Technical Note

Evaluation of a pocket-sized turbine spirometer for clinical use with children

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The results of pulmonary function testing with a turbine spirometer (TS) and a bell spirometer (BS) of a randomized group of 275 patients aged 4-18 years were compared. In the TS, an inexpensive device without graphical display was used. The difference BS minus TS (d) for forced expiratory volume in 1 s (FEV₁) was calculated. The results indicate that the FEV₁ might be overestimated by the TS, and that the difference of the readings of FEV₁ between the spirometers increases with airway obstruction. The TS should be used with caution in young patients with asthma.

Introduction

A pocket sized turbine spirometer (TS), which weighs only 400 g (Stimotron Company, Wendelstein, Germany), was evaluated. The small size, low cost and convenience suggest that this will be useful for pulmonary function studies outside the laboratory, e.g. in asthma sport groups or transplant patients. The compact electronic sensor consists of a turbine flow-volume transducer within the mouthpiece, attached to a hand-held battery-driven control unit. The control unit integrates the impulses and displays digitally the forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV₁).

Previous surveys using a TS of the same type had reported a linearity of 2% at flow rates below 6 l s⁻¹ (1). It was also shown that the performance of the TS was comparable to a dry bell wedge ð spirometer in common use (2). Furthermore, the TS was applied in pharmacological (bronchodilator) studies in the emergency room (3). As former studies evaluating the TS did not differentiate between subjects with various degrees of pulmonary function impairment, the present authors wanted to determine whether the TS could be used as an alternative to the BS under various degrees of airway obstruction in the paediatric age group.

Patients and Methods

Two hundred and seventy-five patients aged 4-18 years of the Children's Hospital of the University of Heidelberg or healthy controls of the same age were studied. About half of them had had previous spirometry experience. During the tests, all patients were instructed by the same two technicians, and the parents of the children were present. Most of the patients had been diagnosed as having asthma.

The subjects were divided into three groups according to the degree of pulmonary function impairment performed by the readings of the bell spirometer (BS) (4). The subjects with normal spirometric parameters compared to predicted normal values (5) included 30 healthy controls and other children in whom no pathology could be detected. There was a smaller number of children with moderate (FEV₁ <65% predicted) than with mild (80-65% predicted)
Table 1. Number of patients (n), arithmetic mean (x) and standard deviation (SD) of the age of patients with various degrees of pulmonary function impairment

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (yr)</th>
<th>d</th>
<th>SD</th>
<th>95% CL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal lung function</td>
<td>142</td>
<td>x=11.95</td>
<td>0.033</td>
<td>0.002</td>
<td>0.490- 0.368</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD=4.44</td>
<td>0.037</td>
<td>0.002</td>
<td>0.372- 0.494</td>
</tr>
<tr>
<td>Mild obstructive</td>
<td>97</td>
<td>x=11.03</td>
<td>-0.063</td>
<td>-0.024</td>
<td>-0.476- -0.343</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD=4.12</td>
<td>0.016</td>
<td>0.016</td>
<td>0.295- 0.429</td>
</tr>
<tr>
<td>Moderate obstructive</td>
<td>36</td>
<td>x=10.92</td>
<td>-0.119</td>
<td>-0.049</td>
<td>-0.589- -0.332</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD=5.35</td>
<td>0.021</td>
<td>0.021</td>
<td>0.252- 0.490</td>
</tr>
</tbody>
</table>

Arithmetic mean of the difference ‘BS minus TS’ with 95% confidence limits (d) in 1 s⁻¹, SD of d (SD₃) in 1 s⁻¹ and 95% confidence limits of d+ - 2SD₃ for measurements of FEV₁ (95% CL).

