Accuracy, precision and linearity of the portable flow-volume meter Microspiro HI-298®

E. Dompeling*, C.P. van Schayck*, H. Folgering**, H.J.M. van den Hoogen*, C. van Weel*


ABSTRACT: The accuracy, precision and linearity of a new portable flow-volume meter, the Microspiro HI-298® (Chest Corporation, Tokyo, Japan), was investigated using a Fleisch no. 4 pneumotachograph as a standard. After connection and calibration of the pneumotachograph and the Microspiro, a healthy subject performed 44 forced vital capacity (FVC) manoeuvres at different levels of lung inflation. The FVC of these expirations ranged from 2.5–5.1 l. Linear regression of Microspiro values (dependent variable) on Fleisch pneumotachograph values (independent variable) showed that a good linear relationship existed: Pearson correlation coefficients ranged from 0.938–0.985. Linearity of the Microspiro was good except for the peak expiratory flow rate (PEFR) and the maximal expiratory flow at 25% of the expired volume (MEF25). The random error (measure of precision) of all flow-volume (F-V) indices was lower than 5%. The systematic error (measure of accuracy) was low for the forced expiratory volume in one second (FEV1) and the FVC (1% and 4.6%, respectively) but much higher for the instantaneous expiratory flows (PEFR 11.0%; MEF25 7.0%; MEF25 8.5%; MEF25 11.4%). Only the total error in FEV1 complied with the tolerance of 4% of the European Community for Coal and Steel (ECCS). When the measured values were adjusted according to the regression equations of this study, all F-V indices were accurate and precise within 5%. It was concluded that the portable Microspiro HI-298® is a useful instrument for bedside, work-site spirometry and for use in general practice. As the accuracy of the instantaneous expiratory flows (PEFR, MEF25, MEF25, and MEF25) is moderate, it is advised to adjust these values with the regression equations of this study.


The forced expiratory manoeuvre is a widely used method for assessing the degree of airflow obstruction in patients with asthma and chronic obstructive pulmonary disease (COPD). It is well-known that the variability of flow-volume (F-V) indices is rather high [1–3]. One of the sources of variability is the random error of the instrument by which the F-V parameters are measured [4]. Therefore, both the American Thoracic Society (ATS) and the European Community for Coal and Steel (ECCS) formulated extensive recommendations on the accuracy and precision of spirometers in order to improve the quality of the F-V data [5–7]. As a number of tested devices appeared to be inadequate [8, 9], it was advised to test new available spirometers [10, 11].

During the past few years the need for simple but reliable spirometers for bedside, work-site spirometry and for use in general practice has been rising. A promising instrument in this field may be the portable Microspiro HI-298® (Chest Corporation, Tokyo, Japan). It is a very compact, light apparatus with useful possibilities.

Although the Microspiro is widely used, the reliability has not been tested. Therefore, this study intends to investigate the accuracy, precision and linearity of the Microspiro.

Methods

Instrument

The Microspiro HI-298® is produced by the Chest Corporation, Tokyo, Japan. Figure 1 shows a schematic drawing of this portable flow-volume meter. The apparatus measures instantaneous flows which are...
ACCURACY AND PRECISION OF THE MICROSPIRO

Fig. 1. - A schematic drawing of the Microspiro HI-298.

integrated electronically into volumes. The following indices are measured: slow expiratory vital capacity (EVC), forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), peak expiratory flow rate (PEFR), maximal expiratory flows at 25%, 50% and 75% of the expired volume (MEF₂₅, MEF₅₀, and MEF₇₅, respectively). The measured values, predicted values, and measured values as percentages of predicted values are shown on a liquid crystal display together with a spirogram and a F-V curve. The two best efforts (the FVC-maneuvres with the largest sum of FEV₁ and FVC [6]) are stored in the memory and can be printed. The print-out takes 2-3 min. The predicted values are based on the equations of the ECCS for adults [5] and of Dickman et al. [12] or Zapletal et al. [13] for children. It is possible to adjust the predicted volume values for different ethnic groups. Measured values are body temperature and pressure saturated (BTPS) corrected. The bronchodilator responsiveness is automatically calculated, as the instrument stores prebronchodilator values and compares them with data after bronchodilation. The warming-up takes five minutes. The Microspiro has a flow range of 0-14 l·s⁻¹. The volume range is 0.4-8.0 l. The measurement time for a FVC manoeuvre takes 18 s at most. These specifications are in accordance with the standards of the ATS and the ECCS [5-7].

The Microspiro HI-298 is a forced oscillatory flow meter [14]. It contains a swirl sensor [15]. The sensing technique of this meter is based on a relatively new method of measuring flows [14, 15]. A set of stationary swirl blades forces gas entering the swirl meter to spin around the central axis of the meter, forming vortices. The vortices advance through the meter like screws. The frequency of the vortices shows a linear relationship with the velocity of the gas. A sensor probe in the meter senses the passage of these vortices. The sensor in the meter is a thermistor (a resistor which changes its resistance with temperature). A constant current passes the thermistor causing the device to heat. The gas passing along the thermistor causes the device to heat. The gas passing along the thermistor removes heat. As the velocity of the gas changes when a vortex passes along the thermistor, the heat removal from the thermistor also changes. In this way each vortex is accompanied by resistance change in the sensor. As a constant current passes through the sensor the voltage across the sensor varies as each vortex passes. This change of voltage is AC coupled into the electronic system and after suitable processing is counted and interpreted as flow velocity. An advantage of the Microspiro is that it does not sample flows but measures the whole flow stream. It is known that through sampling of flows or volumes large errors can result [7, 10].

