

Accuracy and reproducibility of the Assess peak flow meter

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

Accuracy and reproducibility of the Assess peak flow meter. C.P. van Schayck, E. Dompeling, C. van Weel, H. Folgering, H.J.M. van den Hoogen.

ABSTRACT: The variability of peak flow measurements was studied in 24 patients with airway obstruction, using 12 Assess peak flow meters and a Fleisch pneumotachograph type 4 as a standard. The Assess peak flow meter gave systematic under-readings of 19-34% (low accuracy). The value scale of the Assess peak flow meter should be adjusted. As systematic under-readings do not influence the variability in peak flow measurements, variability was only caused by the random error of the instrument. The random error of the Assess peak flow meter was relatively low: about 4% of the measured peak flow value (high precision). The contribution of the Assess peak flow meter to the total variability of peak flow measurements showed a linear relationship ($r=0.53$) with the value of the peak flow rate itself and varied from 9% (at $3 \text{ l}\cdot\text{s}^{-1}$) to 86% (at $10.8 \text{ l}\cdot\text{s}^{-1}$). Reading errors of the peak flow meter were responsible for about 1% of the total variability. The remaining variability is probably caused by the correctness of the peak flow performance and the motivation of the patient. *Eur Respir J.*, 1990, 3, 338-341.

* Dept of General Practice/Family Medicine, Nijmegen University, The Netherlands.

** Dept of Pulmonary Diseases, Nijmegen University, The Netherlands.

Correspondence: C.P. van Schayck, Dept of General Practice/Family Medicine, Nijmegen University, P.O. Box 9101, 6500 HB Nijmegen, The Netherlands.

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The peak flow meter is one of the most widely used instruments for monitoring patients with airway disease and for evaluating the effectiveness of pharmacotherapy of asthma and chronic bronchitis in general practice. However, it is well-known that the reproducibility of peak flow measurements is low [1-3]. Part of the high variability is caused by the diurnal variation of the peak flow [4, 5]. Although the reproducibility improves when the peak flow is measured at fixed times of the day, it is still low: mean coefficients of variation of 5-10% are reported [6, 7]. More research needs to be done to clarify the sources of variability.

The aim of this study was to gain a better insight into the extent of the variability that was caused by the peak flow meter itself, apart from the variability that was caused by the patient or the investigator. We studied the total variability of peak flow measurements, the variability caused by the peak flow meter itself and by reading the peak flow meter.

A new type of peak flow meter was used in this study, the Assess® peak flow meter (Healthscan Products, Inc. USA). EICHENHORN *et al.* [8] concluded that this meter was more accurate than the mini-Wright peakflow meter.

Methods

The study was concerned with the variability (defined as variance; sum of the squared deviations from the mean) caused by the instrument ($\text{Var}_{\text{instr}}$), the reading of the

peak flow meter (Var_{read}) and the total variability of peak flow measurements (Var_{tot}).

We assumed that the total variability consists of the following factors:

The instrument. $\text{Var}_{\text{instr}}$ = the variability caused by the random error of the peak flow meter (measure of precision). The systematic error (measure of accuracy) of the instrument is constant at every flow rate and, therefore, does not influence the variability.

The patient. $\text{Var}_{\text{volume}}$ = the variability caused by differences in lung volume at the level of maximal inspiration [6]. $\text{Var}_{\text{effort}}$ = the variability caused by differences in maximal expiratory force [6]. $\text{Var}_{\text{oscil}}$ = the variability caused by high-frequency oscillations in the flow-time curve [6].

The investigator. Var_{read} = the variability caused by differences in reading the peak flow values of the meter. Var_{stim} = the variability caused by the way in which the patient is stimulated by the investigator.

Unknown factors. Var_n = the variability caused by unknown factors at all levels.

This model is not concerned with the variability caused by diurnal variation, the influence of bronchodilators or variability between patients. So, the total variability (Var_{tot}) is defined as the variability between the peak

flow measurements of one patient at the same time of day, without the influence of bronchodilators.

In using this model we have to make two assumptions: the contributing factors are independent; all factors are normally distributed.

