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Reference Values for Lung Function Tests in Men: Regression Equations with Smoking Variables

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ABSTRACT

Prediction formulas for static and dynamic spirometry, gas distribution, static lung mechanics and the transfer test were derived from measurements in healthy men. The measurements included total lung capacity, residual volume, airways resistance, static elastic recoil pressure of the lung, static compliance, closing volume, slope of the alveolar plateau (phase III), flow-volume variables (including mean transit time) during breathing of air or a helium/oxygen mixture, and conventional spirometric indices. The results from 146 smokers and 124 never-smokers were evaluated separately and combined. For all lung function tests a single regression equation was obtained. The prediction formulas included time-related smoking variables and were valid for both smokers and never-smokers. For many lung function tests, a nonlinear age coefficient resulted in a significant reduction in variance compared with simple linear models. Heavy tobacco smoking influenced most lung function tests less than ageing from 20 to 70 years, but for airways resistance, transfer factor and phase III the opposite was found.

INTRODUCTION

In research on occupational factors, which may influence pulmonary function, many different lung function tests may be employed in research of early signs of functional impairment. Confounding factors such as age, body size and tobacco smoking must be controlled. The present study was undertaken in order to obtain prediction formulas for several lung function tests derived by stepwise multiple regression which included age, body size and tobacco smoking as dependent variables. Special emphasis was laid on the effect of aging on pulmonary function since conventional linear models may lead to anomalous results in elderly subjects.

MATERIAL AND METHODS

Men attending the general health survey in Uppsala were offered pulmonary function tests at the Department of Clinical Physiology at the University Hospital, Uppsala. Smokers who had smoked at least five cigarettes per day during the last five years and never-smokers were included in about equal proportions. A sampling technique was used in order to achieve a stratified even distribution of subjects of ages between 20 and 70 years. A detailed history concerning health and occupation was obtained through a standardized questionnaire. Only subjectively healthy subjects with normal chest radiograms and who had had no significant occupational exposure to noxious dusts or fumes were included.

The pulmonary function tests have been described in detail elsewhere (7, 9). Static lung volumes and airways resistance were measured in a closed type body plethysmograph (Siemens Siregnost FD91S) (23). Vital capacity, forced expiratory flows after breathing air or a helium/oxygen mixture and maximal voluntary ventilation were measured in an dry rolling seal spirometer (Cardiopulmonary instruments (CPI) model 220). Mean transit time and the variance of mean transit time were computed according to the formulas $MTT= 1/VC^* \; t \; dV$ and $VMTT=1/VC^* \; (t-MTT)^2 \; dV$ (15). The single-breath nitrogen test (for measurement of closing volume and the slope of the alveolar plateau) was measured using the CPI model 410B nitrogen analyzer (1). The transfer factor or diffusing capacity for carbon monoxide (single-breath test) was measured with a combined infrared CO analyzer and a thermal conductivity helium cell (CPI model 451). TL(CO) was calculated according to standard methods (17, 21). Static compliance and maximal inspiratory lung elastic recoil pressure were measured according to the method of Milic-Emili et al. (13). The measurement of lung mechanics was performed in a first series of patients with a slightly different technique (smaller oesophageal balloons, causing slightly lower elastic recoil pressure) than in the ensuing series of patients. The difference between the two series can be expressed as a small parallel shift of the volume/pressure curve. The elastic recoil pressures obtained in the first series were corrected by adding 0.52 kPa (the average difference) before the values were used together with those in the second series for the statistical analysis. The variables measured, selection criteria and abbreviations used are shown in Table 1.

Table 1:
List of abbreviations and selection criteria.

