Optoelectronic plethysmography assessment of breathing pattern differences during exercise between endurance and strength-trained athletes

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Introduction

Previous research has shown that rib cage ventilatory mechanics differ between physically active individuals with and without exercise-induced respiratory symptoms (Smyth et al., 2022). Apart from that, physiological and respiratory muscle strength have been demonstrated to be different among sports disciplines due to the specific requirements of each one (Karaduman et al., 2022; Mazic et al., 2015). However, it is unclear whether such differences exist in the breathing kinematics.

Optoelectronic plethysmography (OEP) is a validated method for characterising breathing pattern disorder at rest and during exercise (Smyth et al., 2022). This study, therefore, aims to use OEP to compare breathing patterns between endurance- and strength-trained athletes during exercise. It is hypothesized that endurance athletes will possess better movement coordination under respiratory stress than strength-trained athletes, as a result of their consistent aerobic conditioning.

Methods

A total of 19 participants were recruited (14 males (7 endurance and 7 strength-trained athletes) and 5 females (3 endurance and 2 strength-trained athletes)), each performing at least three weekly sessions of their respective training type, representing ≥60% of total weekly training. During the first visit, participants completed an incremental cycling test (25 W/min until exhaustion) to determine peak power. In the second visit, breathing patterns were assessed during three 5-min upright cycling bouts at 40%, 60%, and 80% of peak power, with arms supported on the sides to avoid thorax obstruction.

Breathing was recorded using OEP with nine Qualisys® cameras (100 Hz) and 90 reflective markers placed according to Massaroni et al., (2017) (Figure 1). The variables were analysed during a 20-60 seconds interval at each intensity. The variables included are the ones that previous papers have seen differences among different populations (Smyth et al., 2022):

- Tidal Volume (Vt): total thoracic volume displacement measured in liters (L).
- Breathing Timing: temporal parameters including phase durations (inspiratory (I), expiratory (E), and total time in seconds (Ttot)), phase ratios (I/E and I/Ttot), and flow dynamics (normalized time to peak flow and I/E flow ratios at 50% Vt).
- Thoracic Contributions: Percentage contribution of individual compartments - pulmonary ribcage (RCp), abdominal ribcage (RCa), total ribcage (RC), and abdomen (AB)- to the total Vt, including specific volume indices.
- Inter-segmental Coordination: Spatio-temporal synchrony quantified via Continuous Relative Phase (CRP) (range: -180º to 180º). 0º indicates perfect in-phase synchrony. Positive values (>0º) mean that segment 1 leads segment 2.

Negative values (<0º) mean that segment 2 leads segment 1. The analysis pairings include hemi-thoracic asynchrony (left vs. right) and phase angles between the ribcage, abdomen, and shoulder segments (S).

Two-Way Mixed ANOVA was used to assess within-subject and between-subject differences ($p<0.05$). This experiment was developed at the University of Kent thanks to a doctoral grant from Universidad Politécnica de Madrid.