Experiment 1: The calculation of Var_{instr}

The Assess peak flow meter was connected in series (8) with the Fleisch No. 4 pneumotachograph (Discom 14). The Fleisch pneumotachograph is a very accurate apparatus [9]. Before the start of the experiment the pneumotachograph (in series with the peak flow meter) was calibrated with a 1 l syringe. Twelve randomly selected new Assess peak flow meters were calibrated at flow rates of approximately 2, 3, 5, 8, 10 and 11 $l \cdot s^{-1}$. The flows were all generated by the second author (E.D.) in the same way at different levels of lung-inflation. Thirty flow rates were measured for each peak flow meter. The averages and standard deviations at all flow values of each peak flow meter were calculated.

Experiment 2: The calculation of Var_{tot}

Twenty-four patients were asked to measure their peak flow five times with the same peak flow meter. After each measurement there was an interval of half a minute. These patients received consistent and adequate instructions and already had experience with weekly peak flow measurements with the Assess peak flow meter during the preceding months. No smoking was allowed before or during the experiments. No bronchodilator medication was taken for a period of 8 h before the measurements. All measurements were performed by the second author. The averages and standard deviations were calculated within subjects.

Experiment 3: The calculation of Var_{read}

To estimate the variability caused by different readings, 60 peak flow values were independently read by two persons. The difference between the values observed is normally distributed, as the readings of the two persons are independent. The variability caused by one person will be half the variability of the differences between the values observed.

Instrument

The Assess peak flow meter is a relatively new instrument produced by Healthscan Products Inc. Figure 1 shows a schematic drawing of this instrument. The flow produced by the patient elevates the piston which slides on a metal rod, from the bottom of the scale to the actual peak flow value. The spring that is mounted between the piston and the lower end of the metal rod will prevent the piston from rising beyond the actual peak flow value.

The position of the red indicator resting on the piston marks this value. After recording the value, the indicator has to be pushed back to the bottom of the scale. The distance between the red indicator and the scale may increase the reading error. During the performance the scale of the instrument should be held vertically. The reading of the peak flow value should be done at an angle of about 90° .

The accuracy of the Assess peak flow meter was calculated by means of regression analyses.

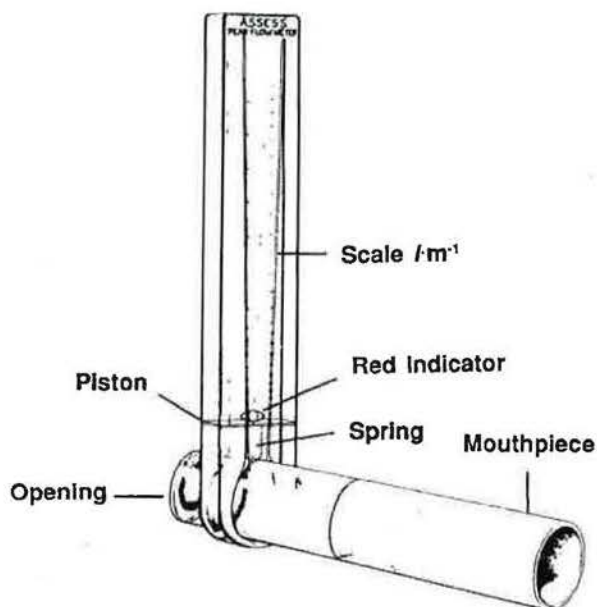


Fig. 1. — A schematic drawing of the Assess peak flow meter.

Patients

A random sample of 24 patients (14 male, 10 female) (experiment 2) from a study group of 223 patients with asthma or chronic obstructive pulmonary disease (COPD) participated [10]. Their average age was 53 yrs (SD 12 yrs); 57% were men, the average number of pack-years was 16 (22% nonsmokers), the average FEV_1 was 75% of the reference value (SD 17%) and the average forced expiratory volume in one second (FEV_1/FVC) was 83% of the reference value [11].

