col. These data are suggestive of respiratory muscle fatigue and are in agreement with previous reports of the effect of exhausting exercise upon respiratory muscle function [11,12, 19,22]. During rowing thoracic muscles are responsible not only for the act of breathing but also for the stabilisation of the thorax [6]. This additional role of respiratory muscles in the locomotive work of rowing might be the reason for the development of inspiratory muscle fatigue in such a short time compared with longer exercise durations reported previously. Even though the entrained breathing observed in rowing is suggestive of a possible scenario for respiratory muscle fatigue, no study has reported it previously. Clearly more work needs to be done in the breathing requirements of rowing to understand the functional significance of these findings.

The precise mechanism(s) responsible for the increase in MIP following the respiratory warm-up cannot be identified easily. A skeletal muscle warm-up has been reported to have an effect on maximum isometric force when the change in the muscle temperature is substantial [2,25]. However, since in the present study it was not possible to measure the temperature of the diaphragm or the intercostal muscles, we can only suggest that a temperature related effect, if any, was unlikely. This suggestion is justified under the assumption that the temperature of the diaphragm and the other inspiratory muscles is essentially equal to the core temperature because of their location.

Thus, by a process of elimination an altered motor control hypothesis is suggested. It is possible that the intermuscular coordination between inspiratory and expiratory muscles is improved in a manner similar to the one identified for other skeletal muscles [15]. Repeated performance of the specific recruitment pattern might decrease the degree of co-contraction known to exist between inspiratory and expiratory muscles at RV and consequently improve force generation.

The protocols used in the general warm-up and the rowing warm-up did not alter MIP. A possible explanation may be that, due to the modest ventilatory response elicited by the general warm-up, the threshold required for the respiratory muscles 'warm-up' was not achieved. However, during the rowing warm-up the ventilatory response was more pronounced, as can be seen from Table 3, but again MIP did not change. Comparing the breathing patterns of the two whole body warm-up protocols, we notice that thoracic excursions were of similar magnitude. The elevated minute volume of the rowing warm-up was effected through increases in breathing frequency as expected. These sub-maximal unloaded breathing patterns, predominantly characterised by diaphragm participation, are different from the pattern of a relative chest wall muscle recruitment observed during the Mueller manoeuvre [24]. Therefore, the recruitment pattern involved could be suggestive of a relative insensitivity of the Mueller manoeuvre to tension changes effected by diaphragm participation.

In contrast, during the respiratory warm-up the recruitment of the chest wall muscles is substantial, as loading compensation enhances the inspiratory activity of the external intercostal muscles. Furthermore, deliberate inspiratory efforts tend to make greater use of inspiratory intercostal muscles of the chest wall than do spontaneous metabolically stimulated inspirations [31]. It has often been observed in strength-training studies that increases in strength depend on how similar th strength test is to the actual training exercise in terms of mus cle fibre length and type of contraction [27]. Indeed, the re cruitment pattern of the Mueller manoeuvre is more simila to the pattern of the respiratory warm-up than the pattern o the two whole body warm-up protocols.

The rowing warm-up increased the peak torque measured during concentric knee extension and confirms its effectiveness as a preliminary activity. These data are also in agreement with previous reports on the beneficial effects of sport specific warm-ups [13,28]. The fact that the rowing warm-up failed to enhance MIP suggests that the respiratory muscles may not be optimally prepared before the start of a rowing race. Additionally, the possibility of a discrepancy between the work intensity required, for an enhanced function of the respiratory muscles and the muscles of locomotion, is raised. An improved functional capacity of the inspiratory muscles, as a result of the warm-up, may allow a decrease in recruitment requirements and minimise in doing so the sensation of breathlessness. Indeed, strong relationship between recruitment of the inspiratory muscles and the perception of dyspnea has been suggested [14]. More work is needed to investigate the potential effect of this upon the perception of breathlessness and rowing performance.

Finally, our data suggest that in the clinical and academic fields studies that examine the function of the inspiratory muscles under different treatment conditions should account for a 'warm-up' effect on baseline MIP. Indeed, studies examining postexercise inspiratory muscle fatigue might reveal that the degree of fatigue reported is larger than previously thought. Likewise, results from studies that have failed to observe the presence of fatigue may have done so because it was masked by the 'warm-up' effect.

Conclusions

A warm-up phenomenon, similar to the one present in locomotion, exists in the inspiratory muscles. This enhancement is more effectively elicited by specific inspiratory manoeuvres than by whole body warm-up protocols.

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