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Letter to editor

Acoustic Analysis of Breath Sounds as a Surrogate for Gas Exchange Thresholds

Dear Editor-in-Chief

Respiratory gas exchange threshold measurements are a reference standard for measuring sustainable exercise capacity (McLellan and Skinner, 1981). A recent consensus report suggested that ‘threshold based’ exercise prescription may be superior (Mezzani et al., 2012) to the relative percent of VO_2 reserve or heart rate (HR) reserve that has been the standard for exercise prescription for a generation (ACSM, 2014). Further, respiratory gas exchange has technical requirements that place it out of the range of the health-fitness community. An alternative approach, which takes advantage of the fact that air moving into and out of the respiratory system creates sound (detectable as breathing frequency and sound volume) might provide an viable approach to threshold determination (Foster et al., 2012). This approach suggests that ventilatory threshold (VT) can be identified by an increase in breathing frequency and that respiratory compensation threshold (RCT) can be identified by a large increase in the perceived sound intensity. Breath sounds from digital recording are at least potentially capable of being analyzed in a way that allows investigators to distinguish changes in the acoustic character of breathing. The purpose of this study was to determine whether acoustic analysis of breath sounds, based on a proprietary algorithm and similar to that used previously (Foster et al., 2012), was systematically related to VT and RCT.

The subjects were healthy young adults aged 18-55 (males n = 9, females n = 11). The university human subjects committee approved protocol and the subjects provided written informed consent prior to participation. The subjects performed two incremental cycle ergometer exercise tests until maximal exertion, with at least 24 hr between tests. Power Output began at 25W and was incremented 25 W every two minutes. HR and the Rating of Perceived Exertion (RPE) were recorded during the last thirty seconds of each stage using radiotelemetry and RPE was measured using the Category Ratio scale. Breath sound recordings were captured using a small microphone inserted into a Hans Rudolph breathing valve through the saliva port. Acoustic analysis from the last 30s of each exercise stage was analyzed from digital recordings for breathing frequency and a variable referred to as ‘intensity’ (obtained from the expiratory phase of the acoustic signature); which is conceptually similar to tidal volume divided by the expiratory time. Blinded to information from respiratory gas analysis, the acoustic signature was analyzed based on the first derivative of change in breathing frequency and sound intensity. Candidates for the VT and RCT were identified and compared to the VT and RCT defined from respiratory gas analysis using standard methods (Foster and Cotter, 2005). Comparisons between VT and RCT determined by gas exchange and acoustic analysis were made using repeated measures ANOVA, reproducibility was determined using paired t-tests and intraclass correlations (ICC).

There were small, but significant, differences in the gas exchange vs acoustic analysis for power output (PO) at VT (105 ± 37 vs 111 ± 30W, r = 0.66) and RCT (174 ± 40 vs 162 ± 34W, r = 0.79) and HR at VT (114 ± 14 vs 119 ± 11 bpm, r = 0.74) and RCT (148 ± 16 vs 142 ± 14 bpm, r = 0.84) (Figure 1). There was a tendency for the acoustic analysis to slightly overestimate PO at VT, and slightly underestimate PO at RCT. The small magnitude of the differences in mean values for gas exchange vs acoustic analysis and strong correlations between respiratory gas exchange and acoustic anlaysis support the concept that acoustic analysis might prove to be a viable surrogate for respiratory gas analysis.

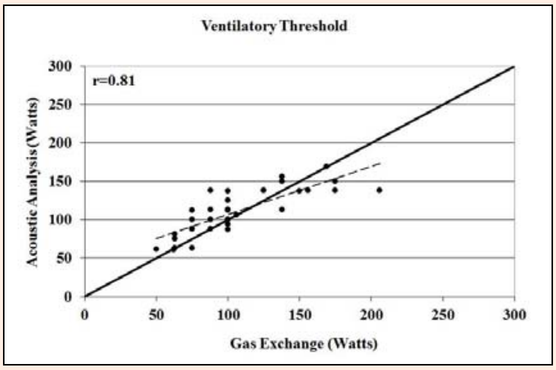

Figure 1. **Relationship between power output at the Ventilatory Threshold (top) and Respiratory Compensation Threshold (bottom) based on simultaneous measurements using respiratory gas exchange and acoustic analysis.**

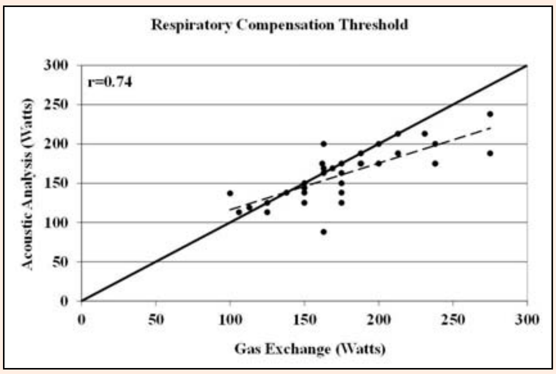

Figure 2. **Relationship between Test 1 and Test 2 for Ventilatory Threshold (left) and Respiratory Compensation Threshold (right), for respiratory compensation threshold (right), for respiratory gas analysis (top) and acoustic analysis (bottom).**

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Reliability estimates of PO@VT by gas exchange (104 ± 40 vs 107 ± 36 W, ICC = 0.62) and RCT (179 ± 46 vs 176 ± 40 W, ICC = 0.75) and by acoustic analysis for VT (109 ± 31 vs 111 ± 32 W, ICC = 0.75) and RCT (161 ± 37 vs 163 ± 29 W, ICC = 0.77) suggest excellent reliability (Figure 2). The results generally agree with our preliminary data (Foster et al., 2012). The current acoustic analysis technique did not allow for acceptable direct measurement of expiratory time in simultaneous measurements. Follow up experiments may give better estimates of the magnitude of decrease in expiratory time.

The data support the concept that a simple analysis of breath sounds during exercise can provide a plausable surrogate of physiologic threshold events measured using respiratory gas exchange. As such, the acoustic analysis may provide a simple method for making threshold measurements, which may be useful for both diagnosis and exercise prescription.

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