

Estimation of *intrinsic* PEEP from plethysmographic alveolar pressure tracing in COPD patients

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Background

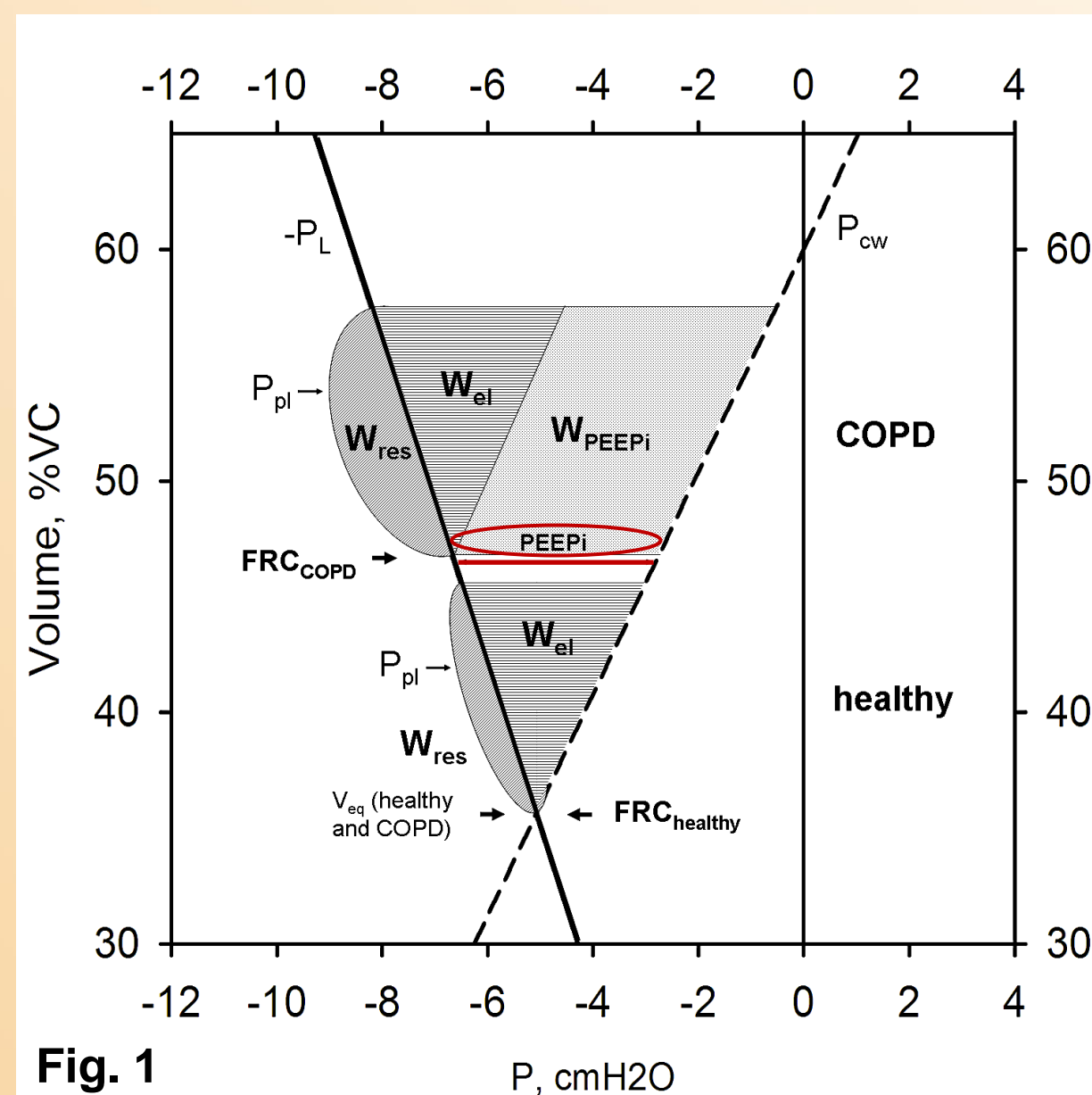


Fig. 1

W_{res} = resistance; W_{el} = elastance of lung and chest wall; P_{pl} = pleural pressure

