Methodological considerations for measuring resting cardiac output by open circuit acetylene breathing technique

Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Canada

Introduction
The calculation of cardiac output (Q) as determined by open circuit technique (OpCirc) is proportional to the uptake of acetylene (ΔC₂H₂) at breath 1 of the manoeuvre. This value is determined by back-extrapolation from the regression of ΔC₂H₂ which includes data from breath 5 onwards. This back-extrapolation is used to account for recirculation and lung mixing of the inert gasses. Breath 5 was chosen as the start of the analysis as breaths 1-4 did not lie on the regression line due to “rapid lung kinetics”. Helium, a marker of lung mixing, often reaches equilibrium (EQ) by breath 5 during exercise. However at rest, it was postulated that differences in tidal volume (TV) would alter lung mixing and affect the number of breaths needed to reach He EQ. Therefore, the purpose of this investigation was to examine the effect of changing the starting breath for the ΔC₂H₂ regression from breath 5 to one breath past EQ, and its impact on the subsequent back-extrapolation to breath 1.

Methods
Seven healthy male subjects (mean ± SD; age = 24.6 ± 3.5 yr; weight = 85.8 ± 11.7 kg; height = 180.7 ± 6.4 cm; and vital capacity = 5.9 ± 1.0 L) volunteered for this study. Subjects were non-smokers, non-asthmatic, without history of pulmonary or cardiovascular disease. Each subject participated in three testing sessions within one week that occurred at the same time of day, without exercise 24hrs prior to testing. Each session consisted of four measurements of resting Q, alternating between sitting and supine positions, after reaching a steady state VO₂. Double inert gas (0.7% C₂H₂, 5% He, 21% O₂, Balance N₂) OpCirc technique was used to measure C₂H₂ uptake in order to calculate Q. Vₚₚ, VCO₂ and VO₂ were analyzed by TrueMax 2400 metabolic cart and end-tidal CO₂, C₂H₂ and He measured by Perkin-Elmer 1100 mass spectrometer. The manoeuvre consisted of 20 breaths past He EQ, defined as an absolute difference of less than 0.034% between inspired and expired He concentration. The back-extrapolation of ΔC₂H₂ to breath 1 was done using two distinct regression analyses; 1) starting at breath 5 to the end of the test (5End) and 2) starting from one breath past He EQ and the subsequent 15 breaths (Eq15).

Results
Mean calculated Q for 5End was 5.32 ± 0.84 L·min⁻¹ whereas Eq15 was 6.59 ± 0.67 L·min⁻¹. Q determined by Eq15 was 1.27 ± 0.02 L·min⁻¹ higher than 5End by Bland-Altman plot. The average difference in Q between methods decreased as TV increased (Fig. 1). This trend was associated with a concomitant reduction in the number of breaths taken to reach EQ. As a result the choice of breaths included in regression analysis of ΔC₂H₂ affected the back extrapolation to breath 1 (Fig. 2). The mean r² values for the regression lines were 0.66 ± 0.29 and 0.86 ± 0.15 for 5End and Eq15, respectively.

Discussion/Conclusion
With increases in TV (%VC), EQ approached breath 5 causing the difference in calculated Q between methods to decrease. As a result, the data set used in each regression method became increasingly similar. Until EQ, decreased expired C₂H₂ is caused by both lung mixing and capillary uptake. By including breaths in the regression prior to He EQ (i.e. 5End), confidence in the back-extrapolation to breath 1 is reduced. This may be a result of a slower rise to peak alveolar C₂H₂ and eventual recirculation prior to EQ resulting in a depressed diffusion gradient. Using a fixed breath number for the starting point of the regression analysis results in a ventilatory bias in the calculation of Q. This bias was removed when the regression began one breath past EQ.

References