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DYNAMIC SPIROMETRY STUDIES IN PATIENTS WITH LUNG DISEASE

II. "*Peak Expiratory Flow*" as a Measure of Ventilatory Capacity: Value in Pharmacological Tests¹

By

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Dynamic spirometry can be used to measure ventilatory impairment of restrictive and obstructive types. A recording volume spirometer suited for this type of study is, however, expensive and immobile and the procedure, including analysis of the tracings, is time-consuming.

Different types of flowmeters have been applied to studies of ventilatory performance and capacities. Some of these have been constructed to give a reading of the maximal flow value during a single breath. An improved "peak flow meter" was introduced in 1957 by *Wright* (91). It is easy to handle and to carry in field studies and can be used for checking the effect of treatment.

The present study on "peak expiratory flow" was made with the *Wright* "Peak Flow Meter". The variation of peak expiratory flow values within and between series of peak flow measurements was studied in normals and in patients with chronic bronchitis. The peak expiratory flow (PEF) was correlated to the spirometric parameters $FEV_{1.0}$, $FEV\%$

¹ Presented in part before the section for pneumonology of Svenska Läkaresällskapet, 13, 5, 1961.

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($FEV_{1.0}/FVC \times 100$), and MVV_{40} ¹. Further, a comparison between PEF and $FEV_{1.0}$ in the evaluation of the effects of bronchoactive drugs within individuals was performed.

MATERIAL AND PROCEDURE

A. For studying the *variability between and within series of PEF*, two groups were studied. The normal group consisted of 4 females and 2 males. They were healthy doctors or laboratory workers, aged 25 to 32 years. They performed a series of 5 PEF once a week for 8 successive weeks. Two subjects, AGB and AP, however, had colds for a week during the series and the values of that week were discarded.

The second group consisted of eleven bronchitis patients, 2 females and 9 males with a mean age of 59 years (39–70 years). Most of the males had generalized airways obstruction; in two of these subjects the obstruction was partly reversible. They were studied at home by a nurse every week for 13 weeks; on each visit the patient performed 4 PEF.

B. *For correlation of PEF to volume spirometric values*, 40 females and 59 males were studied. No selection was made, thus patients with both restrictive and obstructive ventilatory impairment, as well as some with normal ventilatory capacity, were included. The mean age in the female group was 49 years, (23–79 years). The males had an average age of 53 years (12–72 years).

A separate study on the relation between PEF and $FEV_{1.0}$ and $FEV\%$ was done, using 30 male subjects with restrictive ventilatory impairment (among them 10 subjects with pneumonectomy) and 35 male patients with obstructive ventilatory impairment.

In the sitting position the patients performed 4 forced expiratory spiograms alternating with 4 PEF measurements. After this 2–3 MVV_{40} were made.

C. *Pharmacological tests*. In the correlation between the

¹ For terminology, see page 330.

PEF and the $FEV_{1.0}$, both obtained at different levels of bronchoconstriction, 30 subjects (10 females and 20 males) participated. All but one had chronic nonspecific pulmonary disease.

The subjects inhaled nebulized acetylcholine in concentrations increasing from 0.01 to 1 %; the series were ended in 22 cases with 2–3 inhalations of isoprenaline. The effect of the drugs was studied by recording $FEV_{1.0}$ and peak flow 1, 3, 5, 7 and 10 minutes after each inhalation period.

METHOD

The forced vital capacity measurements and the MVV_{40} were performed on spirometers with a low flow resistance, as described in the previous paper (I). The peak expiratory flow (PEF) was measured with a "Wright Peak Flow Meter"¹, which has a low flow resistance even at high flow rates. The PEF read from the meter is the highest flow rate sustained for at least 10 milliseconds (91). Values between 60 and 1000 litres/minute can be read. Two flow meters (no. 801 and 810) were used, and there was no significant difference between the results obtained with them.

The statistical analysis concerning the changes of PEF with "order of performance" (p) or "time lapse" (t) were the same as those concerning $FEV_{1.0}$ and FVC described in the first paper in this series, I.

RESULTS

A. *Variability of Peak Expiratory Flow.*

1. *Normal subjects.* The mean value of 8 series of 5 PEF in a group of 4 females and 2 males was 486 litres/minute, range 364–661 litres. The mean SD was 19.8 ± 3.1 litres. The average variation coefficient was 4 % (1.8–6.3 %). The regression coefficients for PEF and "time lapse" (t) between the series of the different subjects, and for PEF and "order

¹ The Wright Peak Flow Meters were manufactured by Airmed Ltd., London.

of performance" (p) within the series were not significant. The average difference between mean values on successive weeks was 3 % ($-7-+11$ %).

