ONLINE DATA SUPPLEMENT

MEASUREMENT OF TIDAL BREATHING FLOWS IN INFANTS BY USING IMPEDANCE PNEUMOGRAPHY

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METHODS

Signal filtering

The complete signal acquisition and processing chain from the measurement electronics to computer post-processing software was designed to maintain flat frequency response at frequencies below 10 Hz as recommended by an ERS/ATS task force [1]. Furthermore the chain was designed not to introduce phase lag. All conventional linear signal filters applied to signal were applied in a double forward-backward manner (which is possible because processing is done after measurement, not online) which cancels any phase lag that could have been introduced by them. The cardiogenic oscillation removal is based on the principle of ensemble averaging and does not, by its nature, introduce phase distortions.

The Savitzky-Golay digital differentiator used to derive the flow signal from the volume signal has the properties of a type III filter thus having a linear phase response and thus not introducing any lag between flow and volume [2].

Estimation of agreement between IP and PNT

The agreement between IP flow signal $\dot{V}_{\mathrm{IP}}$ and PNT flow signal $\dot{V}_{\mathrm{PNT}}$ for each measurement was analyzed as described earlier [3]. As a measure of the average difference between the two signals, the sample-by-sample absolute difference signal was estimated by $d(n) = \left|\dot{V}_{PNT}(n) - \dot{V}_{IP}(n)\right|,\ n = 1 \ldots m$, where *n* is sample number and *m* is signal length, and presented as the median of *d* for each measurement as D_{SS}. This gives a measure of the average difference between the two signals, but does not contain information whether the difference is distributed randomly or related to the phase of respiratory cycle. In order to characterize the linearity between IP and PNT with respect to flow rate the value pairs $\dot{V}_{\mathrm{IP}}(\mathrm{n})$ and $\dot{V}_{\mathrm{PNT}}(\mathrm{n})$ were plotted for each sample, fitting a line to the distribution and assessing the distance from the line for each sample, as illustrated in Figure 1. The

distances were divided into 10 inspiratory and 10 expiratory bins according their respective values of $\dot{V}_{PNT}(n)$ and the deviation from linearity of each bin *m* was represented by the median of the sample distances in it as $D_{bin,m}$ (Fig. 2). The average deviation from linearity D_L was calculated as the mean of absolute values of all $D_{bin,m}$. In addition, the largest single deviation D_{max} was assessed individually. For each measurement the $\dot{V}_{IP}$ and $\dot{V}_{PNT}$ signals were normalized such that 100 % flow means the median tidal peak inspiratory flow (TPIF) encountered during that measurement.