TLC	a	Total lung capacity
FRC	a	Functional residual capacity
RV	a	Residual volume
FRC/TLC		
RV/TLC		
Raw	b	Airways resistance
Gaw/V	b	Volumic airways conductance
VC	c	Vital capacity
FVC	d	Forced vital capacity
FEV1	d	Forced expiratory volume in 1 s.
FEV1/VC	e	
MVV40	f	Maximal voluntary ventilation
FV		Flow-volume
PEF	d	Peak expiratory flow
MEF75	g	Maximal expiratory flow at 75% of FVC
MEF50	g	Maximal expiratory flow at 50% of FVC
MEF25	g	Maximal expiratory flow at 25% of FVC
AREA	g	Area under expiratory part of flow-volume curve
MTT	g	Mean transit time
VMTT	g	Variance of mean transit time
VISOF	h	Volume of isoflow.
QMEF50	h	100 * (MEF50-He - MEF50)/MEF50
Phase III	i	Slope of alveolar plateau
CV	i	Closing volume
CC	j	Closing capacity
CV/VC		
CC/TLC		
Pel(max)	k	Maximal elastic recoil pressure of the lungs
CR		Coefficient of retraction (Pel(max)/TLC)
Cst	l	Static compliance
Cst/V		Cst/TLC
TL(CO)	m	Transfer factor (diffusing capacity for CO, single breath)

a) Mean of at least three recordings of box- versus alveolar pressures.
b) Mean of at least three recordings of box pressure versus flow during near tidal breaths at a breathing frequency of 30 breaths/min.
c) Highest from at least two VC and three FVC recordings.
d) Highest from at least three acceptable FV curves.
e) Highest FEV1/ highest VC even if different curves.
f) Highest 5 s value during two efforts longer than 10 s at breathing frequency of 40 breaths/min.
g) From FV curve with highest sum of FEV1 + FVC.
h) From an acceptable FV- and FV-He curve after five deep breaths of 20% oxygen in 80% helium. VISOF = the volume from the end of the forced expiration where the flows breathing air or helium/oxygen were equal.
i) Mean from at least three acceptable recordings.
j) Mean from calculations of TLC-VC+CV, where CV and VC were measured at the same curve in at least three acceptable recordings.
k) Highest from at least three acceptable pressure-volume curves.
l) Mean of V/ P, where V is 30% of TLC and P is pressure difference between 50% and 80% of TLC from at least three acceptable static pressure-volume curves.
m) Mean values from two measurements.

For the statistical analysis, stepwise multiple regression with the statistical package for social sciences, SPSS (14) was used for analysing data. The results from the lung function tests were taken as dependent variables and age, body size (height and weight) and tobacco consumption (intensity and duration) as independent variables. The independent variables were chosen from a number of combinations and transformations of these variables following preliminary tests with Pearson and partial correlation. Guided by the results of these tests, the variables age, height, weight, the squares of age, different combinations of height and weight according to Khosla & Lowe (10), Broca´s index (weight/height in cm - 100), years of tobacco smoking, grams tobacco smoked each day, pack-years (smoke-years * grams of tobacco per day /20) and products of age and smoking were included in the multiple regression analysis. Only

Table 2:
Mean values, standard deviations (SD) and ranges of age, height, weight and smoking variables.

		All (n=270)	Never-smokers (n=124)	Smokers (n=146)
Age (years)	Mean	44.5	45.3	43.7
	SD	13.9	13.8	13.9
	Range	20-70	20-70	20-69
Height (cm)	Mean	177	176	177
	SD	6.6	6.5	6.6
	Range	160-196	161-195	160-196
Weight (kg)	Mean	76.2	77.7	74.8
	SD	10.0	9.4	10.3
	Range	55-109	56-105	55-109
Smoke-years	Mean			24.9
	SD			12.4
	Range			5-55
Gram tobacco each day	Mean			15.1
	SD			8.6
	Range			5-60
Pack-years	Mean			17.6
	SD			12.2
	Range			2-77

statistically significant variables (p value < 0.05) were accepted in the regression equations. In some equations where age*age was significant, age was also included due to co-linearity between age and age*age. If several independent variables showed a closely similar reduction in variance, the variable chosen was that which resulted in the simplest and most symmetrical regression equation when compared with the regression equations obtained from similar lung function tests.

