Specific respiratory warm-up improves rowing performance and exertional dyspnea

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ABSTRACT

VOLIANITIS, S., A. K. MCCONNELL, Y. KOUTEDAKIS, and D. A. JONES. Specific respiratory warm-up improves rowing performance and exertional dyspnea. *Med. Sci. Sports Exerc.*, Vol. 33, No. 7, 2001, pp. 1189–1193. **Purpose:** The purpose of this study was a) to compare the effect of three different warm-up protocols upon rowing performance and perception of dyspnea, and b) to identify the functional significance of a respiratory warm-up. **Methods:** A group of well-trained club rowers ($N = 14$) performed a 6-min all-out rowing simulation (Concept II). We examined differences in mean power output and dyspnea measures (modified CR-Borg scale) under three different conditions: after a submaximal rowing warm-up (SWU), a specific rowing warm-up (RWU), and a specific rowing warm-up with the addition of a respiratory warm-up (RWUplus) protocol. **Results:** Mean power output during the 6-min all-out rowing effort increased by 1.2% after the RWUplus compared with that obtained after the RWU ($P < 0.05$) which, in turn, was by 3.2% higher than the performance after the SWU ($P < 0.01$). Similarly, after the RWUplus, dyspnea was 0.6 ± 0.1 ($P < 0.05$) units of the Borg scale lower compared with the dyspnea after the RWU and 0.8 ± 0.2 ($P < 0.05$) units lower than the dyspnea after the SWU. **Conclusion:** These data suggest that a combination of a respiratory warm-up protocol together with a specific rowing warm-up is more effective than a specific rowing warm-up or a submaximal warm-up alone as a preparation for rowing performance.

Key Words: WARM-UP, PERFORMANCE ENHANCEMENT, RESPIRATORY SENSATION, INSPIRATORY MOUTH PRESSURE, RESPIRATORY FATIGUE

Warm-up may be defined as any preliminary activity that is used to enhance physical performance and to prevent sports-related injuries. There are various types of warm-up techniques that competitors use to prepare for their event. The most widely used methods are classified as passive, general, and specific warm-up (23).

Competitive rowing is considered to be one of the most physiologically demanding sports, as rowers work near their maximal physical capacities and recruit a very large muscle mass. Open class rowers generate among the highest values of any athletes in selected physical fitness parameters, including those related to cardiorespiratory and muscular function (14). Warm-up is an integral part of the preparation before the start of the race.

Most general warm-up protocols are of moderate intensity and characterized by a low ventilatory demand (12). In competitive rowing, however, a higher intensity specific warm-up usually follows the general warm-up in an attempt to practice the racing pace (7). The higher intensity of the specific warm-up, among other peripheral adaptations, elicits an elevated ventilatory response that may prepare the respiratory muscles for the demanding entrained breathing of rowing (17,24). However, a recent report has showed that a specific respiratory warm-up protocol is more effective in enhancing inspiratory muscle strength than a whole body specific rowing warm-up protocol (26).

The purpose of this study was a) to compare the effect of three different warm-up protocols, and b) to identify the functional significance of the respiratory warm-up, in terms of rowing performance and perception of dyspnea.

METHODS

Subjects. Fourteen competitive club rowers (7 male) participated in the study after giving informed written consent approved by the local Ethics Committee. One of the subjects was removed from the study because he developed a respiratory tract infection within 2 wk of the data collection, a condition known to have potential effects on respiratory muscle strength (19). Subject characteristics are shown in Table 1.

Procedure. Before data collection, all subjects visited the lab on two occasions to be familiarized with mouth pressure, spirometry, and dyspnea measurements. The subjects performed three different warm-up protocols, on different occasions, followed by an assessment of rowing performance. The three protocols were a submaximal rowing warm-up (SWU), a specific rowing warm-up (RWU), and the same specific rowing warm-up with the addition of a respiratory warm-up (RWUplus). The respiratory warm-up was performed using a pressure threshold inspiratory muscle-training device (POWERbreathe®, IMT Technologies Ltd., Birmingham, UK). Rowing performance was assessed with a 6-min all-out effort, on a rowing ergometer (model c,

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TABLE 1. Group characteristics (mean ± SD).

	Male (N = 7)	Female (N = 7)
Age (yr)	19.9 ± 0.7	20.1 ± 0.9
Height (cm)	181.6 ± 5.8	174.7 ± 2.3
Weight (kg)	78.0 ± 10.7	62.9 ± 4.2
FVC (1)	5.7 ± 0.9	4.2 ± 0.3
FEV_1 (1)	4.8 ± 0.8	4.5 ± 0.5
FEV_1/FVC (%)	84.7 ± 7.0	88.3 ± 6.3
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	61.3 ± 9.0	54.3 ± 2.1

Concept II, Nottingham, UK), as the maximum oxygen uptake ($\dot{V}O_{2max}$) and average power output obtained from this test are strongly related to competitive rowing (22). After SWU, the same all-out rowing effort was duplicated on two separate occasions, in order to evaluate the reproducibility of our protocol. Mouth pressure and spirometry measurements where made before and after every protocol. The heart rate was telemetrically monitored with Polar Accurex Plus heart rate monitor (Polar Electro, Kempele, Finland).

