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DYNAMIC SPIROMETRY STUDIES IN PATIENTS WITH LUNG DISEASE

*V. Dynamic Spirometry and Static lung Volume Measurements*¹

By

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Dynamic spirometry is a better measure of ventilatory capacity than estimations of static lung volumes (16). The FEV%, i.e., the forced one second volume (FEV_{1.0}) in per cent of the forced vital capacity (FVC) is closely connected to flow resistance in the airways (31, 51). On the other hand, an increase of airways resistance will also augment the functional residual capacity (FRC) and the residual volume (RV). This paper contains a study in pulmonary diseased patients on the relationship between the FEV% and the ratios of RV and FRC to the total lung capacity (TLC) and on the relationship of FEV_{1.0} to FRC and RV. A preliminary report was published in *Nordisk Medicin* 1960:63:374.

MATERIAL

One hundred and six subjects were studied. The female group consisted of 38 patients with an average age of 47 years (21-66 years). There were 68 males with an average age of 50 years (19-67 years).

The clinical diagnoses are shown in Table 1. The largest

¹ For terminology see page 330.

References after article no. VI.

group, comprising about 40 % in both sexes, consisted of subjects with chronic bronchitis with or without bronchial asthma or irreversible generalized airways obstruction. The groups pulmonary tuberculosis and lung tumours were smaller and, unfortunately, not of equal size in the two sexes.

TABLE 1
Clinical diagnoses.

	Males	Females
Chronic bronchitis/asthma/chronic non-specific obstructive lung disease	31 (45 %)	16 (42 %)
Pulmonary tuberculosis	20 (29 %)	4 (11 %)
Pulmonary tumours	5 (7 %)	7 (18 %)
Miscellaneous	12 (18 %)	11 (29 %)

In patients with only loss of parenchyma and/or collapse of lung tissue, the vital capacity may be reduced together with slight or no changes in RV and FRC. This will give elevated RV/TLC and FRC/TLC ratios even when no airway obstruction is present; such patients were excluded from the present material. It is important to note that such patients often have a normal FEV%.

METHOD

Forced vital capacity measurements were made on spirometers with a low airflow resistance. The procedure of the dynamic spirometry was described in paper I. The forced expiratory spiograms were as a rule performed on the same occasion as the TLC measurement.

For terminology on static volumes, see *Pappenheimer et al.* (73). Instead of using $RV/TLC \times 100$ and $FRC/TLC \times 100$, the abbreviations RV% and FRC% have been introduced, corresponding to the use of FEV% for $FEV_{1.0}/FVC \times 100$.

The total lung capacity measurements were performed using the "closed circuit helium method" as modified by Holm-

gren (48). Three determinations of slow vital capacity were made, the largest being used. The FRC was calculated according to a nomogram by *Birath* and *Svensson* (13). A helium absorption corresponding to 100 ml. lung volume was considered to occur during an ordinary test (12). In 40 duplicate tests of FRC with this method, Söderholm on this same spirometer found a methodologic error in single measurements of 180 ml. (86). In a smaller series on ten subjects during the present investigation, the same difference for FRC was 196 ml., for RV 70 ml., and for TLC 156 ml.

For calculating the sample correlation coefficients and regression formulas, standard methods using least squares were used. (See *Snedecor, G. W., Statistical Methods, 1957, Chapters 6, 7*). Level of significance $P < 0.05$.

RESULTS

A. *FEV%* in relation to *RV%* or *FRC%*.

In Figs. 1 and 2 are plotted, separately for females and males, the *RV%* and *FRC%* against the *FEV%*. The *RV%* and *FRC%* increase with a decreasing *FEV%*. Mean values and data of correlations are seen in Tables 2 and 3. The average *FEV%* in the female group was only about 10 % below the predicted normal value. The mean *FEV%* in the male group was decreased from predicted 76 % to 59 %, which value is below the lower 95 % confidence limit (10). The mean *RV%* and *FRC%* were augmented in both groups., but more so in the more obstructive male group. Although the percentage of subjects with bronchitis, asthma and/or chronic airways obstruction was almost the same in the two groups, the obstruction was more severe in the male group, where the mean value of *FEV%* was lower.

The correlation coefficients for *RV%/FEV%*, and *FRC%/FEV%* were for the males $R = -0.68$ and -0.57 , respectively, and for the smaller female group $R = -0.65$ and $R = -0.59$ respectively. All the *r*-values were highly significant ($P < 0.001$).

