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.,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 (VC02) 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 step7, 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, VC02, 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, VC02 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.
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 $C_v CO_2$ 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 ($r=0.866$, $p<0.001$).