Maximum inspiratory pressures (MIP). MIP is commonly used to measure inspiratory muscle strength. It reflects the force-generating capacity of the combined inspiratory muscles during a brief, quasi-static contraction (Mueller maneuver) (15). MIP was recorded using a portable hand-held mouth pressure meter (Precision Medical, London, UK). This device has a constant leak to preclude spurious results, due to closure of the glottis and activity of buccal muscles, and has been shown to measure inspiratory efforts accurately and reliably (8). A minimum of five and a maximum of nine technically satisfactory measurements were conducted, and the highest of three measurements with 5% variability or within 5 cm H_2O difference was defined as maximum (28). The initial length of the inspiratory muscles was controlled by initiating each effort from residual volume (RV). This procedure was adopted because, from our experience, RV is more reproducible than functional residual capacity (FRC). Subjects were instructed to take their time and to slowly empty their lungs to RV, thereby avoiding problems associated with variability in lung volumes. All maneuvers were performed in the upright standing position, and verbal encouragement was given to assist the subjects perform maximally. MIP was measured after each warm-up protocol and after the 6-min all-out effort. During the RWUplus protocol, MIP was also measured before and after the specific respiratory warm-up to evaluate its efficacy.

Static spirometry. Pulmonary function was assessed with a Vitalograph 2120 portable spirometer (Vitalograph Ltd., Buckingham, England), which was calibrated before each testing session by using a 3-L calibration syringe (Hans Rudolph Inc., Kansas City, MO). After familiarization, the best of three maneuvers were recorded. Forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), and percentage expired (i.e., 100 × FEV_1/FVC)(FEV1%) were recorded before and after every treatment condition.

Respired gas analysis. Breath-by-breath gas analysis was made with an MGA 2000 Mass Spectrometer (Airspec Ltd., Kent, UK) in conjunction with an ultrasonic phase-shift flowmeter (Birmingham Flowmetrics, Birmingham, UK). Data processing was performed on-line (Labview 3, National Instruments, Austin, TX) on a PowerMac 7100/80 computer (Apple Computer Inc., Cupertino, CA). Calibration of the flowmeter was performed before each test using a 1-L calibration syringe (PK Morgan Ltd., Kent, UK).

Submaximal warm-up (SWU). Eight minutes of submaximal rowing at about 65–70% of the subjects' best previously measured power output during a 6-min all-out effort was performed. The stroke rate was controlled between 22–24 strokes·min^{-1}. After the 8-min warm-up, there was 3 min of rest before the commencement of the 6-min all-out effort. This protocol has been routinely used for physiological assessment of rowers (two stage test) (25). All subjects were familiar with the 6-min all-out effort on the rowing ergometer as part of their training.

Rowing warm-up (RWU). The protocol was designed to mimic as closely as possible the routine that is usually adopted in preparation for a rowing race. Five minutes of very light jogging on the treadmill, at a heart rate of 110–130 beats·min^{-1}, were followed by 10 min of stretching. Subsequently, 12-min rowing of gradually increasing intensity was performed during which the heart rate increased from 148 (± 2) to 178 (± 1.7) beats·min^{-1}. The increase in intensity was achieved primarily by increasing the stroke rate. Then, five sprints with increasing stroke rate and power output were performed. Between each sprint, there was an active rest interval of light paddling, which lasted approximately 2 min. At the end of the sprints, the rower rested for about 5–7 min before any further measurements were made. This rest interval was designed to simulate the small pause between the end of the warm-up and the start of the race. Details of the structure of the rowing warm-up can be seen in Table 2. This warm-up protocol has been shown to effectively enhance the isokinetic strength of peripheral musculature (26). Breath-by-breath gas analysis and heart rate data were collected throughout.

Rowing warm-up plus respiratory warm-up (RWUplus). RWUplus was a combined protocol consisting of a RWU and a specific respiratory warm-up. The specific respiratory warm-up consisted of two sets of 30 breaths using a POWERbreathe® inspiratory muscle trainer (IMT Technologies Ltd.) at 40% of the MIP measured before the start of the protocol. Between the two sets, there was a short rest interval while an inter-

TABLE 2. Description of the rowing warm-up on the rowing ergometer.

Warm-up (time)	Stroke rate/min	Percent Power Max (% Pmax)
1 × 12 min (4-4-3-1)	18-20-22-24	50-55-57-62
2 × 30s	26-28	77 (±5)–80 (±2)
2 × 45s	28	91 (±6)–95 (±2)
1 min	30-32	108 (±9)

% Pmax, percentage of maximum power output achieved during 6-min all-out test.

TABLE 3. Coefficients of variation for selected parameters related with the 6-min all-out test.