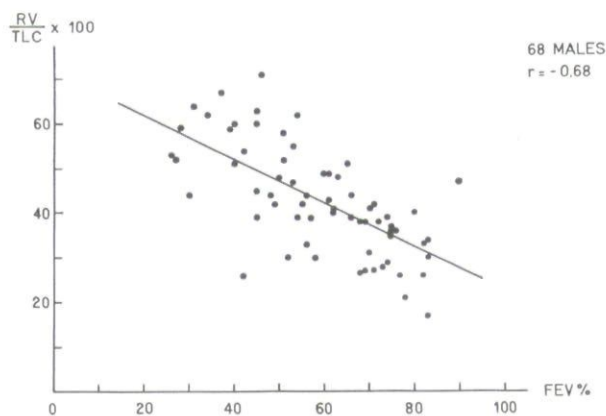
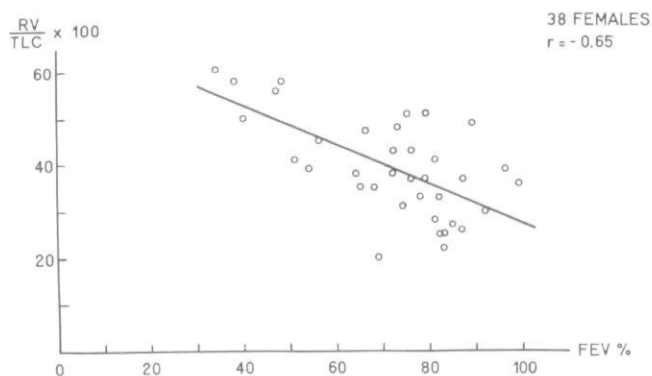


Fig. 1.

RV/TLC% plotted against FEV% in female and male patients.

B. $FEV_{1.0}$ in relation to RV or FRC.

In Figs. 3 and 4 are plotted separately for females and males the $FEV_{1.0}$ against the RV and FRC in litres BTPS. Compared with the plots of FEV% against RV-FRC%, there was a much larger scatter of values. The correlation coefficient for $FEV_{1.0}/RV$ was significant only in the male group, $r = -0.50$, while the corresponding figure for the

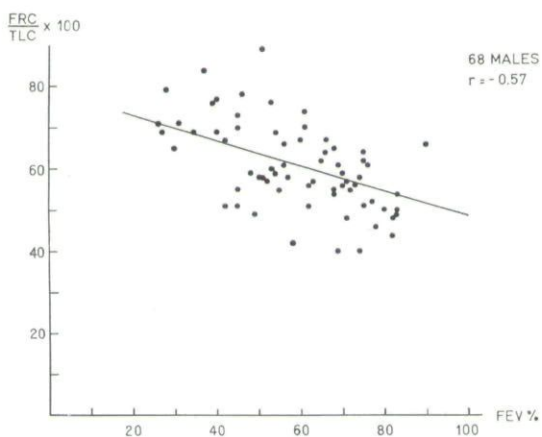
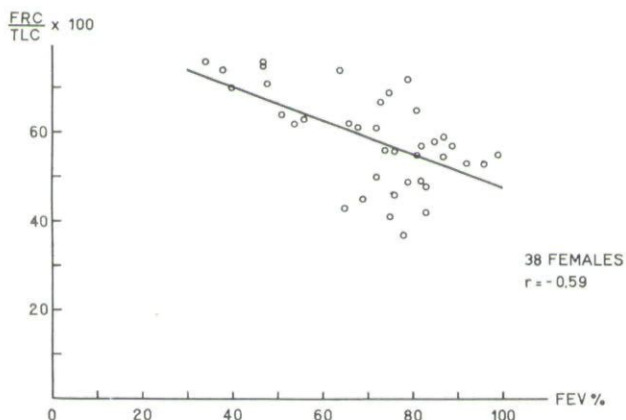


Fig. 2.

FRC/TLC% plotted against FEV% in female and male patients.

females was $r = -0.26$. The coefficients for $FEV_{1.0}/FRC$ were not significant.

Thus there was a better relationship in this material between the FEV% and RV-FRC% than between the $FEV_{1.0}$ and RV-FRC values.

