Comparison of four types of portable peak flow meters (Mini-Wright, Assess, Pulmo-graph and Wright Pocket meters)

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Ambulatory peak flow monitoring plays an important role in the diagnosis and management of patients with bronchial asthma. Today several kinds of portable peak flow meters (PFMs) are available for this purpose and sometimes comparisons between the readings of different kinds of PFMs are necessary in clinical setting. We compared four types of PFMs in patients with various respiratory diseases.

The study population consisted of 294 patients with asthma, chronic obstructive pulmonary disease, diffuse panbronchiolitis and other respiratory systems, and 15 healthy volunteers.

Initially, subjects underwent a spirometry until at least three acceptable forced expiratory curves were obtained. Thereafter each subject blew into a Mini-Wright meter, Assess meter, Pulmo-graph meter and Wright Pocket meter, three times in a random order, with an interval of 4 min. The highest value of three blows was recorded in each PFM measurement. Finally, a second set of spirometric measurements were obtained. Spirometric peak flow rates (PEFRs) were obtained from the best single test which gave the largest sum of forced vital capacity and forced expiratory volume in 1 s (FEV₁). In cases when FEV₁ in the first spirometry examination was less than 1 1 or the readings of the PFM were less than 350 l min⁻¹, low-range PFMs were used. The second spirometric PEFR was used as a standard against which the reading of the PFM was compared.

The correlation coefficients between the readings of each PFM and spirometric PEFR did not differ significantly from each other. The limits of agreement between each PFM were very wide. In both low- and standard-range PFM, the Assess meter had a significantly greater absolute difference from the spirometric PEFR than other PFMs. In the standard range, the Wright Pocket meter also had a greater difference than the Pulmo-graph meter. The standard-range Assess meter tended to lose its strength of correlation with the spirometric measurement at higher flow rates as did the low-range Pulmo-graph and Mini-Wright meters at the lower and higher flow rates, respectively.

All four types of standard-range PFMs gave similarly valid values when spirometric PEFR was used as a reference. However, the limit of agreement between each PFM is so wide that we do not recommend the use of the readings of each meter interchangeably.

Introduction

Ambulatory peak flow monitoring plays an important role in the diagnosis and management of patients with bronchial asthma. The guidelines (1,2) of asthma management recommend the use of a portable peak flow meter (PFM) as a tool for objective monitoring of a patient’s condition and such a strategy is expected to improve the total outcome of asthma management. Today several kinds of portable PFMs are available for this purpose and sometimes comparisons between the readings of different kinds of PFMs are necessary in a clinical setting in such cases as exchanging a PFM for another type or comparing the readings of a PFM at home with those at clinics. There have been some reports which compared the accuracy of several kinds of portable PFMs using a pump system. However, there have not yet been enough reports based on patients with respiratory disease.

We compared four types of PFMs (Mini-Wright, Assess, Pulmo-graph and Wright Pocket meters) against spirometric peak expiratory flow rate (PEFR) and evaluated the agreement of the readings between each PFM.

Subjects and Methods

SUBJECTS

The study population consisted of 127 consecutive patients with chronic obstructive pulmonary disease (COPD;
male:female=123:4), 120 patients with asthma (male:female=72:48), 34 patients with diffuse panbronchiolitis (DPB, male:female=20:14) and 15 patients with other respiratory symptoms (male:female=5:8) who visited the Chest Disease Research Institute Hospital, Kyoto University from December 1992 to March 1994. In addition 15 healthy volunteers (male:female=14:1) working in the institute were included in the study.

The diagnosis of COPD was based on the definition of the American Thoracic Society (3). The patients with COPD in the present study fulfilled the following criteria: (1) a maximum ratio of forced expiratory volume in 1 s (FEV1) to forced vital capacity (FVC) of less than 70% over several measurements of postbronchodilator spirometry; (2) a smoking history of greater than 20 pack-years; (3) no history consistent with asthma such as paroxysmal dyspnoea or wheezing. Diagnosis of asthma was based on the clinical presentation of asthma symptoms and the documentation of increased bronchial responsiveness to methacholine at least once during the clinical course of illness in almost all of the patients. Most of the patients were under inhaled beclomethasone dipropionate treatment. Diagnosis of DPB was made according to the clinical diagnosis guidelines established for DPB in the nationwide survey by the Health and Welfare Ministry of Japan (4). In addition, chronic parasal sinusitis and centriflobular nodules (5) found in computed tomography were confirmed in all patients with DPB. Some patients with non-specific respiratory symptoms such as persistent cough were also included in this study and classified under the ‘others’ category.

METHODS

Initially, spirometry was performed with an AS-600 Spirometer, a hot-wire anemometer (6) (Minato Medical Equipment Co., Tokyo, Japan) with 10 ml volume resolution, until three acceptable forced expiratory curves were obtained in the standing position according to the recommendation of American Thoracic Society (7). An acceptable manoeuvre was defined as one without hesitation or coughing, with at least 6 s of expiration, and a back-extrapolated volume of less than 5% of the FVC or 0·15 l, whichever was greater. Then, after resting for 3·4 min in a sitting position, each subject blew in a standing position into Mini-Wright, Assess, Pulmo-graph and Wright Pocket meter, three times for each in a random order, with intervals of 3·4 min. The highest value of three blows was recorded in each PFM measurement. Low-range PFMs were used when FEV1 was less than 1 l or the reading of the standard-range PFM was less than 350 l min⁻¹.