Experiment

The Microspiro was connected in series with a standard instrument, the Fleisch no. 4 pneumotachograph [4]. The maximal error of the Fleisch pneumotachograph is not more than 3% [16]. Up to a flow of 11 l·s⁻¹ the linearity of a Fleisch no. 4 pneumotachograph was shown to be good [16]. The Fleisch pneumotachometer was a commercial type: Discom-219, Chest Corporation, Tokyo, Japan. The transducer (5 cm ID) is heated to 37°C. At both sides of the transducer, a conical attachment ensures a laminar flow through the transducer. The pneumotachometer measures instantaneous flows which are integrated electronically into volumes.

At the start of the experiment, the pneumotachograph (in series with the Microspiro) was calibrated with a
one litre syringe. A healthy subject performed 44 forced expirations through the connected instruments at different levels of lung inflation. The FVC of these expirations ranged from 2.5-5.1 l. Paired data were taken for the FVC, FEV₁, PEFR and MEF values.

Linear regression analysis was applied to the paired data, in which the Fleisch values were the independent variables and the Microspiro values the dependent variables. The distance from the line of identity to the regression line, \( M = a \cdot F + b \) (\( M = \) Microspiro value, \( F = \) Fleisch value, \( a = \) regression coefficient and \( b = \) the intercept), was defined as systematic error, which is a measure of the accuracy of the instrument [17]. For all F-V parameters except the PEFR the regression lines went through the origin (\( b = 0 \)). In this case the systematic error in % is given by a constant:

\[
(a \cdot F / F) \cdot 100\% = 100 \cdot a\%.
\]

The deviation of Microspiro values from the regression line was defined as the random error, which is a measure for the precision of the Microspiro [17]. The random error in % was calculated by determining the % variance which was not explained by the model \((= (1 - r^2) \cdot 100\%)\) in which \( r = \) Pearson correlation coefficient [17, 18]. The total error was defined as systematic error+random error.

Linearity was assessed in the following way. Firstly, the gain (G) of the system was calculated by dividing Microspiro values by the corresponding Fleisch values \((G = \) Microspiro value/Fleisch value) [16]. The percentage difference between the largest and smallest gains \((\Delta G\%)\) in a specified flow or volume range is a measure for the linearity of the system [16, 19].

**Results and discussion**

A good linear relationship was found between the Fleisch pneumotachograph values and the Microspiro values for all F-V indices (table 1 and fig. 2). Pearson correlation coefficients ranged from 0.938-0.985 (table 1). The \( \Delta G\% \) of F-V indices was lower than 10% (except for the PEFR and the MEF<sub>25</sub>), indicating that the linearity of most F-V indices (FVC, FEV₁, MEF<sub>50</sub> and MEF<sub>25</sub>) was good. The Microspiro gave systematic over-readings for the FVC, systematic under-readings for the other F-V indices. The systematic error ranged from 1% for the FEV₁ (good accuracy) to 11.4% for the MEF<sub>25</sub> (low accuracy). The random error of all indices was within the 5% limit advised for spirometry [10]. However, only the FEV₁ had a total error within the tolerance limits of 4% of the ECCS [5]. Therefore, the portable Microspiro is a reliable meter for measuring

![Fig. 2. - The relationship between the FEV₁, measured by the Microspiro and the FEV₁ of the Fleisch pneumotachograph. The line of identity is presented. FEV₁: forced expiratory volume in one second.](image)

**Table 1. - The regression lines, values of total error (systematic error+random error), linearity (ΔG%) and Pearson's correlation coefficients (r) of six F-V indices**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regr. coef.</th>
<th>Intercept</th>
<th>r</th>
<th>Error %</th>
<th>ΔG%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>1.046 (0.007)</td>
<td>-</td>
<td>0.978</td>
<td>+4.6±4.3</td>
<td>8.5'</td>
</tr>
<tr>
<td>FEV₁</td>
<td>0.990 (0.007)</td>
<td>-</td>
<td>0.985</td>
<td>-1.0±3.0</td>
<td>9.5'</td>
</tr>
<tr>
<td>PEFR</td>
<td>0.794 (0.029)</td>
<td>0.698 (0.204)</td>
<td>0.975</td>
<td>-11.0±5.0</td>
<td>39.6''</td>
</tr>
<tr>
<td>MEF&lt;sub&gt;50&lt;/sub&gt;</td>
<td>0.930 (0.009)</td>
<td>-</td>
<td>0.981</td>
<td>-7.0±3.9</td>
<td>16.7''</td>
</tr>
<tr>
<td>MEF&lt;sub&gt;25&lt;/sub&gt;</td>
<td>0.915 (0.018)</td>
<td>-</td>
<td>0.982</td>
<td>-8.5±3.6</td>
<td>1.9''</td>
</tr>
<tr>
<td>MEF&lt;sub&gt;25&lt;/sub&gt;</td>
<td>0.886 (0.017)</td>
<td>-</td>
<td>0.938</td>
<td>-11.4±3.9</td>
<td>1.6''</td>
</tr>
</tbody>
</table>

The intercept of PEFR is given in /s<sup>4</sup>. The standard errors are in parentheses. Regr. coef.: regression coefficient; ' range of FVC and FEV₁: 1-4 l; '' range of PEFR 1.5-10 l/s<sup>4</sup>; "" range of MEF values 1-8 l/s<sup>4</sup>; FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; PEFR: peak expiratory flow rate; MEF<sub>50</sub>, MEF<sub>25</sub> and MEF<sub>25</sub>: maximal expiratory flow at 25%, 50% and 75% of the expired volume, respectively.

Acknowledgement: The authors would like to thank Prof. Ph.H. Quanjer for his critical comments on the study.

References