TABLE 2
Mean values.

	Males	Females
Number of subjects	68	38
Mean age, years	50	47
Mean FEV%	59 (74 > 59)	71 (80 > 69)*
SD	16	16
Mean RV%	43 (35)	39 (33)
SD	12	11
Mean FRC%	61 (53)	59 (53)
SD	10	11
Mean FEV _{1,0}	2.2	1.9
SD	0.9	0.7
Mean RV	2.7	1.8
SD	1.0	0.7
Mean FRC	3.8	2.6
SD	1.0	0.8

* Predicted normal values within brackets, the last figure being the mean value minus 2 SD.

TABLE 3
Correlations.

	Sex	Regression formulas	Coeff. of correlation	P
RV% / FEV%	M	RV% = 72.9 - 0.51 FEV%	- 0.68	< 0.001
	F	RV% = 69.3 - 0.42 FEV%	- 0.65	< 0.001
FRC% / FEV%	M	FRC% = 83.2 - 0.37 FEV%	- 0.57	< 0.001
	F	FRC% = 85.7 - 0.38 FEV%	- 0.59	< 0.001
RV / FEV _{1,0}	M	RV = 3.9 - 0.56 FEV _{1,0}	- 0.50	< 0.001
	F		- 0.26	> 0.05
FRC / FEV _{1,0}	M		- 0.28	> 0.05
	F		- 0.05	-

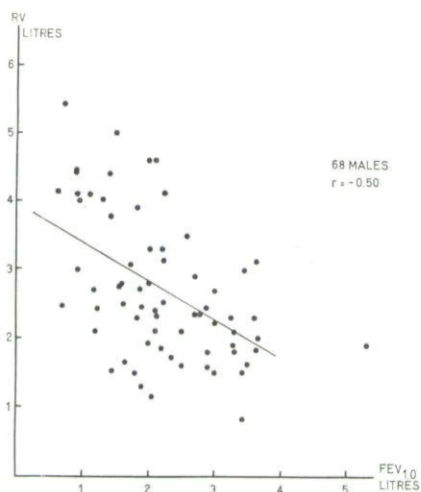
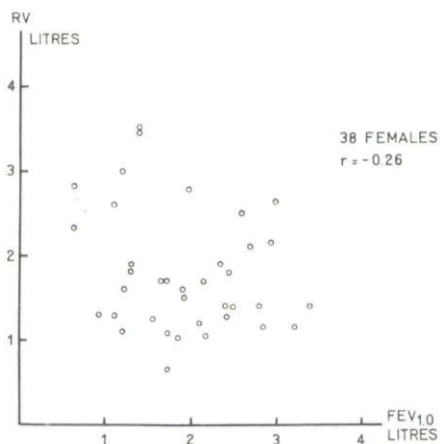


Fig. 3.

RV plotted against FEV_{1.0} in female and male patients.

DISCUSSION

Although there is a significant correlation between simple spirometric evaluation of airways resistance and gas dilution determination of the residual volumes in relation to the total

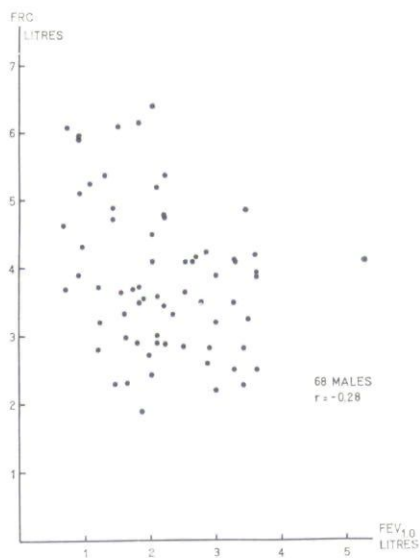
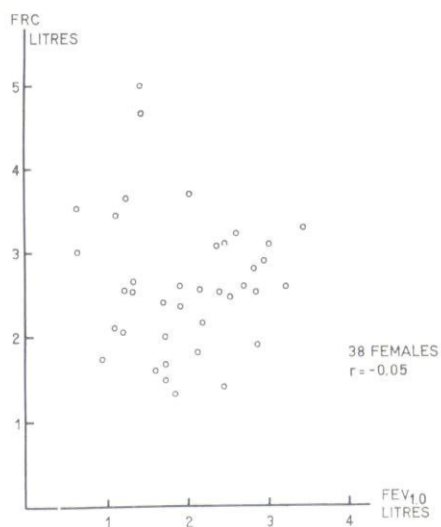


Fig. 4.