Three of the participants developed common colds showing as sore throat, cough and some phlegm; in two this occurred during the test period and in one immediately after the test period. The PEF during those weeks were significantly lower than the usual values in the series. Thus the normal mean values were 412, 445 and 661 litres/minute, and during the colds the values of 5 PEF were 374, 326 and 537 litres/minute, respectively. Thus the colds brought about a reduction of 9-27 %.

2. *Bronchitis patients.* The mean value of 13 series of 4 PEF in a group of 9 males and 2 females was 271 litres per minute with a mean SD of 26.8 litres, ± 3.7 litres, and a coefficient of variation of 10 % (3.9-13.7 %). The regression between PEF and "time lapse" showed a significant coefficient, comprising a relative increase of 0.8 %/series. No change occurred within each series.

B. *Correlation between PEF and $FEV_{1.0}$ and MVV_{40} .*

Figs. 1a and 1b show the plots of PEF against $FEV_{1.0}$ for female and male patients. The correlation coefficients were significant, $r = +0.83$ and 0.88 respectively. The mean values and regression formulas can be seen in Table 1.

Figs. 2a and 2b shows the plots of PEF/ MVV_{40} for females and males. The correlations here were also significant, $r = +0.86$ and $+0.90$ respectively. Formulas and sample means may be seen in Table 1.

The PEF correlated to $FEV_{1.0}$ and to $FEV\%$ in male subjects with purely obstructive or restrictive lung disease is shown in Figs. 3 and 4. The correlation coefficients for PEF/ $FEV_{1.0}$ were significant for both groups, $r = +0.62$ for the obstructive group and $+0.69$ for the restrictive lot. The correlation coefficient for PEF/ $FEV\%$ was $r = +0.65$ in the obstructive group, compared to $+0.52$ in the subjects with restrictive disease. See Table 2.

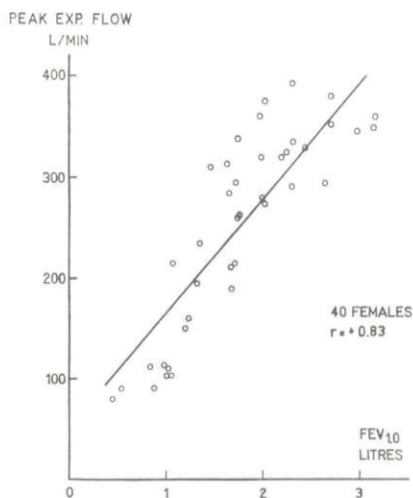


Fig. 1 a.

Peak expiratory flow plotted against FEV_{1.0} in female patients.

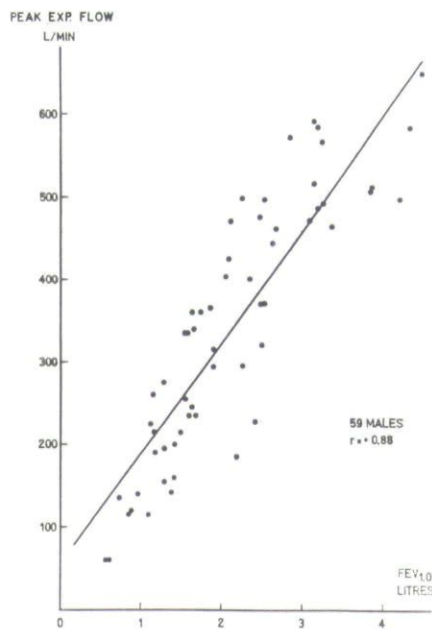


Fig. 1 b.

Peak expiratory flow plotted against FEV_{1.0} in male patients.

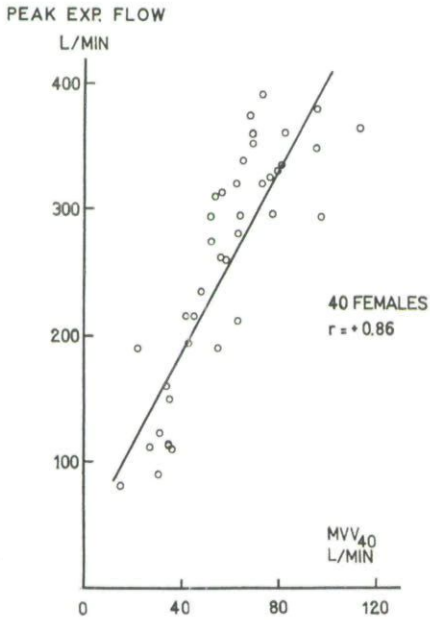


Fig. 2 a.

