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%; MEF₅₀%, 8.5%; MEF₇₁%, 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%, MEF₅₀%, and MEF₇₁%) 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 spiroimeters 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 spiroimeters [10, 11].

During the past few years the need for simple but reliable spiroimeters 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 613

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

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 heat removal. 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-21®, 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·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·F/F)-100%=100·a%. In the case of the PEFR a mean systematic error was calculated.

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-r²)·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 (ΔG%) 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 ΔG% of F-V indices was lower than 10% (except for the PEFR and the MEF₂₅), indicating that the linearity of most F-V indices (FVC, FEV₁, MEF₅₀ and MEF₂₅) 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 MEF₂₅ (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>
<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>MEF₅₀</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>MEF₂₅</td>
<td>0.915 (0.008)</td>
<td>-</td>
<td>0.982</td>
<td>-8.5±3.6</td>
<td>1.9**</td>
</tr>
<tr>
<td>MEF₇₅</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 l/s₄. 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; ** range of MEF values 1–8 l/s; FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; PEFR: peak expiratory flow rate; MEF₅₀, MEF₂₅ and MEF₇₅: maximal expiratory flow at 25%, 50% and 75% of the expired volume, respectively.
the FEV₁ but it is less accurate in measuring instantaneous forced expiratory flows (PEFR, MEF₅₀, MEF₇₅ and MEF₁₀₀). However, the accuracy can be increased by adjusting the values according to the linear regression equations of this study (table 1). With these adjustments the total error of all F-V indices will be lower than 5%. As the swirl sensor itself probably is accurate and linear within 1% [14, 15], the manufacturer may change the electronic amplifier and signal conditioner. These parts of the electronic system are the links where the sources of error may exist. The Microspiro can be used in general practice, for bedside and work-site spirometry and for epidemiological purposes. The automatic calculation of the reversibility of bronchial obstruction (in percentages of the initial FEV₁) is a convenient additional feature. Because of the moderate accuracy of the instantaneous expiratory flow rates, it is advisable to use the adjusted values.

It was concluded that the Microspiro HI-298® gives reliable values for the FEV₁. However, when the measured values of the other F-V indices are corrected with the regression equations of this study, all values will be accurate and precise within 5%.

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References


RÉSUMÉ: l'exactitude, la précision et la linéarité du Microspiro HI-298 (Chest Corporation, Tokyo, Japon), ont été investiguées par comparaison avec les résultats du pneumotachographe de Fleisch no. 4 utilisé comme standard. Après connexion et calibration du pneumotachographe et du Microspiro, un sujet sain a réalisé 44 manoeuvres de capacité vitale forcée à différents niveaux d'expiration pulmonaire. La capacité vitale forcée de ces expirations s'est échelonnée entre 2.5 et 5.1 litres. La régression linéaire des valeurs du Microspiro (variable dépendante) sur les valeurs du pneumotachographe de Fleisch (variable indépendante), a montré l'existence d'une bonne relation linéaire. Les coefficients de corrélation de Pearson s'inscrivent dans les limites de 0.985. La linéarité du Microspiro s'avère bonne, sauf pour la débit expiratoire de pointe et le débit maximum expiratoire 75. L'erreur au hasard (mesure de la précision) de toutes les courbes débit-volume était inférieure à 5%. L'erreur systématique (mesure d'exactitude) s'avère basse pour le VEMS et la capacité vitale forcée (respectivement 1% et 4.6%), mais beaucoup plus élevée pour les débits expiratoires instantanés (débit de pointe 11.0%, MEF₅₀, MEF₇₅, MEF₉₀, MEF₇₅, MEF₉₀, MEF₇₅, MEF₉₀, MEF₇₅, MEF₉₀). Seule l'erreur totale pour le VEMS s'inscrit dans les limites de 4% de tolérance imposées par la Communauté Européenne du Charbon et de l'Aciére. Quand les valeurs mesurées sont ajustées au moyen des équations de régression de cette étude, tous les indices débit-volume sont exacts et précis dans des limites de 5%. On en conclut que le Microspiro HI-298 portable est un instrument utile pour la spirométrie au lit ou sur le lieu du travail, ainsi pour l'utilisation en médecine générale. Comme l'exactitude des débits expiratoires instantanés (débit expiratoire de pointe, MEF₅₀, MEF₇₅ et MEF₉₀) est modérée, il est conseillé d'ajuster leurs valeurs au moyen des équations de régression de cette étude.