obstructive airway disease (Table 1). A 9-l BS, Spiromat Junior (Jaeger Company, Würzburg, Germany), meeting American Thoracic Society recommendations, served as the reference spirometer. The volume calibration of the BS was performed daily with a 1-0-l syringe. The accuracy of TS was assessed before and at the end of the study by the manufacturer of the BS. The pulmonary function tests consisted of three measurements of FEV₁ and vital capacity (VC) by both TS and BS apparatus. For each patient, the order for use of the TS and BS was changed alternatively, meaning that half of the subjects started with BS and the other half started with TS. Thus, significant effects of the order of the instruments were avoided. Spirometric tests were performed in a sitting position, with a nose clip, according to commonly accepted standards (5). In each case, the maximal value was taken, and expressed as a percentage of the predicted normal values for height and gender.

The TS was tested for repeatability in a preliminary study of 100 patients. Each patient performed the FEV₁ manoeuvre five times. The test/re-test correlation coefficients for all patients were calculated, and the average of these correlation coefficients was determined using the Fisher-Z transformation.

The extent of agreement between two spirometers is often assessed by the statistical method of calculating the correlation coefficients and determining the regression lines. However, the correlation coefficient only describes the strength of a relation between two variables, not the agreement between them (6). For this reason, a method was used which is based on evaluating the limits of agreement, by using the arithmetic mean of the difference ‘BS minus TS’ (d) and the standard deviation of d (SD₃) (2, 6).

Results

The test/re-test correlation coefficients of the TS for the FEV₁ ranged from 0.813 to 0.902 (rFisherZ=0.85). They are statistically significant (P<0.0001) and close to the test/re-test correlation coefficients of the BS (r>0.90).

The determination coefficient r² obtained by the TS and the BS ranged from 0.88 to 0.94, meaning that the strength of relation between the two machines is very high in all groups.

The results of all statistical analyses of the agreement of BS and TS are shown in Table 1. The arithmetic mean d of the difference d ‘BS minus TS’ was lower than zero in most of the groups, showing that the TS provides slightly higher values than the BS. The d for the FEV₁ is, however, not constant, but depends on the degree of obstruction. The tendency of the TS to provide higher values than the BS for the FEV₁ is more pronounced with an increasing degree of obstruction. Also, the correlation, as expressed by the regression lines shown in Fig. 1(a–c),
Fig 1. Regression lines for forced expiratory volume in 1 s (FEV₁) (in l s⁻¹) for (a) normal lung function (n=142); (b) mild obstructive (n=97) and (c) moderate obstructive (n=36) pulmonary function tests.

**Discussion**

It is known from the literature that different spirometers, which meet the requirements of the American Thoracic Society, provide different values in clinical studies (7). Although the determination coefficient and the mean difference \( \bar{d} \) between the results of the TS and BS in the present study were tolerable throughout the sample, the overall agreement between the spirometers is not as good as shown previously for the agreement between a TS and a dry bellows spirometer (2). However, this study had not identified the number of children and adults included in its patient samples, and had not specified the results according to the degree of lung function impairment (1).

Clinically, the difference of the values of the FEV₁ provided by the TS and the BS is of uppermost importance in patients with at least moderate bronchial obstruction. This finding is not hampered by the fact that a graphical display was not used. The detection of suboptimal spirometric manoeuvres would have mainly excluded pulmonary function tests with low reading in the TS. So, it is possible that with a graphical display, the difference \( \bar{d} \) would have been even higher in favour of the TS. The resistance in both machines was similar, around 0.7 to 0.8 kPa, when an airstream of 5 l s⁻¹ was applied. Inertia might be a factor leading to more frequent rotations of the fan of the TS after the airstream is turned off early in obstructive patients (8). The possibility that the 'end-of-test criteria' were not fulfilled satisfactorily by the TS (9–11) cannot be excluded.

In practice, comparison has to be drawn between spirometric values assessed in the lung function laboratory and outside. For economical reasons, one is tempted to use TS without graphical display in clinical practice. Following
the results of this study, the operators of spirometers without graphical displays should be aware of their limitations, especially in patients with asthma.

References