RESULTS

A total of 270 subjects, 124 never-smokers and 146 smokers, were investigated. Mean values for age and for anthropometric and tobacco-consumption data in the different groups are given in Table 2. At least 20 never-smokers and 20 smokers were examined in each age decade. For technical reasons TL(CO) was measured in only 165 subjects; of these there were at least 10 never-smokers and 10 smokers in each age group (with the exception of age groups 20-30 and 40-50 years, where only five measurements of TL(CO) were performed on smokers). MTT, VMTT, VISOF and QMEF50 were measured in 70 persons (38 never-smokers and 32 smokers) evenly distributed between 40 and 70 years. Recordings of static lung mechanics were obtained for 144 subjects (51% smokers) evenly distributed between 20 and 70 years. Mean values, standard deviations, coefficients of variation and regression equations for all lung function tests are presented in Table 3.

Age. Age was included in the regression equations of all lung function variables, but in many variables age*age resulted in a larger reduction in variance than age alone. The age coefficients obtained when only never-smokers were analyzed were closely similar to those obtained from the combined groups.

Size. Height was usually chosen as the index of body size but weight was chosen in addition to height in the regresssion equations of different static lung volumes. Other indices of overweight (10) did not result in a significant reduction of variance compared with height and weight combined, neither did height squared or cubed.

Tobacco smoking. There were significant differences between never-smokers and smokers in all lung function tests, except TLC, FRC and static elastic recoil pressures. As a rule smoke-years was the most significant variable for smoking and was therefore chosen in the regression equation but in some lung function tests the variable pack-years was more

Table 3:
Coefficients of the multiple regression equations, fraction of explained variance (r2), standard error of the multiple regression equation (SE), SE in per cent of the mean value (SE%), mean value (M), standard deviation (SD) and number of cases in the regression equations (N). All coefficients are statistically significant (p<0.05) except coefficients indicated with ' which are included due to co-linearity with age*age.

Variable	Age*age	Age (years)	Height (cm)	Weight (kg)	Smoke-years	pack-years	const	r2	SE	SE%	M	SD	N
TLC (L)		+0.0117	+0.1234	-0.0172			-13.73	0.45	0.79	10.8	7.33	1.07	267
FRC (L)		+0.0195	+0.1107	-0.0484			-12.78	0.44	0.70	17.5	4.01	0.94	267
RV (L)		+0.0268	+0.0498	-0.0181		+0.0077	- 6.59	0.42	0.46	21.7	2.12	0.61	267
FRC/TLC (%)		+0.1761	+0.6017	-0.5415		+0.0602	-19.26	0.40	6.01	11.0	54.3	7.33	267
RV/TLC (%)		+0.3248	+0.1685	-0.1671		+0.0999	- 3.76	0.45	5.16	17.8	28.9	6.95	267
Raw (Pa/(L/s))											126	80.7	267
Gaw/V (1/(kPa*s))											2.35	1.77	267
Ln Raw		+0.0029	-0.0098	+0.0107	+0.0039		+ 5.47	0.12	0.43	9.1	4.72	0.46	267
Ln Gaw/V		-0.0075	-0.0157		-0.0050		+ 3.90	0.13	0.44	60.3	0.73	0.47	267
VC (L)	-0.000686	+0.0471	+0.0752		-0.0069		- 8.56	0.49	0.62	11.7	5.27	0.86	270
FVC (L)	-0.000705	+0.0467	+0.0744		-0.0065		- 8.44	0.50	0.61	11.8	5.17	0.86	270
FEV1 (L)	-0.000406	+0.0145'	+0.0509		-0.0081		- 4.67	0.59	0.46	11.5	3.99	0.72	270
FEV1/VC (%)		-0.2251	-0.1286		-0.0568		+109.4	0.25	6.04	8.2	75.9	6.93	270
MVV40 (L/min)		-0.7629	+1.5524		-0.3045		-102.5	0.50	18.5	13.8	134	26.3	270
PEF (L/s)	-0.000342	+0.0169'	+0.0885		-0.0139		- 5.80	0.20	1.29	13.3	9.69	1.45	270
MEF75 (L/s)	-0.000508	+0.0193'	+0.0678		-0.0173		- 3.73	0.18	1.56	20.0	7.79	1.71	270
MEF50 (L/s)	-0.000639	+0.0245'	+0.0375		-0.0167		- 1.71	0.27	1.15	26.1	4.40	1.35	270
MEF25 (L/s)	+0.000216	-0.0513	+0.0193		-0.0076		+ 0.19	0.53	0.51	30.5	1.67	0.74	270
AREA (L*L/s)	-0.002586	+0.0911	+0.5067		-0.0810		-65.48	0.49	5.17	23.7	21.8	7.20	70
MTT (s)		+0.0061	+0.0044			+0.0018	- 0.27	0.25	0.15	18.5	0.81	0.18	70
VMTT (s*s)		+0.0175	+0.0051			+0.0042	- 0.85	0.43	0.29	31.5	0.92	0.36	70
VISOF (L)		+0.0096	+0.0301		+0.0049		- 4.80	0.09	0.51	43.5	1.17	0.76	70
QMEF50 (%)		+0.1322	+0.3393		-0.1221		-21.97	0.15	14.4	33.6	42.8	21.8	70
Phase III (%N2/L)	+0.000276	-0.0080	-0.0149		+0.0128	+0.0106	+ 3.25	0.41	0.62	54.8	1.13	0.76	263
CV (L)	-0.000280	+0.0357	+0.0077			+0.0022	- 1.61	0.46	0.18	23.7	0.76	0.25	263
CC (L)	-0.000559	+0.0869	+0.0625	-0.0171		+0.0122	- 9.36	0.55	0.52	16.4	3.17	0.77	263
CV/VC (%)		+0.2993	-0.0644			+0.0910	+13.30	0.66	3.48	21.6	16.1	5.85	263
CC/TLC (%)		+0.4102				+0.1631	+23.32	0.62	5.10	11.8	43.1	8.33	263
Pel(max) (kPa)		-0.0121					+ 3.64	0.08	0.56	18.3	3.09	0.57	144
CR (kPa/L)		-0.0025	-0.0081				+ 2.00	0.22	0.10	22.8	0.45	0.12	144
Cst (L/kPa)		+0.0409	+0.0905				-14.37	0.22	1.25	34.6	3.65	1.40	144
Cst/V (100/kPa)		+0.4108					+30.38	0.15	13.7	27.6	49.9	14.6	144
TL(CO) (µmol/(s*kPa))		-1.0103	+1.3149			-0.7040	-24.44	0.49	22.2	14.2	156	33.6	165