Results

In table 1 the results of experiment 1 (the calculation of Var_{instr}) are shown. The flow rates of all Assess peak flow meters showed a linear relationship with those of the Fleisch pneumotachograph. The mean regression equation of the twelve Assess peak flow meters was $y=0.86x - 0.23$ (y =value peak flow meter in $l \cdot s^{-1}$, x =value pneumotachograph in $l \cdot s^{-1}$). In figure 2 the relationship between the flow rates of the Fleisch pneumotachograph

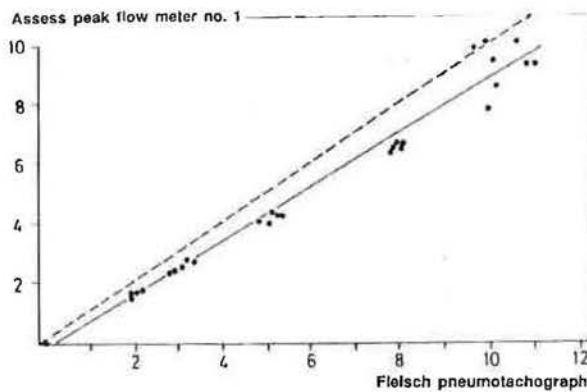


Fig. 2. — The relationship between the flow rates ($l \cdot s^{-1}$) of the Fleisch pneumotachograph and the Assess peak flow meter no.1. The unbroken line is the regression line, the dotted line is the line of identity. Regression equation is: $y = 0.89x - 0.21$.

The differences between the 60 readings (experiment 3) were normally distributed as expected (skewness=0.23 and kurtosis=0.13). The average difference was $0.55 \times 10^{-2} l \cdot s^{-1}$, the variance was $0.32 \times 10^{-2} l^2 \cdot s^{-2}$. The variance due to reading was estimated at $0.16 \times 10^{-2} l^2 \cdot s^{-2}$. The contribution of Var_{read} to Var_{tot} was 1.1%.

Discussion

The variability caused by the Assess peak flow meter (Var_{instr}) depends on the value of the peak flow rate produced by the patients. When the peak flow rate is low, for example $3.0 l \cdot s^{-1}$, the contribution of Var_{instr} to the total variability can be estimated at 9%. When the produced peak flow rate is high, for example $10.8 l \cdot s^{-1}$ (maximum value of the Assess peak flow meter) the contribution of Var_{instr} to the total variability can be estimated at 86%. As could be expected, the variability caused by reading errors of the Assess peakflow meter is low: 1%.

Table 1. — Systematic and random error of the peak flow at several flow rates

PEFR-Fleisch $l \cdot s^{-1}$	PEFR-Assess $l \cdot s^{-1}$	SD of PEFR-Assess $l \cdot s^{-1}$	Systematic error $l \cdot s^{-1}$	Total error in % (syst. e. \pm random e.)
2.00	1.49	0.06	0.51	34 \pm 4.0
3.00	2.35	0.06	0.65	28 \pm 2.6
5.00	4.07	0.10	0.93	23 \pm 2.5
8.00	6.65	0.17	1.35	20 \pm 2.6
10.00	8.37	0.52	1.63	19 \pm 6.2
11.00	9.23	0.43	1.77	19 \pm 4.7

PEFR: peak expiratory flow rate; syst. e. : systematic error; random e.: random error; Fleisch: Fleisch pneumotachograph; Assess: Assess peak flow meter; sd: standard deviation.

and the Assess peakflow meter no. 1 is shown as an example. The Assess peak flow meter gave lower values than the Fleisch pneumotachograph at all flow rates. The systematic error and the random error were calculated in percentages at different flow rates (table 1). The random error (measure of precision) was about 4%, the systematic error (measure of accuracy) was 19–34%. The total variability (experiment 2) for the 24 patients was on average $15.0 \times 10^{-2} l^2 \cdot s^{-2}$ (SD = $15.1 \times 10^{-2} l^2 \cdot s^{-2}$). The variability caused by the instrument (Var_{instr}) was interpolated from the standard deviations given in table 1. It was on average $5.61 \times 10^{-2} l^2 \cdot s^{-2}$ (SD $6.72 \times 10^{-2} l^2 \cdot s^{-2}$). The contribution of Var_{instr} to Var_{tot} showed a linear correlation with the value of the Assess peak flow meter: $Var_{instr}/Var_{tot} (\%) = -20.37 + 9.88 \text{ PEFR } (l \cdot s^{-1})$ ($r = 0.53$, SE 32.88%). In the patients studied the contribution of Var_{instr} to Var_{tot} ranged from 8–100%.

