THE VALIDITY OF THE CARDIODYNAMIC HYPOTHESIS FOR EXERCISE HYPERPNEA IN MAN

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INTRODUCTION

According to the cardiodynamic hypothesis proposed by Wasserman et al.,1,2 CO₂ flow from venous blood to the lung (\(QCO₂\)), i.e., the product of cardiac output (\(Q\)) and mixed venous CO₂ content (\(CvCO₂\)), causes an increase in ventilation during exercise by means of some unidentified mechanisms. Close correlation between CO₂ output (\(VCO₂\)) and ventilation (\(VE\)) has repeatedly been observed during the steady- and unsteady-state of exercise.3,4,5 More recently, Miyamoto et al.6 have determined the kinetics of \(Q\) by adopting an ensemble-averaging technique to impedance cardiography, evidently showing that the change in \(Q\) precedes that in \(VE\) during the unsteady-state of step impulse and sinusoidal exercise.5 However, the mechanism which links CO₂ flow to hyperpnea remains uncertain.

In the present study, certain variables which are considered to be possible stimuli to the respiratory controller, i.e., \(Q\), \(\dot{V}CO₂\), end-tidal CO₂ tension (\(P_{ET}CO₂\)), \(CvCO₂\), and \(\dot{Q}CO₂\) were measured together with \(VE\) in human subjects during both the steady- and unsteady-state of mild to moderate exercise. Simultaneous measurement of \(Q\), \(\dot{V}CO₂\) and \(P_{ET}CO₂\) made it possible to estimate the kinetics of \(CvCO₂\) during the unsteady-state, assuming that arterial CO₂ tension (\(P_{a}CO₂\)) can be predicted from \(P_{ET}CO₂\). The quantitative relationships between \(VE\) and these variables were determined, and the potential mechanisms to link ventilation and these factors are discussed.

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METHODS

Healthy young laboratory staff volunteered as subjects in the experiment. The measurement of $\dot{Q}$ during the steady-state of exercise was carried out using the new rebreathing method of Mochizuki et al. A comparison between the $\dot{Q}$ values determined by this method and the direct Fick method resulted in a correlation coefficient of 0.88, thus validating the new technique. The $\dot{Q}$ measurement during the unsteady-state of exercise was performed using an automated impedance cardiograph developed by Miyamoto et al. The validity of the cardiac output determined by the impedance method ($\dot{Q}_{imp}$) was tested on four subjects using the values determined by the rebreathing method ($\dot{Q}_{reb}$) as a control. The relationship between $\dot{Q}_{reb}$ and $\dot{Q}_{imp}$ was linear in all subjects tested (see Fig. 1). $\dot{Q}_{imp}$ during the unsteady-state of exercise was thus corrected by taking $\dot{Q}_{reb}$ determined in the steady-state as references for each subject.

The $\text{CvCO}_2$ values during the steady- and unsteady-state of exercise were also determined using both the rebreathing and impedance methods.

Fig. 1 Comparison between cardiac output determined by the impedance and rebreathing methods. The data were obtained during the steady-state of exercise which ranged from 30 to 90 W, and also at rest. The regression equation was: $\dot{Q}_{reb} = 1.1 \dot{Q}_{imp} - 0.28$, or $\dot{Q}_{imp} = 0.91 \dot{Q}_{reb} + 0.25$ l/min ($r = 0.866$, $p < 0.001$).