PERSPECTIVES

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Breathing in exercise: battle of the sexes

Craig A. Harms
Department of Kinesiology, Kansas State University, Manhattan, KS 66506, USA
Email: caharms@ksu.edu

Most healthy people rarely notice difficulty with their breathing either at rest or even during heavy exercise. Yet, muscular exercise makes unique and multifaceted demands on the respiratory system. During dynamic exercise, ventilation rises in proportion to the metabolic demands of the locomotor muscles. The ventilatory response to exercise requires substantial changes in intrathoracic pressure and in the work output and metabolic rate of the respiratory muscles. As a result, the oxygen cost of breathing represents a significant fraction of total oxygen uptake during intense exercise. These effects may exert significant influences on the cardiovascular response to exercise, both in total cardiac output (Harms *et al.* 1998) and in its distribution (Harms *et al.* 1997). Quantifying the metabolic demands of the respiratory muscles is necessary for understanding cardiorespiratory control during exercise. Energy expenditure required by the respiratory muscles during exercise is dependent upon exercise-induced changes in several types of mechanical work performed by the respiratory muscles. Historically, it has been very difficult to measure the oxygen or energy cost associated with exercise hyperpnoea. Aaron *et al.* (1992*a*) has estimated that in healthy untrained humans, the oxygen uptake of the respiratory muscles during maximal exercise represents ∼10% of whole-body maximum oxygen uptake. In endurance trained men, who possess a high $\dot{V}_{O_2\max}$ and sustain high rates of ventilation, the oxygen uptake of the respiratory muscles can represent upwards of 15% of $\dot{V}_{O_2\max}$ (Aaron *et al.* 1992).

To date, the vast majority of studies that have made estimates of the work of breathing (WOB) during exercise have come from men. Is the WOB different for women? A compelling rationale for a sex difference exists. Women have smaller lungs and airways than height- and age-matched men (Mead, 1980), and are also likely to develop expiratory flow limitation more often than men (Guenette *et al.* 2007). In fact, it has been reported that women demonstrate a higher WOB than men across a range of ventilations (Guenette *et al.* 2007). Therefore, with an increased WOB in women, an unanswered follow-up question is: would the oxygen cost of breathing during exercise be greater in women compared to men? In this issue of *The Journal of Physiology*, Dominelli *et al.* (2015) tested this question and present their work in a detailed and well-conducted study. These researchers had nine men and nine women mimic the breathing patterns associated with five to six different exercise stages. Pressure and flow volume loops were superimposed on target loops obtained during exercise to accurately replicate the work of breathing. The authors report that for a given ventilation, women had a greater absolute oxygen cost of breathing and this represented a greater fraction of the total oxygen uptake compared to men. Additionally, in those subjects that experienced expiratory flow limitation (regardless of sex), the oxygen cost of breathing at maximal exercise was greater than in those who did not. The authors also found that neither men nor women reached their maximal effective ventilation, but women may be relatively closer to this value than men.

What are the implications of these results? The greater oxygen cost of breathing in women indicates that a greater fraction of total oxygen uptake (and possibly cardiac output) is directed to the respiratory muscles, which may influence blood flow distribution during exercise. Dominelli *et al.* (2015) hypothesized that, when compared to men, women may show greater changes in leg blood flow when the WOB is altered by the same amount as in men. While this postulate has been theorized for many years, this study is the first to provide solid evidence to substantiate that it may indeed occur. To date, the influence of WOB on blood flow distribution during exercise has not been studied in women. To accurately determine the potential effect of sex differences on WOB-related alterations in blood flow, respiratory muscle work will need to be experimentally reduced while leg blood flow is directly measured.

In summary, Dominelli *et al.* (2015) have provided a significant step forward in our understanding of sex differences in the work of breathing during exercise by their careful, quantitative approach in estimating the oxygen cost of breathing during exercise. The greater oxygen cost of breathing in women may have implications for the integrated physiological response to exercise. The results from this study clearly indicate that, due to morphological differences between men and women, sex differences exist in respiratory mechanics which may help account for differences in exercise tolerance between men and women. Hopefully, these finding will provide an impetus for future studies to examine the cardiovascular consequences of a sex differences in the oxygen cost of breathing.

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Additional information

Competing interests

None declared.

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