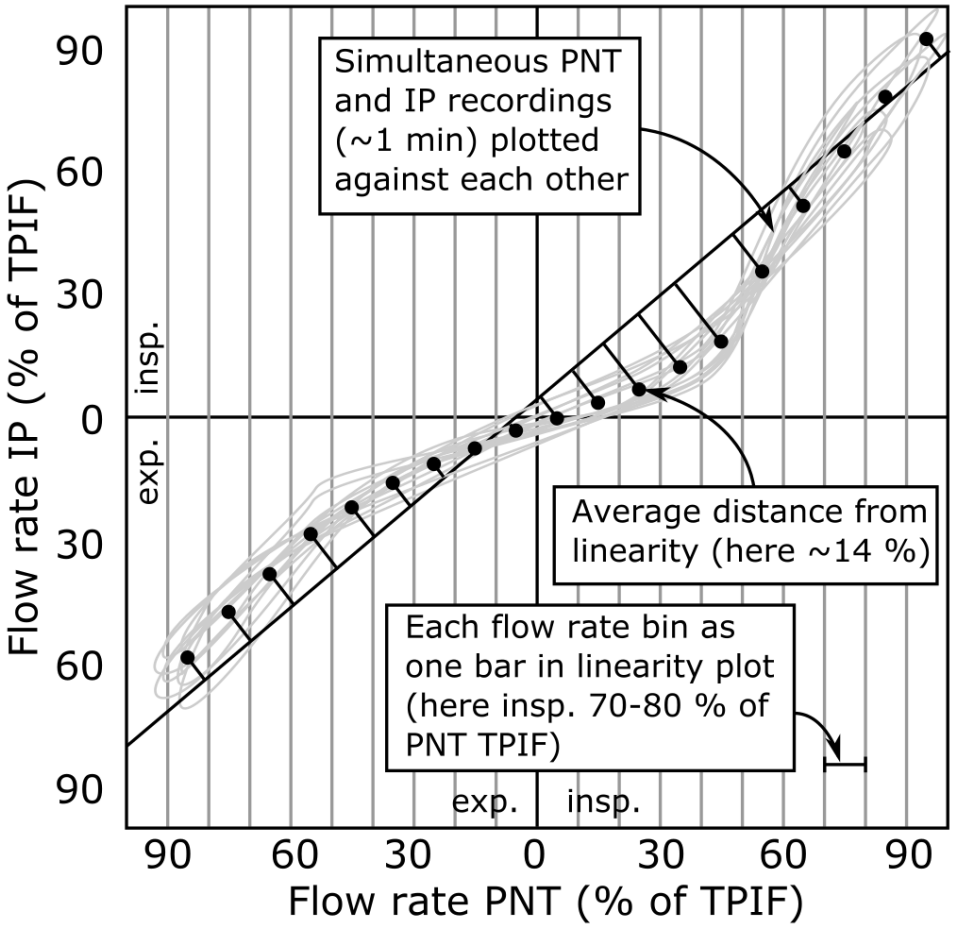

Figure 1. Illustration of the method estimating linearity between pneumotachograph (PNT) and impedance pneumography (IP) flow rate signals. For each measurement sample the distance (deviation) from a fitted line is calculated and the median value (black dots) of the deviations is provided in each 25% flow range. Each measured flow signal was normalized to 100%, representing median tidal peak inspiratory flow (TPIF).

RESULTS

Repeatability of tidal breathing parameters

The repeatability of TBFV parameters for PNT and IP at baseline were also illustrated by Bland Altman plots (Fig. 2). In terms of coefficient of repeatability, the repeatability was similar for PNT (0.10 for T_{PTEF}/T_E and 0.10 for V_{PTEF}/V_E) and for IP (0.11 for T_{PTEF}/T_E and 0.11 for V_{PTEF}/V_E).