- ▶ In healthy subjects, functional residual capacity (FRC) is equal to the equilibrium volume (V_{eq}).
- ▶ In patients with *chronic obstructive pulmonary disease (COPD)*, increased expiratory resistances cause FRC to be greater than V_{eq} and the alveolar pressure immediately before the subsequent inspiration to be positive (*intrinsic positive expiratory pressure, PEEPI*).
- ▶ The presence of PEEPI (red line in Fig. 1) is responsible for adverse respiratory and haemodynamic effects, such as increased work of breathing, contributing to muscle fatigue and dyspnoea, and depressed cardiac output.

- ▶ During spontaneous breathing, PEEPI can be assessed with *oesophageal pressure recordings*, but due to the invasiveness of the procedure, it is not routinely measured in clinical practice.
- ▶ Using a modern plethysmograph, it is possible to estimate alveolar pressure (P_{alv}) during the breathing cycle and, theoretically, to assess PEEPI non invasively directly on the alveolar pressure tracing.

Aims

- ▶ The aim of the study was to develop and test an *algorithm able to identify PEEPI on the plethysmographic P_{alv} tracing*, in COPD patients spontaneously breathing.
 - Development of the algorithm was based on the assumption that young healthy subjects breathing spontaneously at rest should not exhibit PEEPI, while this is often the case in COPD patients with *tidal expiratory flow-limitation (FL)* at rest.
 - The algorithm was tested by measuring PEEPI in older healthy subjects, and in flow-limited (FL) and non flow-limited (non-FL) COPD patients, expecting that the majority of older healthy subjects will not show PEEPI, while in non-FL COPD patients, PEEPI might or might not be present.
 - The algorithm was further validated in COPD patients after the administration of a bronchodilator, to assess whether the algorithm was able to detect the expected fall of PEEPI [Dal Vecchio et al., 1990].

Methods

- ▶ In 20 young and 22 elderly healthy subjects, and in 60 COPD patients, static and dynamic lung volumes, and airway resistances were measured with a constant-volume plethysmograph (MasterScreen Body Plethysmograph, Erich Jaeger GmbH, Würzburg, Germany), during spontaneous breathing at rest.
- ▶ FL was assessed by means of the *negative expiratory pressure method* [Koulouris et al., 1995].
- ▶ In COPD patients, lung function parameters and FL assessment were repeated after administration of a short acting β_2 -agonist (salbutamol).

Data analysis

- ▶ During plethysmographic resistance measurement, shift-volume (ΔV_s) was recorded, and converted into $P_{alv,t}$ (Eq. 1):
$$P_{alv,t} = - \frac{P_B \Delta V_{s,t}}{(V_{rs,t} + \Delta V_{s,t})}$$
- ▶ 10 consecutive breaths from each subject were analysed with a custom-built LabView program (National Instruments, Austin, TX, USA) and averaged to obtain a representative breath for each subject.

Plethysmographic criteria for PEEPI

- ▶ PEEPI was identified as the P_{alv} at the beginning of the sudden drop of alveolar pressure occurring immediately before the next inspiration (Fig. 2).