FRC plotted against FEV_{1.0} in female and male patients.

lung capacity, this relationship cannot be expected to be perfect. There are several reasons for this.

The FEV% is not linearly related to obstruction. Sometimes the FEV% can remain unchanged after induced bronchoconstriction when there is a considerable increase in the amount of trapped air in the lungs (24), or the FVC may even be proportionally more reduced than the FEV_{1.0}, which results in a falsely high FEV% (24). On the other hand, the true residual volume in cases with airways obstruction is not always revealed by the usual gas dilution methods. In such patients measurements of the thoracic gas volume with a body plethysmograph and of the communicating gas volume by gas dilution methods have shown a considerable difference, indicating that large volumes can be trapped (6). The poor mixing makes a prolonged gas dilution test desirable and has been shown to decrease the difference in volumes obtained with the gas dilution method and with the body plethysmograph (89). A further reason for lack of correlation between residual volume/total lung capacity ratios and FEV% is that the latter is obtained during a forced expiration from a maximal inspiratory level. The flow resistance is lowest at the high inspiratory level but rapidly increases during the forced expiration (59, 69). "Air trapping" may then occur, which corresponds to a temporary increase of the RV and a decrease of the FVC. The FRC measurement, on the other hand, is performed during slow "normal" breathing, probably with a lower airway resistance than during a forced expiration. The tests are consequently performed with different states of flow resistance.

In patients with partially occluding bronchial tumours the FEV_{1.0} and the FVC might thus be proportionally impeded, thereby even simulating a restrictive ventilatory impairment, while the FRC% and RV% are normal due to good ventilation during slow breathing. In bronchial asthma, contrarywise, a very low FEV% may be correlated with a comparatively less pathologic FRC% and RV%, which, however, is calculated on falsely low values for the lung capacities. *Gaensler* accordingly reported a poorer correlation for FEV_{1.0}/RV% in subjects

with asthma and bronchostenosis, having a decreased $FEV_{1.0}$ but an RV less than 45 % of TLC (38).

Hirdes and *Van Veen* also report a low $FEV\%$ with only slightly elevated residual volumes in asthma patients (47). *Brille* found a good correlation between a decrease of $FEV_{1.0}/VC$ and an increase of the ratios RV/TLC and FRC/TLC (14).

Tammeling and *Laros* reported on patients with pneumonectomy, some even with asthma, that a good negative correlation existed between the ratios $FEV_{1.0}/TLC$ and RV/TLC (88). Accordingly there should be a good correlation also between $FEV_{1.0}$ and RV, which is somewhat astonishing, because the $FEV_{1.0}$ may change more or less than the corresponding FVC. In the present study and in a study by *Sadoul* and *Saunier* this correlation was poor (79).

In the present material a large RV and FRC was found to coexist with a normal $FEV_{1.0}$ in some females. *Sadoul* and *Saunier* also reported this combination (79), and it was earlier observed in female subjects without obvious pulmonary disease by *Birath*, who considered nervous factors to play a part (11). Thus the residual volumes seem to be influenced by apprehension, which probably elevates the resting respiratory level due to lack of muscular relaxation in the thorax.

SUMMARY AND CONCLUSION

Forced vital capacity measurements and residual volume determinations by the closed helium method were performed in patients with chronic non-specific lung disease, pulmonary tuberculosis or lung tumours. No patients with markedly reduced lung volumes were included. The material consisted of 38 females and 68 males.

In both groups the forced one second volume in per cent of forced vital capacity ($FEV\%$) correlated significantly to the ratios residual volume/total lung capacity, and functional residual volume/total lung capacity.

Low $FEV\%$ values were usually related to increased resi-

dual volumes, while a normal FEV% may be connected to an increased FRC% or RV% in subjects without significant airways obstruction. This might be the case in subjects with restrictive lung disease with a diminution of the inspiratory capacity. Thus the FEV% more seldom is misleading as a sign of airways obstruction than the FRC and RV values. As dynamic spirometry also is easier to perform, it seems more recommendable as a qualitative screening test for obstructive bronchial diseases than the gas dilution test.

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