	CV %
MIP decrease (%)	10.1 ± 2.7
Power (W)	0.36 ± 0.12
Dyspnea	1.7 ± 0.7
$\dot{V}O_2$ (L)	1.4 ± 0.7
$\dot{V}E$ (L)	3.2 ± 0.3

mediate MIP measurement was made. Forty percent of maximum capacity has been suggested to approximate the upper loading limit before fatigue of the diaphragm occurs (20). POWERbreath® is a pressure-threshold device that requires continuous application of inspiratory pressure throughout inspiration in order for the inspiratory regulating valve to remain open. As with the maximal inspiratory pressures, subjects were instructed to initiate every breath from RV. They continued the inspiratory effort up to the lung volume where the inspiratory capacity for the given resistance limited further excursion of the thorax. Powerful execution of the maneuvers was encouraged to ensure maximal voluntary output for the given loading conditions. Because of the increased tidal volume, a decreased but spontaneous breathing frequency was adopted by the subjects in order to avoid hyperventilation. This breathing pattern resulted in a very low duty cycle (inspiratory time/total breath duration) and further ensured that fatigue was avoided. The respiratory warm up was performed before the RWU. This protocol has been shown to enhance the strength of the inspiratory muscles (26).

Perception of dyspnea. A category scale, the modified Borg (3) scale, was chosen to evaluate the respiratory effort during exercise. The scale consists of a series of integers from 0 to 10. The rower was asked to estimate the effort required to breath but not the effort of the exercise. During rowing, the Borg scale remained in front of the rower, and an assessment immediately followed the all-out effort. The rowers were asked to assess their dyspnea retrospectively, i.e., during the 6-min effort.

Statistical analyses. One-way ANOVA with repeated measures and Bonferroni *post hoc* test were used to assess differences between the three different warm-up protocols and between the MIP values before and after the different warm-up protocols. Pearson's correlation coefficient was used to assess the association between variables. Values of $P < 0.05$ were considered statistically significant. Data points were means (± SE) unless otherwise stated.

RESULTS

Test-retest reliability of the 6-min all-out effort. Reliability was expressed as a coefficient of variation, (SD/mean) × 100; for mean power, this was 1.4% and the retest correlation was 0.99 (see Table 3).

MIP response to the respiratory warm-up. The respiratory warm-up was effective in enhancing the strength of the inspiratory muscles. MIP increased by 7.0 (± 1.0) % from baseline values.

Inspiratory muscle fatigue. After the 6-min all-out rowing effort, MIP was lower for all three protocols. After the SWU and the RWU, the deficits in inspiratory muscle strength were 10.2 (± 1.4) and 11.1 (± 1.3)%, respectively. In the RWUplus protocol fatigue was significantly reduced to 4.2 (± 0.3)% ($P < 0.01$) compared with the other two warm-up protocols (see Fig. 1).

Rowing performance. As can be seen from Table 4, power output in the 6-min all-out test was 3.2% higher after the RWU compared with power output after the SWU ($P < 0.01$). After the RWUplus, power output increased significantly a further 1.2% compared with the power output after the RWU ($P < 0.05$). The distances covered in meters were increased by 11 (± 15) m ($P < 0.05$) and 18 (± 13) m ($P < 0.01$) after the RWU and RWUplus protocols, respectively, compared with the SWU protocol. There were no significant differences between any gas exchange parameters.

Perception of dyspnea. The perception of dyspnea during the 6-min all-out effort was not statistically different between the SWU and RWU protocols. However, it was significantly decreased after the RWUplus protocol by 0.8 (± 0.3) and 0.6 (± 0.3) units of the Borg scale compared with the SWU and RWU protocols, respectively ($P < 0.05$; see Table 4). Even though none of the parameters related to the 6-min all-out effort were significantly correlated, the association between changes in dyspnea and improvements in power output gave an r = 0.474, which accounts for 22.5% of the variance.

DISCUSSION

The main finding of this study was that a specific respiratory warm-up has a significant impact upon rowing performance. Indeed, the RWUplus was more effective as a preparatory and warm-up routine for the 6-min all-out effort than both the RWU alone and the SWU protocols.

Reproducibility data for the 6-min all-out effort are in agreement with previous reports, suggesting that this test is very reliable and suitable for monitoring rowing performance (9,21). Indeed, high reproducibility was observed in

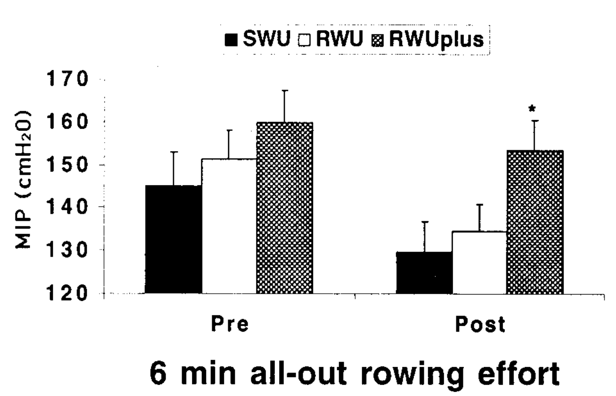

FIGURE 1—Maximum inspiratory pressures (MIP) in cm H_2O before and after the 6-min all-out rowing test, for the three different warm-up protocols. Values are means (± SE); * ($P < 0.05$) significantly different reduction of baseline MIP from the two other conditions.

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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results of the present study do not contribute endorsement of the product by the authors or ACSM.

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