Peak expiratory flow plotted against MVV₄₀ in female patients.

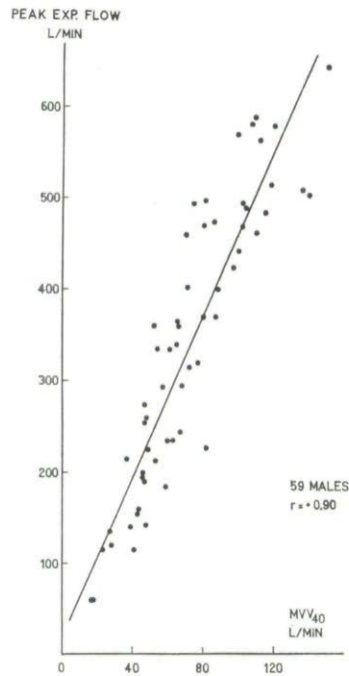


Fig. 2 b.

Peak expiratory flow plotted against MVV₄₀ in male patients.

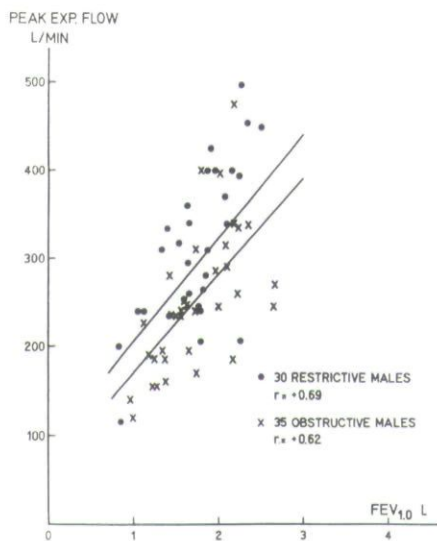


Fig. 3.

Peak expiratory flow plotted against FEV_{1.0} in male subjects with purely obstructive or restrictive lung disease.

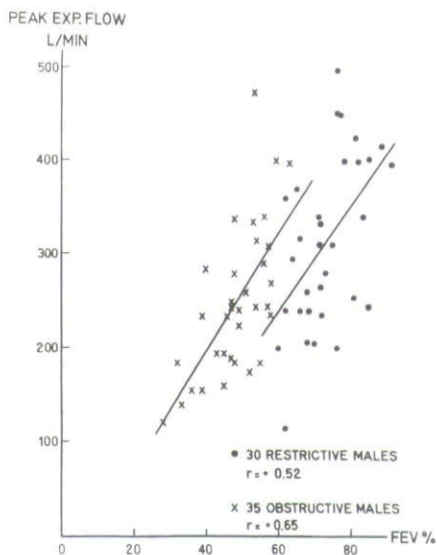


Fig. 4.

Peak expiratory flow plotted against FEV% in male subjects with purely obstructive or restrictive lung disease.

TABLE 1
Relations PEF/FEV_{1.0} and PEF/MVV₄₀.

		Females	Males
Number of subjects		40	59
Average PEF, litres ATPS		253	338
SD		95	154
Average FEV _{1.0} , litres BTPS		1.8	2.1
SD		0.7	1.0
Average MVV ₄₀ l./min. BTPS		58	72
SD		22	31
Regression coefficient (b)	PEF/FEV _{1.0}	113.8	140.3
	PEF/MVV ₄₀	3.6	4.4
Correlation coeff. (r)	PEF/FEV _{1.0}	+ 0.83 (P < 0.01)	+ 0.88 (P < 0.01)
	PEF/MVV ₄₀	+ 0.86 (P < 0.01)	+ 0.90 (P < 0.01)
<i>Regression formulas:</i>	PEF =	51.4 + 113.8 FEV _{1.0}	36.6 + 140.3 FEV _{1.0}
	PEF =	40.6 + 3.6 MVV ₄₀	17.3 + 4.4 MVV ₄₀

TABLE 2
Relations PEF/FEV_{1.0} and PEF/FEV% in subjects with purely obstructive or restrictive ventilatory impairment.