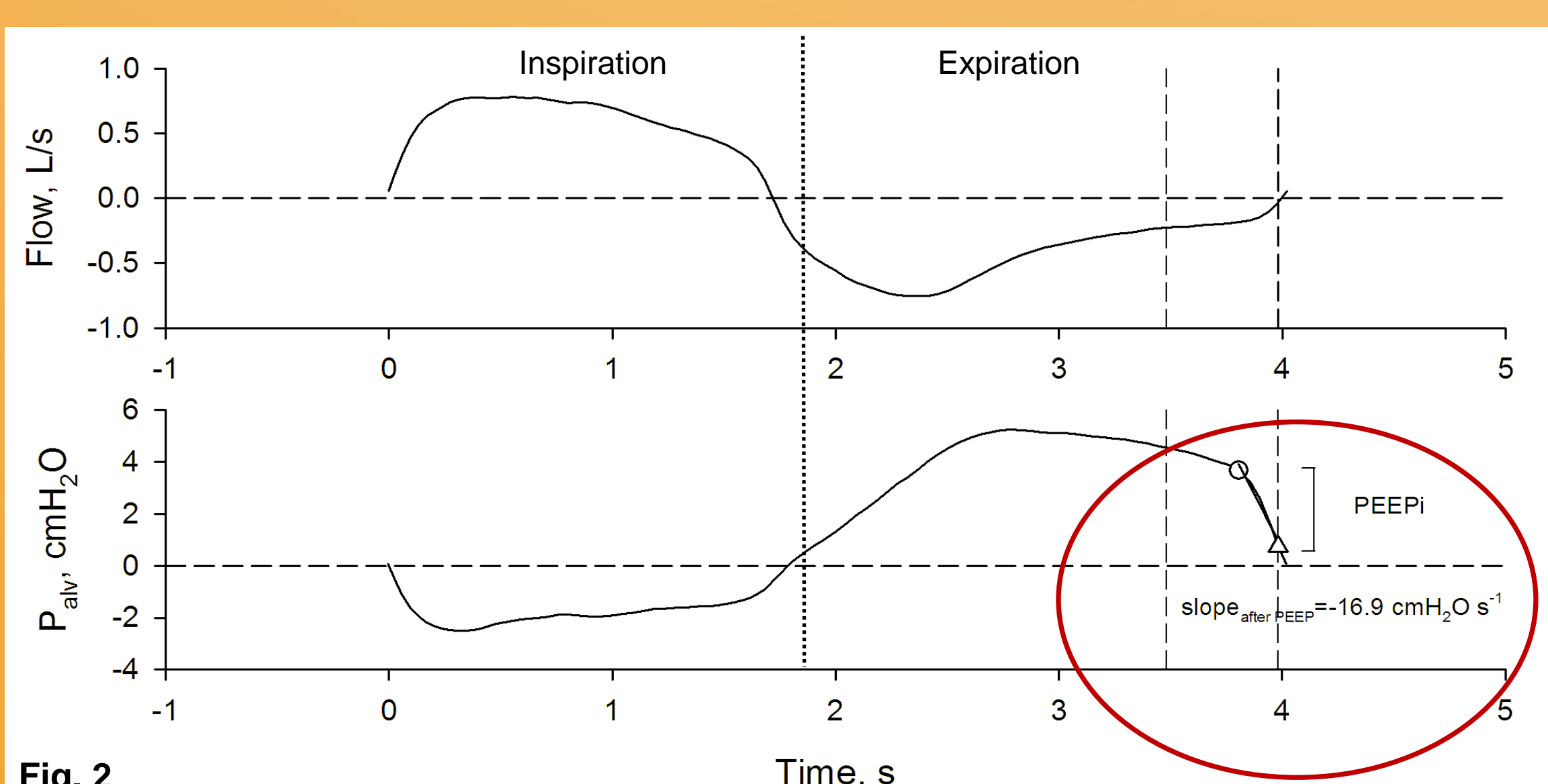


Fig. 2

- ▶ The drop of P_{alv} was characterized by the slope of the time- P_{alv} tracing, from PEEPI to the end of expiration ($SLOPE_{afterPEEPI}$) (Fig. 2).
- ▶ A cut-off value for the $SLOPE_{afterPEEPI}$ was chosen as the value better discriminating between healthy young and FL COPD subjects: the threshold was $< -10.0 \text{ cmH}_2\text{O}\cdot\text{s}^{-1}$ (Fig. 3).
- ▶ Additionally, it was required that the decompression from PEEPI to the end of expiration lasted *less than 0.22 sec*, in accordance with previous studies.