significant and therefore preferred. Mostly only one of the smoking variables was chosen as the addition of the other did not reduced the variance. For phase III, however, a combination of smoke-years and pack-years resulted in an even larger reduction in variance than smoke-years or pack-years alone.

Table 4:
Effects of ageing, body size and tobacco smoking on pulmonary function calculated from the coefficients of the multiple regression equations in Table 3. The differences in predicted values using extreme values with regard to age, body size and tobacco smoking are expressed in percent of the mean value for each test. The extreme values: Age 20 to 70 years, height 160 to 200 cm, height and weight 160 cm, 90 kg to 200 cm, 65 kg and smoking 40 cigarettes/day for 50 years.

VARIABLE	EFFECT OF AGEING	EFFECT OF BODY SIZE	EFFECT OF SMOKING
TLC	+ 8.0	+ 73.2	
FRC	+24.3	+140.6	
RV	+63.2	+115.1	+ 36.3
FRC/TLC	+16.2	+ 69.3	+ 11.1
RV/TLC	+56.2	+ 37.8	+ 34.6
Raw	+12.1	- 57.5	+ 25.9
Gaw/V	-36.2	+ 54.5	- 17.8
VC	-13.8	+ 57.1	- 6.6
FVC	-16.2	+ 57.6	- 6.3
FEV1	-27.6	+ 51.0	- 10.2
FEV1/VC	-14.8	- 6.8	- 3.7
MVV40	-28.5	+ 46.3	- 11.4
PEF	- 7.2	+ 36.5	- 7.2
MEF75	-16.9	+ 34.8	- 11.1
MEF50	-37.5	+ 34.1	- 19.0
MEF25	-95.2	+ 46.1	- 22.8
AREA	-32.5	+ 92.9	- 18.6
MTT	+37.7	+ 21.7	+ 22.2
VMTT	+95.1	+ 22.0	+ 45.9
VISOF	+40.9	+102.9	+ 21.0
QMEF50	+15.4	+ 31.7	- 14.3
Phase III	+74.3	- 52.7	+150.4
CV	+69.1	+ 40.5	+ 29.0
CC	+57.7	+ 92.4	+ 38.5
CV/VC	+92.9	- 16.0	+ 56.5
CC/TLC	+47.5		+ 37.8
Pel(max)	-19.8		
CR	-28.4	- 73.6	
Cst	+56.6	+100.3	
Cst/V	+41.4		
TL(CO)	-32.4	+ 33.6	- 45.1

