THE VALIDITY OF THE CARDIODYNAMIC HYPOTHESIS FOR EXERCISE HYPERPNEA IN MAN

Y. Miyamoto, K. Niizeki*, T. Sugawara, Y. Nakazono, K. Kawahara and M. Mussell

Department of Information Engineering, Faculty of Engineering
Yamagata University, Yonezawa, 992 Japan

*Department of Physiology, Yamagata University School of Medicine Yamagata, 990-23 Japan

INTRODUCTION

According to the cardiodynamic hypothesis proposed by Wasserman et al., 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 (VO₂) and ventilation (VE) has repeatedly been observed during the steady- and unsteady-state of exercise. More recently, Miyamoto et al. 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. 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, VO₂, end-tidal CO₂ tension (PETCO₂), CvCO₂, and QCO₂ were measured together with VE in human subjects during both the steady- and unsteady-state of mild to moderate exercise. Simultaneous measurement of Q, VO₂ and PETCO₂ made it possible to estimate the kinetics of CvCO₂ during the unsteady-state, assuming that arterial CO₂ tension (Paco₂) can be predicted from PETCO₂. 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 ($\dot{Q}(\text{imp})$) was tested on four subjects using the values determined by the rebreathing method ($\dot{Q}(\text{reb})$) as a control. The relationship between $\dot{Q}(\text{reb})$ and $\dot{Q}(\text{imp})$ was linear in all subjects tested (see Fig. 1). $\dot{Q}(\text{imp})$ during the unsteady-state of exercise was thus corrected by taking $\dot{Q}(\text{reb})$ determined in the steady-state as references for each subject.

The $C_VCO_2$ 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: $\dot{Q}(\text{reb}) = 1.10 \dot{Q}(\text{imp}) - 0.28$, or $\dot{Q}(\text{imp}) = 0.91 \dot{Q}(\text{reb}) + 0.25$ l/min ($r = 0.866$, $p < 0.001$).]