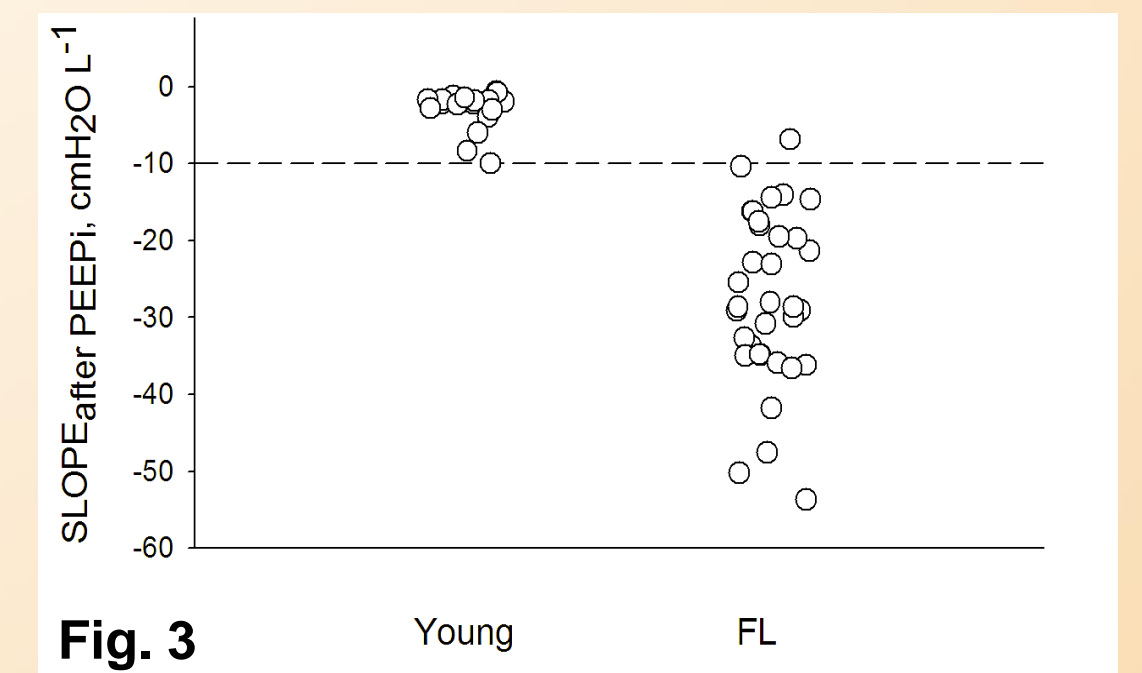


Fig. 3

- ▶ Unless specified, all results are shown as median (IQR). Statistical significance was taken at $p \leq 0.05$.