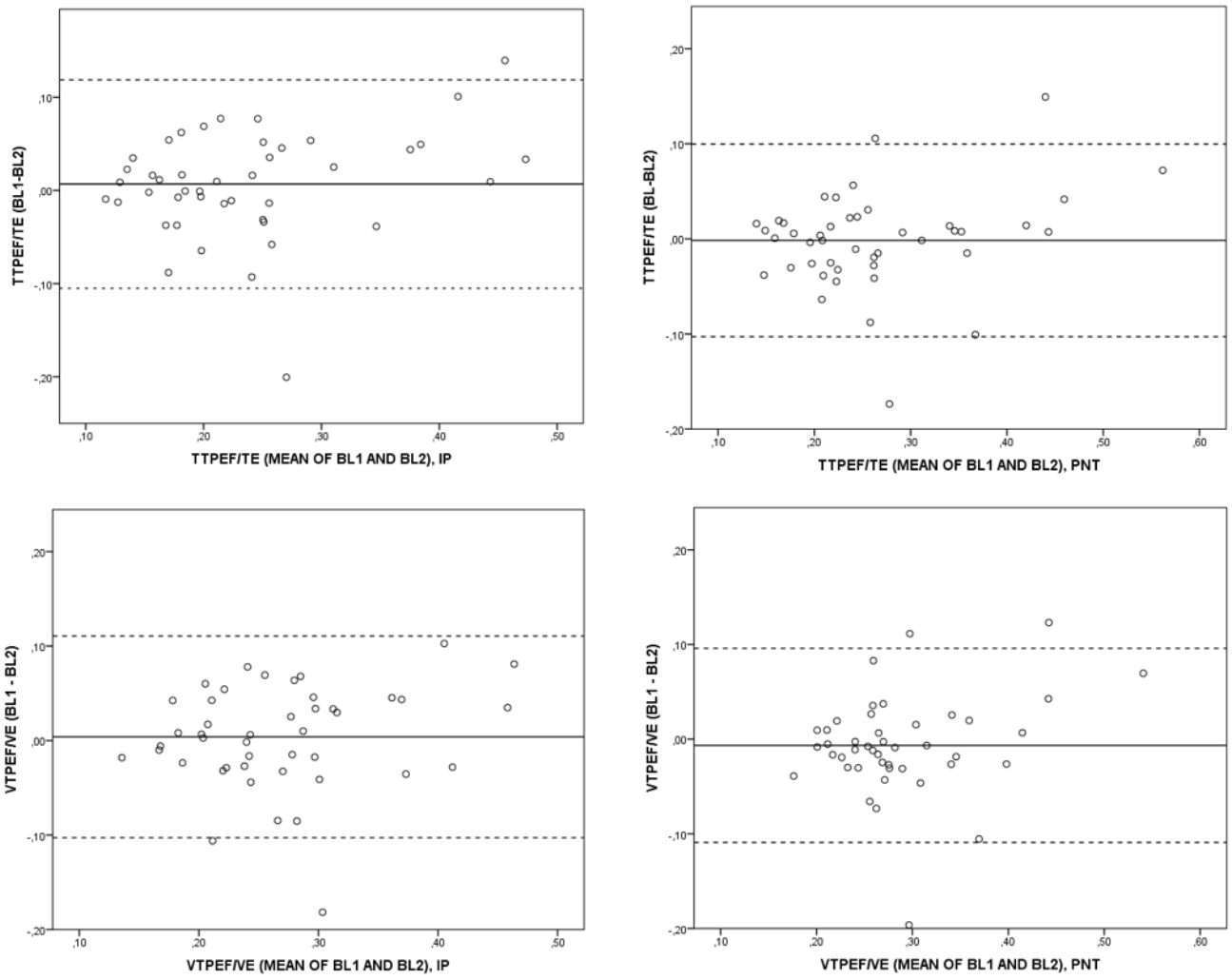

Figure 2. Bland Altman plots for the repeatability of the tidal breathing parameters between baseline measurements BL1 and BL2.

Agreement between IP and PNT in clinical groups

The distribution of the difference between PNT and IP flow signals was slightly dependent on the respiratory cycle phase, and in the clinical groups, characteristic patterns were observed (Fig. 3). In the group with UAO, deviation from linearity was predominantly inspiratory, whereas in infants with LAO, a deviation during expiratory phase seemed also evident. The most striking differences between PNT and IP flow signals were noted in two infants with laryngomalacia (maximal inspiratory deviation 30-48 % of TPIF), who had severely reduced sG_{aw} (z-scores below -4).

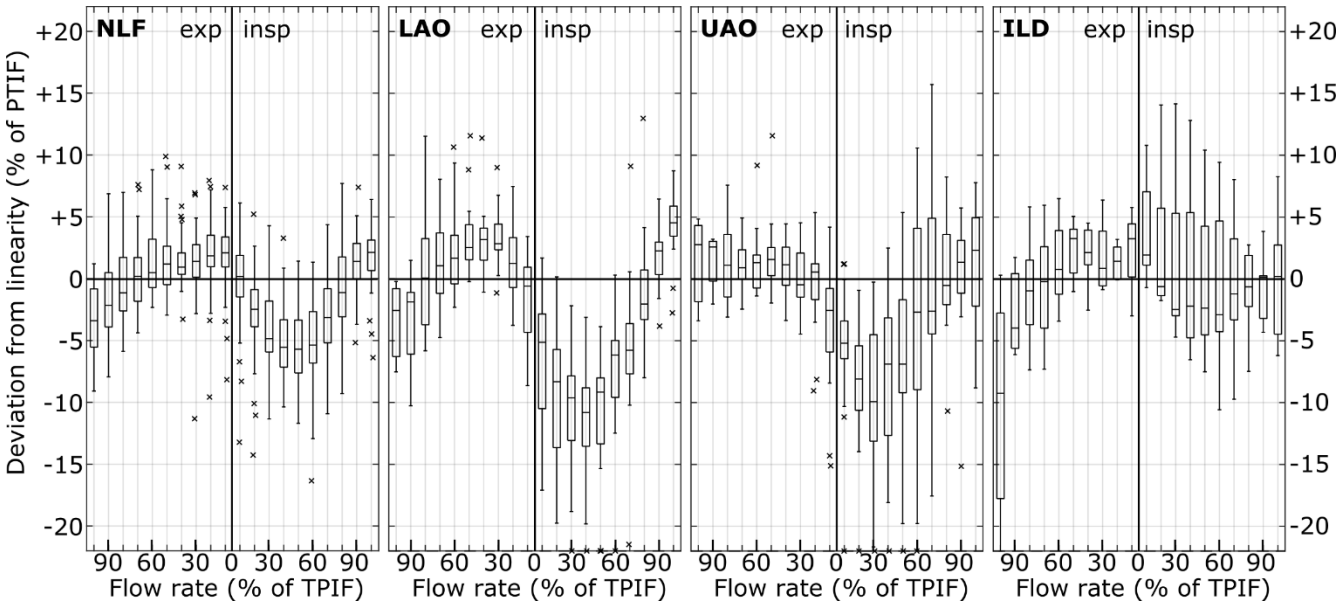

Figure 3. The linearity between PNT and IP in simultaneous flow rate measurement in different clinical groups. The boxes denote the 25th-75th percentiles, the middle lines denote the median, and the whiskers extend to extreme values excluding outliers (crosses). NLF=normal lung function; LAO=lower airway obstruction; UAO=upper airway obstruction; ILD=interstitial lung disease.

REFERENCES

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3. Seppä V-P, Pelkonen AS, Kotaniemi-Syrjänen A, Mäkelä MJ, Viik J, Malmberg LP. Tidal breathing flow measurement in awake young children by using impedance pneumography. *J Appl Physiol* 2013: 115: 1725-1731.