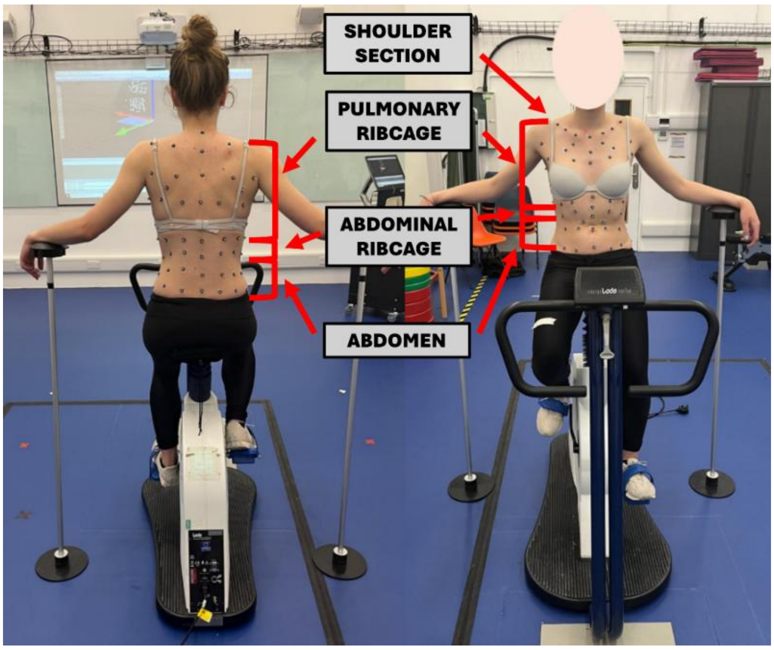

Figure 1: Experimental setup and thoracic sections distribution.

Results

Post-hoc comparisons revealed differences between sport disciplines when clustering all the intensities captured. The differences were found on the phase angle between RC and AB variable, and the phase angle between AB and S variable, with mean differences of −1.04° ($p = 0.032$) ($\eta^2p = 0.242$) 95% CI [-1.980, -0.098] and −1.38° ($p = 0.039$) ($\eta^2p = 0.228$) 95% CI [-2.670, -0.079], respectively.

Discussion and conclusion

Differences between sport discipline groups were mainly observed in coordination variables with a large effect size. The results obtained in this study reject the hypothesis denoting a worse coordination in the endurance group due to AB movement occurring earlier than RC movement, and the S movement precedes AB motion. Together, these findings point to a sequential expansion pattern in the endurance group (S-AB-RC). This sequence did not seem to agree with Smyth et al. in 2022 which characterize a healthy breathing sequence during high intensity exercise as RCa-AB-S-RC. In contrast, the strength training group appears to exhibit a synchronous thoracic expansion, with no clear movement sequence. However, the endurance thoracic expansion seems to have a smoother movement of the different sections, as seen in Figure 2. Overall, these results suggest endurance and strength training are associated with distinct thoracoabdominal coordination patterns.

This data provides reference values to distinguish athletes with normal breathing mechanics from those with dysfunctional patterns within specific disciplines. These observations may be used to tailor breathing exercises aimed at enhancing athletic performance.

The main limitations of the study are: the small sample size, the gender imbalance within the sample, and the fact that the strength-training group consisted primarily of cross-training athletes. Since these athletes perform part of their daily training as a cardiovascular effort, the distinction between the two training profiles may have been blurred, potentially preventing some differences from reaching statistical significance.

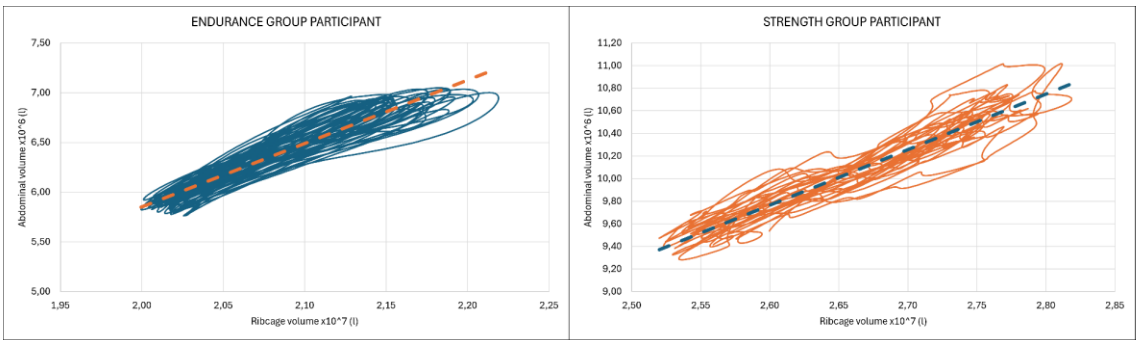

Figure 2: Breathing pattern differences among sport discipline groups. Example of two participants of the study.

References

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