Results

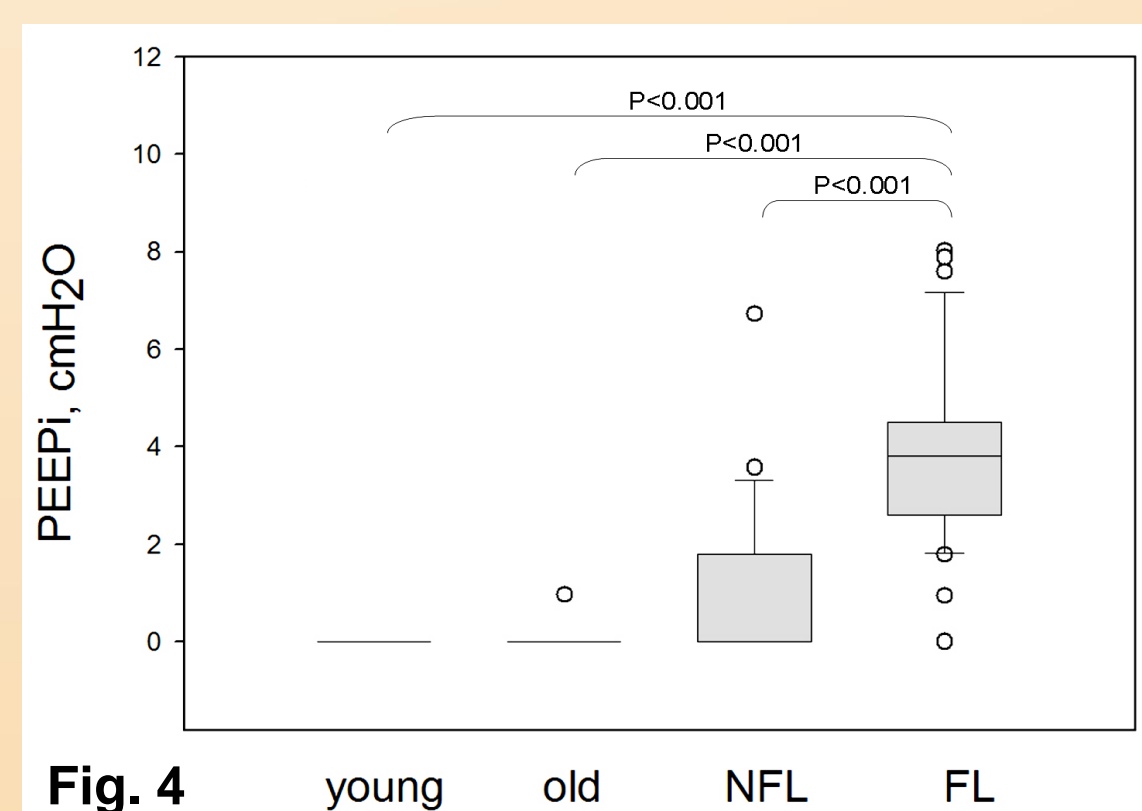


Fig. 4

- ▶ As expected, PEEPI was not detected in healthy controls, except for one elderly subject (Fig. 4).
- ▶ Almost all FL and about half of non-FL COPD patients exhibited PEEPI.
- ▶ Overall, PEEPI in FL COPD patients was significantly higher than in those without FL (3.8 (1.8) vs 0.0 (6.7) cmH_2O).

- ▶ Plethysmographic PEEPI values appeared comparable to results previously obtained in COPD patients with similar disease severity using the oesophageal pressure technique by Haluszka et al., 1990 (Fig. 5) and Dal Vecchio et al., 1990.
- ▶ The present plethysmographic PEEPI also shared the same correlations previously reported for oesophageal PEEPI.

