Effects of combinations of breathing resistance and inspiratory CO_2

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At rest, the respiratory system compensates for moderate increases in either work of breathing (WOB) or inspired carbon dioxide fraction (F_iCO_2). Heavy exercise stresses adjustment to either load. In exercising subjects we show that combined elevated F_iCO_2 and moderate WOB impairs ventilatory responses to heavy exercise, leading to CO_2 retention (Figure 1).

End tidal CO_2 fraction ($F_{ET}CO_2$) is an indicator of arterial CO_2; with unimpeded breathing at sea level, $F_{ET}CO_2$ is 5.3% for rest through moderate exercise, and lower at heavy exercise. $F_{ET}CO_2$ above 7.2% (shaded on Figure 1) has been associated with mildly impaired cognition,[1] and above 8.4% (horizontal line on Figure 1) is considered unsafe for diving[2].

Two groups of subjects exercised to voluntary termination at 85% maximum oxygen uptake. One group with no added restance (R) breathed air with F_iCO_2 0, 2, and 3 %. The other breathed air with no R or R and F_iCO_2 of 0, 1, or 2%. With R, WOB per tidal volume (WOB/V_T) was 3 kPa if minute ventilation (V_E) was 100 L/min.

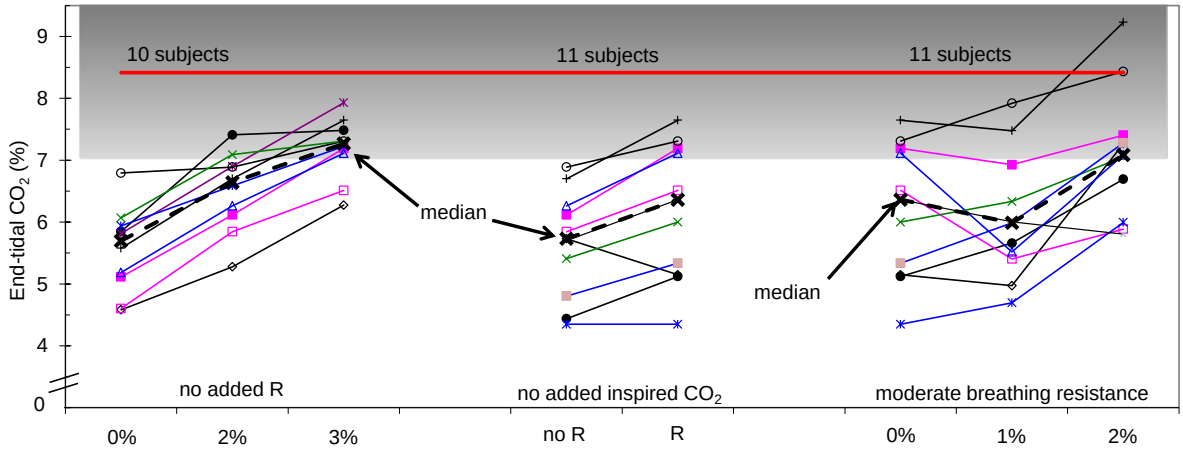

Figure 1. $F_{ET}CO_2$ at heavy exercise with varied respiratory loads. Dashed line = median

Subjects increased V_E in response to F_iCO_2 alone, but insufficiently to maintain $F_{ET}CO_2$ [Figure 1, left]. With resistance alone, V_E decreased and $F_{ET}CO_2$ climbed slightly [Figure 1, middle]. With resistance and elevated F_iCO_2, V_E remained depressed and $F_{ET}CO_2$ climbed [Figure 1, right].

Acceptable F_iCO_2 was lower with R than without it. R and 2% F_iCO_2 elevated $F_{ET}CO_2$ to dangerous levels in some subjects.

1. Sayers J *et al*, Effects of carbon dioxide on mental performance, J Appl Physiol 63(1):25-30, 1987.
2. Warkander *et al*., Physiologically and subjectively acceptable breathing resistance in divers' breathing gear. Undersea Biomed Res 19(6):427-445, 1992.