Finally, a second series of spirometric measurements was performed until three acceptable forced expiratory curves were obtained in the standing position. Up to five procedures were performed until the reproducibility criteria were met for each session. No data were excluded from the analysis on the basis of reproducibility criteria.

All measurements were conducted by chest physicians (A.I. and H.K.). Each standard-range and low-range PFM was changed to a new device for every 50 and 30 subjects, respectively. The spirometer was calibrated every morning with a 3 l syringe. Spirometric PEFR was obtained separately for the first and the second spirometric measurements according to the recommendation of American Thoracic Society (6), that is from the best single test that gave the largest sum of FVC and FEV1.

Inhalations of β-receptor agonists or anticholinergic drugs were withheld for at least 6 h before this study to avoid the influence of bronchodilators during the study.

ANALYSIS

Accuracy

Assuming the spirometric PEFR to be the true value of the PEFR, the accuracy was compared using the difference between readings of each PFM and the spirometric PEFR. An analysis of variance for repeated measurements and a least significant difference test was used for the analyses of the differences and the Kruskal–Wallis non-parametric test and Mann–Whitney U test were used for the analyses of the absolute differences; \( P<0.05 \) was considered to be statistically significant.

### Table 1. Pearson’s correlation coefficients between the readings of each PFM and the spirometric PEFRs

<table>
<thead>
<tr>
<th></th>
<th>Mini-Wright</th>
<th>Assess</th>
<th>Pulmo-graph</th>
<th>Wright Pocket</th>
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</thead>
<tbody>
<tr>
<td><strong>Low-range PFM</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>First*</td>
<td>0.85</td>
<td>0.79</td>
<td>0.80</td>
<td>0.85</td>
</tr>
<tr>
<td>Second†</td>
<td>0.86</td>
<td>0.80</td>
<td>0.80</td>
<td>0.87</td>
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<tr>
<td>( P )</td>
<td>0.79</td>
<td>0.86</td>
<td>1.00</td>
<td>0.59</td>
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<tr>
<td><strong>Standard-range PFM</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First*</td>
<td>0.92</td>
<td>0.91</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>Second†</td>
<td>0.93</td>
<td>0.92</td>
<td>0.93</td>
<td>0.94</td>
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<tr>
<td>( P )</td>
<td>0.49</td>
<td>0.53</td>
<td>0.48</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*The first spirometric PEFRs and readings of portable PFMs.
†The second spirometric PEFRs and readings of portable PFMs.
Fig. 1. Relationship of spirometric PEFRs and the readings of PFM: (a) low-range meters; (b) standard-range meters. Abscissa, the second spirometric PEFR (l min⁻¹); ordinate, the readings of the PFM (l min⁻¹); — line of identity.

Interchangeability
The limits of agreement (8) were used to evaluate the interchangeability of the readings of each PFM. These limits are defined as the mean difference ± 2 × sd of the readings between two of each PFM. Thus 95% of the differences will be within this limit.
The correlation coefficient between the first and the second spirometric PEFR was 0.985; the random error ($1-r^2$) was 3.1%. The mean difference between the second and first spirometric PEFR was 10.2 ± 28.2 l min$^{-1}$ (2.88% ± 9.44% of the second spirometric PEFR).

The simple linear correlation analysis produced consistently better correlation coefficients using the second spirometric PEFR than those based on the first spirometric PEFR, although these differences were not statistically significant (Table 1). Therefore, the subsequent analyses were performed using the second spirometric PEFR (hereafter called spirometric PEFR) as the standard value. There was no order effect on the correlation coefficients between the PFM readings and the spirometric PEFRs.

The scatter plots of the readings of each PFM against spirometric PEFRs are shown in Fig. 1. In the standard-range meters, all PFMs have almost equivalent correlation coefficients (Table 1), indicating that each PFM gave a similarly valid value when a spirometric PEFR was taken as a representative of a true value. In the low-range meters, the Wright Pocket meter tended to have a better correlation coefficient than the Assess or Pulmo-graph meter but without statistical significance ($P=0.11$ for both).

Plotting of the squared residuals showed that the standard-range Assess meter had greater squared residuals at the higher flow rates. In addition the low-range Pulmo-graph and Mini-Wright meters had greater squared residuals at the lower and the higher flow rates, respectively. These observations indicate that these meters have tendencies to lose their strength of correlation with the spirometric measurements at the flow rate where they had greater squared residuals.

The box-whisker plots of the difference and absolute difference between the spirometric PEFR and readings of each PFM are shown in Figs 2 and 3, respectively. In both the low- and standard-range meters, the Assess meter had significantly greater absolute differences from the spirometric PEFR than any of the other PFMs. In addition, the standard-range Wright Pocket meter had a greater difference than Pulmo-graph meters.