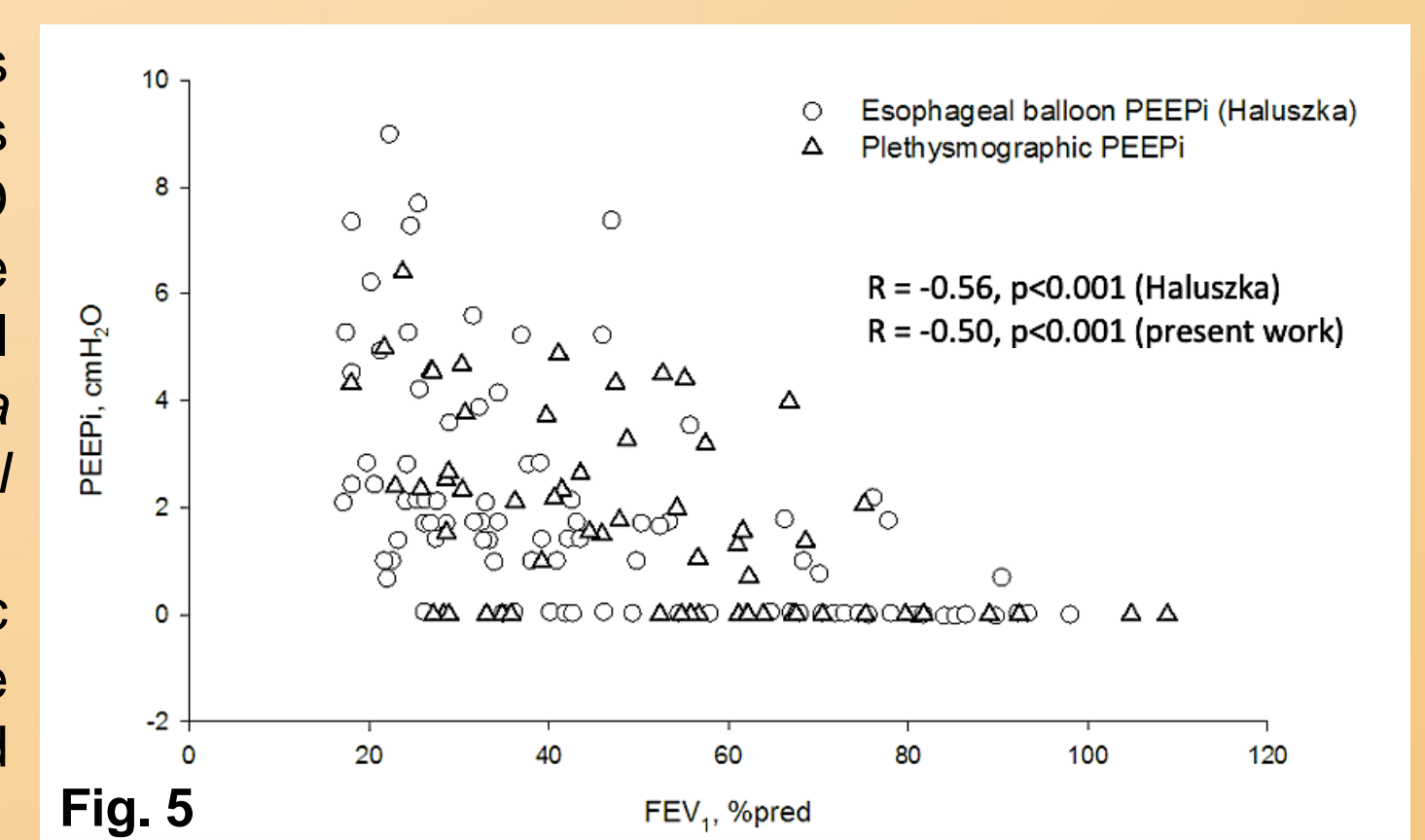


Fig. 5

- ▶ After bronchodilation, PEEPI decreased significantly in both COPD groups, especially in those with FL ($\Delta = -1.1$ (2.0) cmH_2O , $p < 0.001$ in FL, $\Delta = -0.9$ (2.0) cmH_2O , $p = 0.050$ in non-FL) (Fig. 6 panel A and B). This is in accordance with data previously reported after bronchodilation [Dal Vecchio et al., 1990].

