TABLE 4. The effect of the three warm-up protocols on parameters related with the 6-min all-out effort.

	SWU	RWU	*P*	RWUplus	*P*
MIP decrease (%)	10.2 ± 1.4	11.1 ± 1.3	NS	4.2 ± 0.3	*
Power (W)	292 ± 14	302 ± 14	**	305 ± 15	**†
Distance (m)	1690 ± 29	1701 ± 31	*	1708 ± 32	**
$\dot{V}O_2$ (L)	4.17 ± 0.15	4.29 ± 0.21	NS	4.35 ± 0.21	NS
$\dot{V}E$ (L)	155.2 ± 5.0	158.2 ± 5.5	NS	160.4 ± 6.0	NS
Dyspnea	7.8 ± 0.3	7.6 ± 0.2	NS	7.0 ± 0.3	*

SWU, submaximal warm-up; RWU, specific rowing warm-up; RWUplus, specific rowing warm-up with respiratory warm-up.
Values are mean (SE). Comparisons between SWU and RWU.
* $P < 0.05$; ** $P < 0.01$; † significant difference between RWU and RWUplus ($P < 0.05$).

all of the parameters assessed. The coefficient of variation of 0.36% for the average power output, during the 6-min all-out test, is even smaller than the 0.9% of the second trial in the report by Schabort and colleagues (21).

Respiratory muscle fatigue has been reported after prolonged submaximal exercise (16), as well as short-term maximal exercise (10,18). However, it has been suggested that the respiratory muscles of "athletic" individuals have superior strength and greater fatigue resistance (5). Nevertheless, the present data suggests that competitive rowers are susceptible to inspiratory muscle fatigue and confirm reports from Johnson and colleagues (11), who suggest that a high level of aerobic fitness does not protect the inspiratory muscles from fatigue during heavy exercise. A possible explanation for this respiratory fatigue may be the high ventilatory requirements of rowing. The entrainment of breathing with the stroke rate, observed during rowing, as well as the dual role assumed by the respiratory, both as actuators of the thoracic expansions and as stabilizers of the thorax for the promotion of external work (24), makes them susceptible to fatigue.

Despite this fatigue, the respiratory muscles as a whole did not reach the point of "task failure" as was evident by the continuous rise of minute ventilation throughout the 6-min all-out test. However, the recruitment pattern of the respiratory muscles might have been altered as a result of this fatigue. Furthermore, the additional motor output to the fatiguing respiratory muscles, necessary to maintain the same pressure generation, would have been perceived as an increased breathing effort and associated dyspnea (4).

The respiratory warm-up was effective in enhancing the functional capacity of the inspiratory muscles, confirming our previous findings (26). After this improved function of the inspiratory muscles, the inspiratory muscle fatigue and the associated dyspnea were decreased. These findings are consistent with previous data (18) suggesting that the severity of the inspiratory muscle fatigue is related to their baseline strength. The most likely explanation for this is that greater absolute strength leads to a smaller relative demand for force generation during exercise.

Respiratory sensations are believed to be one subcluster of the overall perceived exertion that is responsible for exercise intolerance (27). Moreover, all subclusters are considered interdependent, and a significant reduction of the respiratory cluster would somewhat improve the perceived exertion of the peripheral musculature. A report from Killian and colleagues (13) has shown that, at maximal exercise capacity, dyspnea can be as important, or more so, than leg fatigue in limiting exercise. In this context, the improvements that we have demonstrated in rowing performance during the 6-min all-out test after the RWUplus may be ascribed, at least partially, to the reductions in dyspnea.

The RWU was more effective as a precompetitive preparation than the SWU, despite the fact that the intensity and duration of the SWU was sufficient for increasing the body's temperature and inducing the temperature-related phenomena of warm-up, as evidenced by the profuse sweating of the subjects. However, the functional condition of the peripheral musculature is usually neglected in favor of the more centrally oriented adaptations, brought about by temperature increases. Blood flow to the muscles has been shown to increase depending on whether the muscle or muscle fibers (i.e., specificity of muscle fiber type recruited) was used before the main exercise (1). Therefore, it is possible that the specificity of the RWU in terms of race-pace intensity induced a more pronounced effect of blood flow elevation. Consequently, it could be speculated that both the improved muscle oxygenation and removal of metabolites induced by the increased blood flow might have contributed the improvements in performance after the RWU protocol.

Another speculation on the mechanisms responsible for the performance improvements that we observed might be that the intermittent nature of the RWU was more effective than the equicaloric continuous nature of the SWU in improving the mechanical efficiency and the power output, as suggested by previous reports (2,6). Therefore, although $\dot{V}O_2$peak was not different during the 6-min effort that followed each protocol, improvements in efficiency could have resulted in the observed improvements in power output during the 6-min all-out test after the RWU.

In summary, the RWUplus improved the subsequent performance in the 6-min all-out ergometer rowing effort more than the SWU and the RWU protocols. The mechanisms responsible for these improvements are probably associated with the concomitant decreases in dyspnea and inspiratory muscle fatigue. The principle of specificity of adaptive response is exemplified by our findings which suggest that the respiratory muscles should be adequately prepared for optimal performance.

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