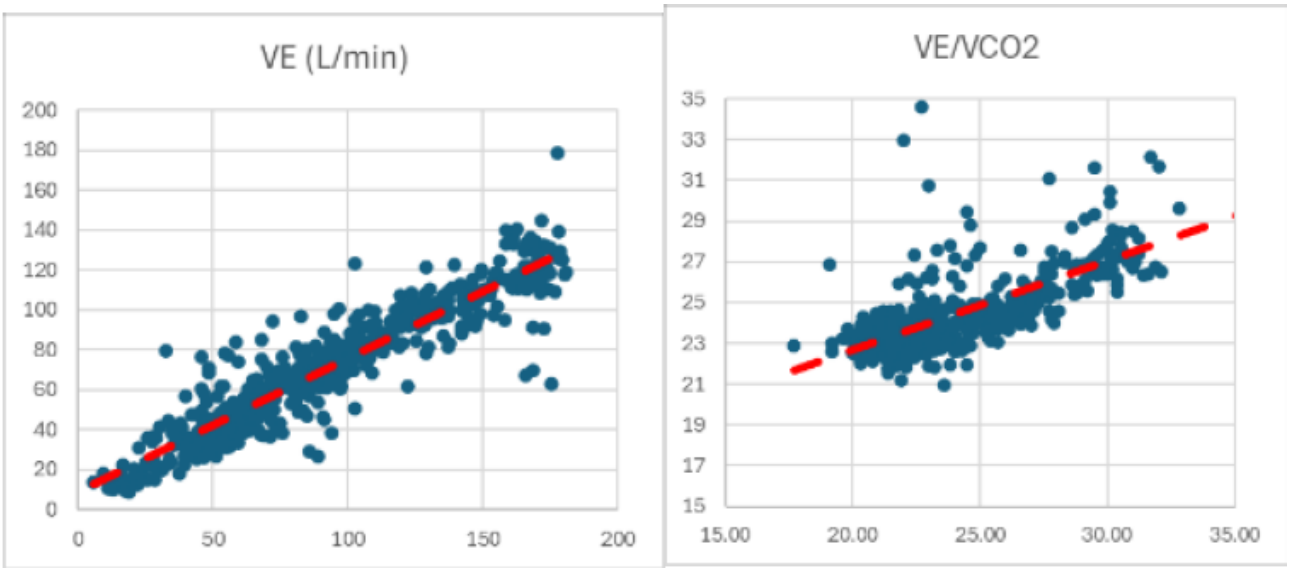


Figure 2. Correlation of VE and VE/VCO_2

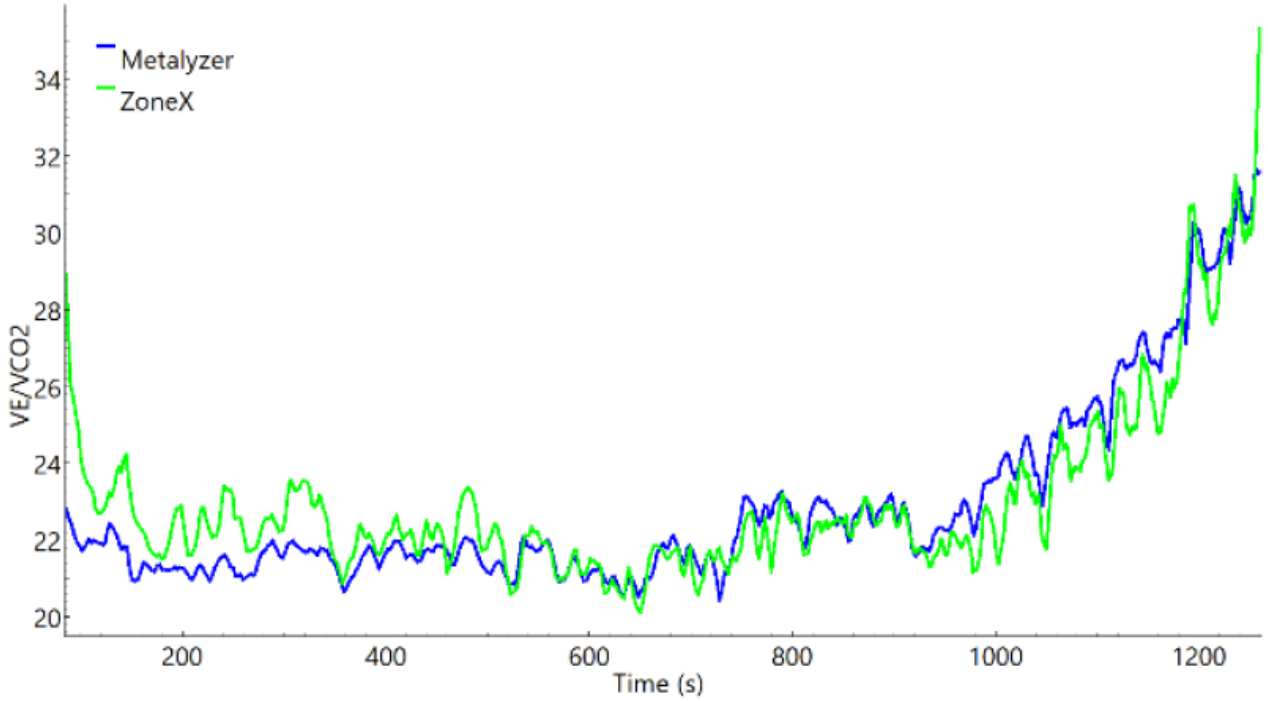


Figure 3. Illustration of VE/VCO_2 signals of both systems (at scale)

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