		Obstructive	Restrictive
Number of males		35	30
PEF, litres/min. ATPS.....		249	313
SD		79	90
FEV _{1.0} l.BTPS		1.72	1.74
SD		0.45	0.43
FEV%		48.4	72.9
SD		8.2	8.1
Regression coeff. (b)	PEF/FEV _{1.0}	+ 110.3	+ 146.7
	PEF/FEV%	+ 6.3	+ 5.7
Correlation coeff. (r)	PEF/FEV _{1.0}	+ 0.62 (P < 0.01)	+ 0.69 (P < 0.01)
	PEF/FEV%	+ 0.65 (P < 0.01)	+ 0.52 (P < 0.01)

C. *The sensitivity of PEF compared with FEV_{1.0} in pharmacological tests.*

Fig. 5 shows the PEF values corresponding to different magnitudes of the FEV_{1.0} before and after inhalation of drugs in each of 14 patients. With increasing concentrations of acetylcholine a stepwise decrease of FEV_{1.0} and PEF was obtained. Afterwards the subjects received inhalations of isoprenaline, which improved the parameters studied. The individual mean values obtained during the series lie on almost straight lines. The correlation coefficient for the pooled values was very high in this group, $r = +0.95$. Thus, when the airway constriction was varied, there was very good agreement between the FEV_{1.0} and the PEF.

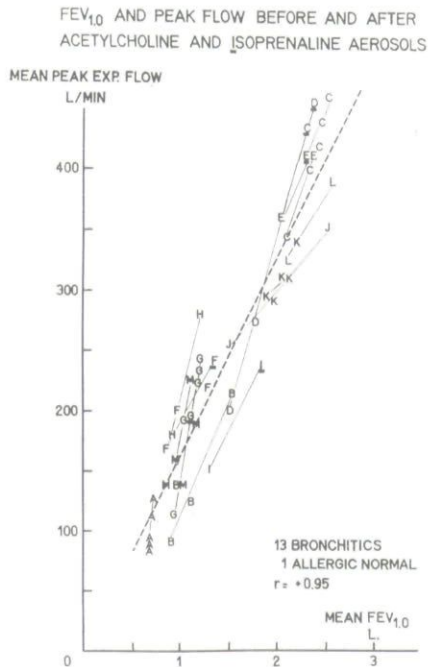


Fig. 5.

The sensitivity of peak expiratory flow compared with FEV_{1.0} in pharmacological tests.

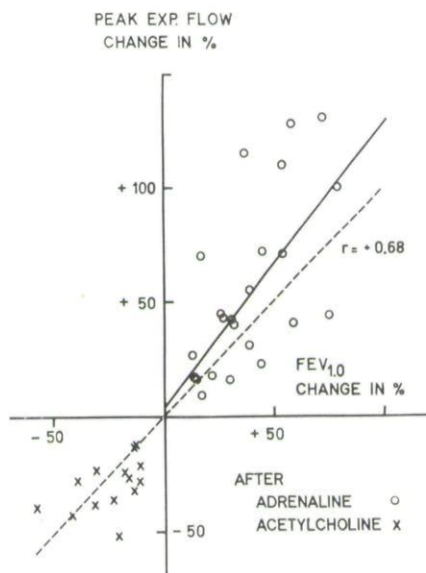


Fig. 6.

The percentage changes of peak expiratory flow and $FEV_{1.0}$ after inhalation of bronchoactive drugs.

Fig. 6 shows the percentage changes of the PEF (+52 %) and of the average $FEV_{1.0}$ (+39 %) after inhalation of adrenaline in 22 patients. Thus the PEF values usually changed relatively more than the $FEV_{1.0}$. The regression coefficient, calculated as a rectilinear function, for the group of "post adrenaline values" was 1.22. The correlation coefficient was +0.68 ($P < 0.001$).

DISCUSSION

The peak flow meter measures the maximal expiratory flow over a short period of time instead of the volume expelled during a breath. The peak flow thus may not be the ideal parameter of ventilatory capacity, for it occurs in a very early phase of a forced expiration and often lasts only for a very short period. The peak expiratory flow values nevertheless have proved to be a good index of ventilatory capacity.