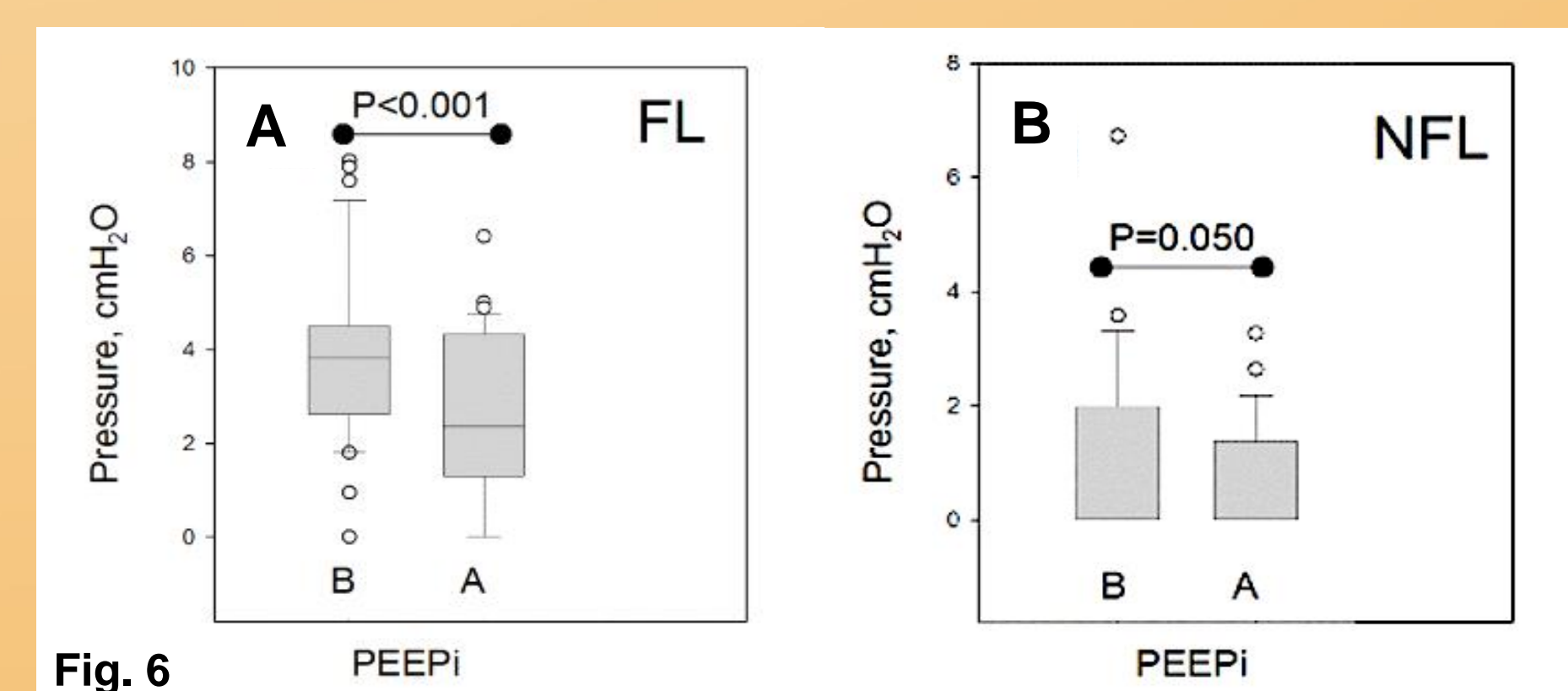


Fig. 6

B and A below the boxplots = before and after bronchodilation

Discussion

- ▶ Estimation of PEEPI with a commercially available plethysmograph seems to provide results comparable to those previously obtained with the oesophageal technique, with the advantage of being non invasive.
- ▶ The plethysmographic assessment of PEEPI may become a valuable and safe tool to provide a better *phenotypization* of the mechanical alterations in COPD patients, and to tailor the therapeutic management in this population.
- ▶ Additionally, the non invasive determination of PEEPI could be used to *titrate external PEEP* in patients requiring assisted mechanical ventilation.
- ▶ These results should be confirmed by a direct comparison of the plethysmographic and oesophageal PEEPI, recorded at the same time.

References

- ▶ Dal Vecchio, L., Polese, G., Poggi, R., Rossi, A., 1990. "Intrinsic" positive end-expiratory pressure in stable patients with chronic obstructive pulmonary disease. Eur. Respir. J. 3, 74–80.
- ▶ Haluszka, J., Chartrand, D.A., Grassino, A.E., Milic-Emili, J., 1990. Intrinsic PEEP and Arterial PCO_2 in Stable Patients with Chronic Obstructive Pulmonary Disease. Am. Rev. Respir. Dis. 141, 1194–1197.
- ▶ Koulouris, N.G., Valta, P., Lavoie, A., Corbeil, C., Chass, M., Braidy, J., Milic-Emili, J., 1995. A simple method to detect expiratory flow limitation during spontaneous breathing. Eur. Respir. J. 8, 306–313.