It is probable that some of the factors we did not measure in this study (Var_{volume} , Var_{effort} and Var_{stim}) are not completely independent. For instance, stimulating the patient will probably reduce Var_{volume} and Var_{effort} . Therefore, the model should be applied with some caution, because it requires independence of the factors involved.

In comparison with the Fleisch pneumotachograph, the Assess peak flow meter systematically under-reads the peak flow value by 19–34%. Our findings differ from the study by EICHENHORN *et al.* [8], who found a lower systematic error of the Assess peak flow meter. The reason for this might be the analysis they used: discrepancy rates instead of regression analyses. Discrepancy rate is defined as the mean of the differences of the measured (peak flow meter) and actual (pneumotachograph) flow, divided by the actual flow [8]. As a consequence of

adding positive and negative values, discrepancy rates may give an underestimation of the systematic error. Thus, we cannot confirm the conclusion of EICHENHORN *et al.* that the Assess peak flow meter is more accurate than the mini-Wright peak flow meter. As EICHENHORN *et al.* did not examine the random error, the precision of the mini-Wright and the Assess peak flow meter cannot be compared. We suggest that the reading scale of the Assess peak flow meter should be changed in order to improve the (relatively low) accuracy of this meter. The manufacturer should increase the reading scale by $0.5 \text{ l}\cdot\text{s}^{-1}$ at the low range and by $1.7 \text{ l}\cdot\text{s}^{-1}$ at the high range. After adjusting the value scale, the total error will not exceed 4% (only caused by the random error). Spirometers have to comply with this requirement [11, 12]. It is important that all intra-individual measurements are performed with the same peak flow meter because of the inter-instrumental variation of the Assess peak flow meter. It is concluded that the Assess peak flow meter systematically gives under-readings of 19–34%. In spite of the relatively low random error of this peak flow meter, the instrument contribution to the total variability of peak flow measurements was substantial, in particular in the range above $7 \text{ l}\cdot\text{s}^{-1}$. In the range below $7 \text{ l}\cdot\text{s}^{-1}$ other sources of variability (correctness of the peakflow performance and the motivation of the patient) probably play a more important part in the total variability. In order to improve the reproducibility of peak flow measurements it is therefore important to instruct the patient very carefully and to check the peak flow performance regularly.

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Précision et reproductibilité du débitmètre de pointe "Assess". C.P. van Schayck, E. Dompeling, C. van Weel, H. Folgering, H.J.M. van den Hoogen.

RÉSUMÉ: La variabilité des mesures du débit de pointe a été étudiée chez 24 patients atteints d'obstruction des voies aériennes, en utilisant 12 débitmètres de pointe "Assess" et un pneumotachographe de Fleisch de type 4 comme standard; le débitmètre de pointe "Assess" donne systématiquement des valeurs sous-estimées de 19 à 34% (précision faible). L'échelle des valeurs du débitmètre de pointe "Assess" devrait donc être ajustée. Puisque les sous-estimations systématiques n'influencent pas la variabilité des mesures du débit de pointe, la variabilité est causée exclusivement par l'erreur liée à l'instrument. L'erreur du débitmètre "Assess" est relativement faible; elle atteint environ 4% de la valeur de pointe mesurée (précision élevée). La contribution du débitmètre "Assess" à la variabilité totale des mesures du débit de pointe, montre une relation linéaire ($r=0.53$) avec la valeur du débit de pointe lui-même, et varie entre 9% (à $3 \text{ l}\cdot\text{s}^{-1}$) et 86% (à $10.8 \text{ l}\cdot\text{s}^{-1}$). Les erreurs de lecture du débit de pointe étaient responsables pour 1% environ de la variabilité totale. Le reste de la variabilité est probablement en rapport avec la qualité de la mesure du débit lui-même et avec la motivation du patient.

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