Table 4 illustrates the effects of ageing, body size and tobacco smoking on the results of the different lung function tests. As a rule, ageing (defined as from 20 to 70 years) had a greater effect than smoking (defined as 40 cigarettes/day for 50 years). However, phase III, Raw and TL(CO) were changed to a proportionally greater extent by smoking than by ageing.

A comparison with other reference equations is presented in Table 5, where the lung function test values of our subjects are expressed in per cent of predicted values using reference equations presented by some other authors (2-6, 8, 12, 16, 18-20, 22).

Table 5:
Comparison with other prediction formulas. Individual data are expressed as percentages of predicted values obtained from other prediction formulas. If the prediction formula was based on non-smokers, only non-smoking persons in the present material were used; otherwise the whole reference material was used for the comparison.

TLC	103(A)	94(D)	94(F)	
FRC	116(A)	109(D)	95(F)	
RV	103(A)	101(D)	96(F)	
Raw			103(F)	
Gaw/V			119(F)	
VC	107(A)	99(C)		
FEV1	104(A)	101(C)	96(F)	100(K)
FEV1/VC	97(A)	101(C)	94(F)	100(K)
MVV40	109(E)			
PEF	106(A)	105(G)	93(F)	
MEF75	99(A)	95(G)		
MEF50	88(A)	78(G)	80(F)	95(I)
MEF25	77(A)	62(G)	91(F)	89(I)
Phase III	166(B)	96(H)	80(K)	
CV/VC	142(B)	99(H)	81(K)	
CC/TLC	127(B)	98(H)		
TL(CO)	93(A)	95(J)	97(F)	

(A) Summary equations from Quanjer, 1983 (16)
(B) Knudson et al., 1977 (11)
(C) Berglund et al., 1963 (2)
(D) Grimby & Söderholm, 1963 (8)
(E) Birath et al., 1963 (3)
(F) Viljanen et al., 1981 (20,22)
(G) Cherniack & Raber, 1973 (6)
(H) Buist & Ross, 1973 (4,5)
(I) Knudson et al., 1983 (12)
(J) Van Ganse et al., 1975 (19)
(K) Sixt et al., 1984 (18)

DISCUSSION.

Only subjectively healthy subjects with a normal history ,normal clinical findings and a normal chest radiogram were accepted for inclusion in the study. Thus the average effects of tobacco smoking on pulmonary function were probably underestimated, since many subjects who had developed obvious chronic lung disease as a result of tobacco smoking did not come to the general health survey because they were already under treatment. Other smokers may have come to the survey but were excluded from our investigation because they had accquied radiographic lung changes. Persistent cough and sputum production were not disqualifying factors, however. The selection mechanisms may therefore have had an effect somewhat similar to the "healthy worker effect" observed in industry.

A great effort was made to obtain valid coefficients, first by screening a large number of variables, then by stepwise multiple regression, using different transformations of variables to test linearity, etc. Airways resistance and conductance had a markedly skewed distribution but logarithmic transformation resulted in a nearly normal distribution.

