haustion, a 6-min walk, or an incremental test are used for evaluation of exercise tolerance. Even though the 6-min walk might be argued to be representative of a task encountered by patients with COPD, it is still not a simulation of any known sport. In contrast, the 6-min and the 5000-m time trial represent very close simulations of competitive rowing events and are therefore one step closer to actual sports performance than any test attempted in previous studies.

Because the early report of Leith and Bradley (21), many different groups have demonstrated that ventilatory muscle training increases maximal voluntary ventilation, ventilatory muscle strength, ventilatory muscle endurance, and functional exercise capacity. Our results of 45.3% improvement in PI_{max} are similar in magnitude to other studies (see Smith and colleagues' (29) meta-analysis on patients with COPD) ranging from 32% to 53% (22,32,33). However, because there may well be important differences between healthy subjects and those with COPD, a more appropriate comparison would be with studies using healthy subjects (5,13) where PI_{max} also increases in the range of 34% to 45.3%, respectively, after 4 wk of inspiratory muscle training.

Previous reports (4,5,30) have shown that after inspiratory muscle training a submaximal power output can be maintained for longer (Tlim test). However, the intensity used for the Tlim test in these studies was associated either with the anaerobic threshold (Th_{an}) or the maximum lactate steady state (MLSS). Even though these physiological markers correlate very well with endurance performance, this approach is one step removed from competitive sports performance. Our study shows that inspiratory muscle training can improve performance in two tests that simulate competitive performance as closely as possible in the laboratory context, viz. the 6-min all-out effort and the 5000-m trial. Both tests are routinely used for rowing-specific performance evaluation by coaches. Both IMT and placebo groups improved their performance after 11 wk of training. The margin of their improvement was expected because the study commenced at the beginning of the preparatory training period and lasted for the bigger part of it. Even though we acknowledge the possibility that the responses observed may have occurred as a result of the subjects' regular training, the 1.9% improvement of the IMT group in the 6-min all-out effort over and above the improvement of the placebo group suggests that this is unlikely. Therefore, the data suggest that the inspiratory muscle training had an additional effect upon rowing performance beyond that expected by regular training. The significance of this difference can be appreciated more within the context of competitive rowing where Olympic medals are decided with a much smaller margin than 1.9%.

We believe that there are a number of reasons why other studies have not reported any significant improvements in performance after IMT. Arguably, the most important of which is the low reliability of the tests used to evaluate performance in other studies, compared with the 6-min all-out effort used in our study, made the detection of a meaningful effect difficult. For example, the coefficient of variation for the Tlim test has been reported to be anything between 25% and 40%, whereas the 6-min all out test is only 2.4% (17). Therefore, much larger improvements were required to assure that the observations were not due to the variability of the test itself. Other studies (13,24) have reported improvements in performance but failed to reach significance. We suspect that insufficient statistical power, due to the small sample size of these studies, may have introduced a type II error and failed to reject the null hypothesis. Support of our findings is provided by studies using isocapnic hyperpnea training protocols, which suggest that respiratory muscle training induces significant improvements in cycling performance (Tlim) (4,30). In addition, a recently completed study showed that after 5 wk of respiratory muscle training, using a high velocity (flow) and a high resistance (pressure) training protocol, cycling time trials improved significantly by approximately 5% (J. Dempsey, personal communication). In the absence of any clear insight into the hard evidence of the underlying physiological mechanisms for the observed effects, we are forced to speculate on possible mechanisms, three of which are discussed below.

Respiratory Muscle Fatigue

First, even though respiratory muscle fatigue of the IMT group was diminished, there was no evidence for significantly different ventilatory response between the two groups. These data support the notion that respiratory muscle fatigue was without significant consequence for the ventilatory response. This is consistent with the suggestion that when the diaphragm is confronted by fatiguing contraction patterns, the accessory inspiratory muscles become more active and the overall ventilation is not compromised. Therefore, since the respiratory pump did not fatigue to the point of "task failure," it is unlikely that the improvements in performance were the result of improved gas exchange or a better compensation for metabolic acidosis. However, the altered breathing pattern observed after IMT suggests that respiratory muscle fatigue might have been of physiological significance to the regulation of the breathing pattern. In the IMT group, tidal volume increased significantly, whereas the placebo group resorted to a more tachypneic breathing pattern, characteristic of respiratory muscle fatigue for the maintenance of minute ventilation. Indeed, as the breathing pattern during exercise seems to be optimized to avoid exhaustive fatigue and "task failure" of the respiratory muscles, the increased strength of the IMT group might have enabled them to increase tidal volume without fatiguing. In contrast, the placebo group, which was susceptible to fatigue, resorted to an increased breathing frequency. Even though we did not assess the degree of entrainment between breathing and stroke rate, it is possible that the prevention of a tachypneic breathing pattern in the IMT group enhanced the mechanical efficiency of the rowing work by enabling the maintenance of entrainment. Indeed, our data are in agreement with previous suggestions that breathing in rowing occurs at times where muscle synergy produces larger ventilatory volumes for a given amount of respiratory work, or alternatively, the same volume for less respiratory work (28); consequently performance may be improved.