The limits of agreement (8) between two of the evaluated PFMs are shown in Table 2. Those limits were very large, with the greatest limits between the readings of the Assess meter and the others.

Discussion

The results of the present study demonstrated that the readings of all four types of standard-range PFMs had an equivalent correlation coefficient with spirometric PEFRs,
indicated that each PFM gave a similarly valid reading when a spirometric PEFR was taken as a representative of the true value. Although the correlation coefficients of the standard-range PFMs may be reasonably good, those of low-range PFMs seem to be less satisfactory.

The Assess meter had significantly greater absolute differences from the spirometric PEFR than any other PFMs. This means that Assess meters are less accurate when the spirometric PEFR was taken as a representative of the true value. However, this does not necessarily mean poor performance of the Assess meter. Actually, the regression analysis showed that all four types of standard-range PFMs have almost equivalent correlation coefficients. Therefore, the performance of each PFM is fairly good and comparison of day-to-day values in each subject will be reliable as long as the same PFM is being used. However, the Assess meter overread throughout the evaluated range in this study, leading to a possible overestimation of patient's condition if the reading of the Assess meter is evaluated based on the predicted values for the other types of PFMs. In addition, the standard-range Assess meter has larger squared residuals at high flow rates in linear regression analysis, suggesting that it may lose its strength of correlation with the spirometric measurements to some extent there. Therefore, it may be important to take this into account when interpreting the readings of the Assess meter in a patient who has a high PEFR. Obviously the direct comparison of the readings of the different types of PFMs also needs caution.

The limits of agreement between each PFM were very wide. For example, it is difficult to estimate the reading of the Assess meter from that of the Mini-Wright meter with
certainty, because the limit of agreement between the standard-range Mini-Wright meter and the Assess meter ranged from \(-206\, \text{1 min}^{-1}\) to \(851\, \text{1 min}^{-1}\). Even the narrowest limit of agreement among six pairs, which was observed between the Mini-Wright and Pulmo-graph meters, was from \(-571\, \text{1 min}^{-1}\) to \(961\, \text{1 min}^{-1}\). As a consequence, we do not recommend the use of the readings of different PFMs interchangeably.

Although the spirometric PEFR was used as a representative of the true value in this study, it is possible to determine a true value of PEFR in human subjects and the spirometric PEFR itself should contain measurement error. Repeating the forced expiratory manoeuvre appeared to have reduced this error to some extent because the PEFRs in the second spirometric measurement produced superior correlation coefficients to those obtained in the first spirometry in all types of PFMs in the linear regression analysis. Therefore the second spirometric PEFR was used as the standard value in this study. However, the second spirometric PEFR was greater than the first PEFR by only \(102\, \text{1 min}^{-1}\), with a correlation coefficient of 0.984 between them. This left a random error of only 3-1%, making no significant changes in the results of analysis. Indeed, there were no significant differences between the coefficients based on the first and second spirometric measurements. Thus, the PEFRs measured by the first and second spirometries were virtually the same, indicating that there was no significant variability in the performance of the forced expiratory procedures in the PFM recordings which were done between two spirometries. This provided us with the basis for the comparison between PFMs. In addition, no order effect was observed on the correlation between the PFMs readings and the spirometric PEFRs.

Shapiro et al. (9) reported that Mini-Wright meters overread in the range below \(300\, \text{1 min}^{-1}\) and underread in the high range over \(500\, \text{1 min}^{-1}\). This characteristic of the Mini-Wright meter was consistent with the present study in that the regression line intersects the line of identity at a flow of \(550\, \text{1 min}^{-1}\). Gardner et al. (10) and Miller et al. (11) reported the underestimation of PEFR by the Assess meter using a flow generator, and Simmons et al. reported a similar tendency in the data obtained from human subjects (12). On the contrary, Shapiro et al. showed an overread by the Assess above \(300\, \text{1 min}^{-1}\) based on the human data (9), which is largely consistent with the present data. In addition, their data were also generally consistent with our results regarding the Mini-Wright. Furthermore, Simmons et al. reported similar results regarding the Mini-Wright and Pulmo-graph meters to ours in that the Mini-Wright overread at lower flow rates and underread at higher flow rates as well as the underreading of the Pulmo-graph at higher flow rates. However, their results were different from ours regarding the Assess and Wright Pocket meters. We cannot address the causes of these similarities and discrepancies among these studies here, although the differences in methods might explain some of them. For example, while Gardner et al. and Miller et al. used a flow generator, human subjects blew into a spirometric connected in line to the PFM in the studies of Simmons et al. and Shapiro et al., and the spirometry and PFM measurements were performed separately in our study. In this regard, a concern has been expressed about the validity of a machine-generated waveform as the standard method for testing PFM accuracy. Pretto et al. reported a difference in accuracy measurements depending on whether flows were generated by human subjects or an explosive decompression device and suggested that accuracy data obtained from human subjects might be more clinically relevant (13).

In conclusion, all four types of the standard-range PFMs have an equivalent validity. However, the limit of agreement between each PFM is so wide that we do not recommend the use of the readings of each meter interchangeably.

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**References**