In normal subjects, "peak flow meter" readings repeated during one day show a low variation coefficient in the present study as well as in others (52, 57, 81). Week-to-week variations were smaller in the present material than in others reported for succeeding days (81); this may be due to the low average age and the selection of subjects.

In the bronchitic group the variation was larger than in the normals. There was a small but significant increase of PEF with time lapse between the series, which might be due either to training or to an improvement of the bronchitis during the test period, even though no history of this was given.

The correlation coefficients were equally high for PEF/FEV_{1.0} and PEF/MVV₄₀. This could be expected in view of the good relation between FEV_{1.0} and MVV₄₀. (IV, 10). High correlation coefficients have been reported for PEF/FEV_{0.75} and for PEF/FEV_{1.0} in adults (32, 46) and in asthmatic children (44). The correlation of PEF to MVV_F is not always as good as the correlation to FEV (46, 76).

Both in patients with obstructive and in patients with non-obstructive ventilatory impairment there was a positive correlation between values of PEF and FEV_{1.0}. The PEF was also well correlated to the FEV% and this correlation was slightly but not significantly better in the obstructive group than in the non-obstructive group. A significant difference in the PEF/FEV% correlation between two such groups was reported by *Shephard* (81), and a non-significant difference by *Fairbairn* (32). Peak expiratory flow thus indicates the degree of ventilatory impairment and not the degree of obstruction.

In the present pharmacological study a change in FEV_{1.0} was always accompanied by a change of PEF in the same direction. In several cases the PEF change was greater than the FEV_{1.0} change; this is similar to findings recently reported by *Ritchie* (78). *Frank et al.* recently compared peak expiratory flow using Wright's Peak Flow Meter with pulmonary flow resistance obtained with the volume displacement body plethysmograph. After inhaling SO₂ the PEF decreased on average with 7 %, while the pulmonary resistance increased with

89 %. The peak expiratory flow showed decreasing values when pulmonary flow resistance had increased with a mean value of 1.16 cm H₂O/L/sec. from an average of 1.45 cm H₂O/L/sec. The authors did not obtain any significant decrease of the FEV_{1.0} for obscure reasons (34).

To explain the greater sensitivity of PEF to drug-induced changes in flow resistance, one should consider the type of expiratory flow curve at various lung volumes. At low lung volumes the airway resistance is relatively great (15), and the peak expiratory flow, in the early part of expiration, is only slightly greater than the mean expiratory flow. At large lung volumes, the peak expiratory flow is markedly greater than the mean expiratory flow. The FEV_{1.0} reflects mean expiratory flow over a given time. Administration of bronchodilating drugs is followed by an increased lung volume. Then, the discrepancy between peak expiratory flow and mean expiratory flow or FEV_{1.0} should increase.

An alternate explanation of the greater effect of drugs on PEF than in FEV_{1.0} is furnished by a study of pulmonary resistance in relation to pulmonary inflation in patients with airways obstruction (19). Two different types of relationships were found: 1) normal resistance near maximal inflation, increasing early during forced expiration, and 2) high resistance near maximal inflation with a smaller increase during expiration. Bronchodilators were reported to lower the resistance at all levels of inflation. After administration of a bronchodilating drug one might expect the PEF to change more than FEV_{1.0} in the second group with high resistance near full inflation; however, in the first group of patients with a normal resistance at maximal inflation, the drug would probably affect FEV_{1.0} at least as much as the PEF.

SUMMARY AND CONCLUSION

Peak expiratory flow measurements (PEF) with Wright's Peak Flow Meter were performed on six normal young subjects once a week for 8 successive weeks. The average variation coefficient was 4 %, i.e., similar to that of the FEV_{1.0} reported in the previous paper. Eleven bronchitics were studied for 13 weeks; the mean variation coefficient was 10 %, which is somewhat larger than that of FEV_{1.0} on a similar material

(I). A small increase of the PEF values was discernible with time lapse in the bronchitic group. The sensitivity of PEF was such that a common cold clearly reduced the flow rate in normal subjects.

Eighty-nine patients with various lung diseases showed a good correlation between the PEF and the $FEV_{1.0}$ or MVV_{40} . The PEF values were closely related to forced expiratory volumes, but *per se* do not discriminate obstructive from restrictive ventilatory impairment. Dynamic spirometry is necessary as a basic measurement; the PEF is useful for following changes in the ventilatory capacity of the patient.

When changes of airflow resistance were induced by pharmacological agents, the relative change of PEF was often larger than that of $FEV_{1.0}$.

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