



Fig. 1 Bland-Altman plot for reproducibility of baseline MIP between whole body warm-up protocols and respiratory warm-up.

## MIP

### Test – retest reproducibility of MIP

The two baseline measurements, i.e. before the whole body and respiratory warm-ups, permitted a test-retest assessment of MIP. For the comparison of baseline MIP values the data of both groups were pooled. The mean baseline MIP values of the whole body warm-up protocols and the respiratory warm-up were not significantly different, the mean difference being less than 5 cm H<sub>2</sub>O. The mean ( $\pm$  SE) coefficient of variation (CV = 100%  $\times$  SD/mean) for the baseline MIP measured on the two occasions was 4.65 ( $\pm$  0.76)%. Additional analysis using the Bland-Altman plot [6] (Fig. 1) revealed a repeatability coefficient of 26.6 cm H<sub>2</sub>O.

### Influence of maximal testing upon MIP

Immediately after the incremental cycling (peak  $\dot{V}O_2$ ) test MIP decreased by 2.2  $\pm$  3.0% from the baseline; this difference was not significant. After the incremental rowing (peak  $\dot{V}O_2$ ) test MIP decreased by 7.0  $\pm$  2.0% which was significant ( $P < 0.01$ ).

### Influence of whole body warm-up on MIP

For the comparison between whole body warm-up protocols the two groups have been analysed separately. After the general warm-up MIP increased from a baseline of 171.4 ( $\pm$  9.0) cm H<sub>2</sub>O to 178.8 ( $\pm$  12.6) cm H<sub>2</sub>O, a mean ( $\pm$  SE) percent increase of 3.4 ( $\pm$  2.5); this difference was not significant ( $p > 0.05$ ). After the rowing warm-up baseline MIP increased from a mean of 161.1 ( $\pm$  7.5) cm H<sub>2</sub>O to 162.8 ( $\pm$  10.7), a mean ( $\pm$  SE) percent increase of 0.3 ( $\pm$  3.2)% which again was not significant ( $p > 0.05$ ).

### Influence of respiratory warm-up on MIP

For the comparison of MIP values before and after the respiratory warm-up the data from the two groups were pooled. The respiratory warm-up induced a significant increase in MIP from a mean baseline of 171.2 ( $\pm$  7.0) cm H<sub>2</sub>O to 178.1 ( $\pm$  6.8) cm H<sub>2</sub>O after 30 breaths, a 4.5  $\pm$  1.1% increase ( $P < 0.001$ ). After 60 breaths the mean MIP increased further to 184.2 ( $\pm$  6.4) cm H<sub>2</sub>O, an additional significant increase of 3.8  $\pm$  1.3% ( $p < 0.01$ ). The total increase from baseline was 8.5  $\pm$  1.8% ( $p < 0.0001$ ).

Table 4 Mean (SE) percent changes between baseline and the three warm-up protocols. Results shown under respiratory warm-up are pooled data for both groups

	General (n = 12)	Rowing (n = 11)	Respiratory (n = 23)
MIP %	3.4 (2.5)	0.3 (3.2)	8.5 (1.8)*
FVC %	1.9 (2.4)	-1.0 (1.4)	1.0 (1.2)
FEV <sub>1</sub> %	-1.0 (1.3)	0.4 (0.9)	0.4 (0.9)
FEV <sub>1</sub> /FVC %	-1.3 (1.5)	1.4 (1.5)	1.4 (1.5)
PIFR %	-1.2 (2.3)	0.3 (3.1)	1.75 (2.1)

MIP = maximum inspiratory pressure, PIFR = peak inspiratory flow rate. \*Denotes significance ( $p < 0.0001$ )

## Lung function

There were no significant changes in the parameters measured other than MIP. Pulmonary function data obtained after the general, rowing and respiratory warm-ups are summarised in Table 4.

### Prediction of warm-up effect

Post-respiratory warm-up MIP was significantly correlated with the baseline MIP ( $p < 0.001$ ), and this relationship can be described by the two linear models on Table 5, derived from data taken after the two sets of 30 breaths of the respiratory warm-up.

Table 5 Predictive equations for MIP

Respiratory warm-up	R <sup>2</sup>	Regression equation
30 breaths	0.9409	$y = 0.9344x + 18.099$
60 breaths	0.8667	$y = 0.8506x + 38.539$

## Discussion

The main finding of this study was that MIP increased significantly following the respiratory warm-up but not following the two whole body warm-up protocols. This phenomenon, which emerges with at least 30 breaths using POWERbreath<sup>®</sup>, raises the possibility that the respiratory system may have different warm-up requirements (threshold) than the locomotor system.

Emphasis was given to the methodological issues related with the Mueller manoeuvre. The variability in MIP between baselines is in agreement with previous reports on test-retest reproducibility [17]. The mean coefficient of variation, which was smaller than reported previously [1.4, 32], as well as the coefficient of repeatability from the Bland-Altman plot, which is in agreement with the study of Maillard and others [21], suggest that the task learning effect was expressed and reliable baselines were established.

Another interesting observation was that following the incremental rowing test to exhaustion MIP decreased, whilst no significant changes occurred after the incremental cycling proto-