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$_i$CO$_2$). Heavy exercise stresses adjustment to either load. In exercising subjects we show that combined elevated F$_i$CO$_2$ 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, and above 8.4% (horizontal line on Figure 1) is considered unsafe for diving.

Two groups of subjects exercised to voluntary termination at 85% maximum oxygen uptake. One group with no added resistance (R) breathed air with F$_i$CO$_2$ 0, 2, and 3%. The other breathed air with no R or R and F$_i$CO$_2$ 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](image.png)

**Figure 1.** F$_{ET}$CO$_2$ at heavy exercise with varied respiratory loads. Dashed line = median

Subjects increased V$_E$ in response to F$_i$CO$_2$ 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$_i$CO$_2$, V$_E$ remained depressed and F$_{ET}$CO$_2$ climbed [Figure 1, right].

Acceptable F$_i$CO$_2$ was lower with R than without it. R and 2% F$_i$CO$_2$ elevated F$_{ET}$CO$_2$ to dangerous levels in some subjects.