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 (l)	5.7 ± 0.9	4.2 ± 0.3
FEV_1 (l)	4.8 ± 0.8	4.5 ± 0.5
FEV_1/FVC (%)	84.7 ± 7.0	88.3 ± 6.3
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	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