One issue of special concern was the possibility that the pooling of smokers and never-smokers may result in average regression coefficients which are not valid for either of the categories. We therefore compared the age, height and weight coefficients derived from never-smokers alone, from smokers alone and from the pooled groups. Both the age coefficients and the body size coefficients derived from smokers, never-smokers and from the pooled groups were, however, closely similar (no statistically significant differences). This is not surprising with regard to height and weight but since the effects of tobacco smoking are probably influenced by the duration of smoking, the age coefficients might have differed between the groups. The absence of differences in age coefficients is probably explained by the fact that the regression procedure resulted in the choice of a tobacco smoking index which included duration of smoking. The standard errors of the regression equations for never-smokers were not smaller than for the pooled groups. These observations make it possible to present one reference equation, valid for both smokers and never-smokers, for each lung function variable.

The composition of the material was controlled in order to permit accurate determination of the coefficients of age and tobacco smoking. All variables were influenced by ageing, and in many variables a significantly larger reduction in variance was observed with age*age than with age alone.

The distribution of body size was, however, approximately normal, which means that the coefficients of height and weight were determined with less accuracy. Overweight reduced static lung volumes as expected. Several indices of overweight were tested but were not superior to the combination of height and weight in reducing the residual variance of the regression equations.

Differences in material, methods and selection criteria may explain the rather marked differences commonly observed in comparisons of regression equations from different studies. Thus when studying environmental influences on pulmonary function, it is desirable to use control subjects which are tested by the same staff, on the same equipment and during the same time period as the study subjects. Regression equations are therefore necessary for correcting for differences in age, size and smoking habits between cases and controls. They are, of course, also useful in routine spirometry, provided that the methods and algorithms are identical. For the latter purpose no correction for smoking habits is used, since in our opinion the patient results should be compared with "normal values" rather than with "abnormal values" obtained in a combined group of smokers and never-smokers.

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REFERENCES

1. ANTHONISEN N.R., DANSON J., ROBERTSON P.C. & ROSS W.R.D.: Airway closure as a function of age. Resp Physiol 8:58-65, 1969/1970

2. BERGLUND E., BIRATH G., GRIMBY G., KJELLMER I., SANDQVIST L. & SÖDERHOLM B.: Spirometric studies in normal subjects. I. Forced expirograms in subjects between 7 and 70 years of age. Acta Med Scand 173:185-192, 1963.

3. BIRATH G., KJELLMER I. & SANDQVIST L.: Spirometric studies in normal subjects. II. Ventilatory capacity Tests in Adults. Acta Med Scand 173:193-198, 1963.

4. BUIST A.S. & ROSS B.B.: Predicted values for closing volumes using a modified single breath nitrogen test. Am Rev Dis 107:744-752, 1973.

5. BUIST A.S. & ROSS B.B.: Quantitative analysis of the alveolar plateau in the diagnosis of early airway obstruction. Am Rev Resp Dis 108:1078-1087, 1973.

6. CHERNIACK R.M. & RABER M.B.: Normal standards for ventilatory function using an automated wedge spirometer. Am Rev Resp Dis 106:38-46, 1972.

7. FRIDRIKSSON H.V., MALMBERG P., HEDENSTRÖM H. & HILLERDAL G.: Reference values for respiratory function test in males: prediction formulas with tobacco smoking parameters. Clinical physiology 1: 343-363, 1981.

8. GRIMBY G. & SÖDERHOLM B.: Spirometric studies in normal subjects. III. Static lung volumes and maximum voluntary ventilation in adults with a note on physical fitness. Acta Med Scand 173: 199-20, 1963.

9. HEDENSTRÖM H., MALMBERG P. & AGARWAL K.: Reference values for lung function tests in females. Regression equations with smoking variables. (Accepted for publication in Clin Resp Phys 1985).

10. KHOSLA T. & LOWE C.R.: Indices of obesity derived from body weight and height. Brit J Prev Soc Med 22:122-128, 1967.

11. KNUDSON R.J., LEBOWITZ M.D., BURTON A.P. & KNUDSON D.E.: The closing volume test: evaluation of nitrogen and bolus methods in a random population. Am Rev Resp Dis 115:423-43, 1977.

12. KNUDSON R.J., LEBOWITZ M.D., HOLBERG C.J. & BURROWS B.: Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Resp Dis 127:725-73, 1983.

13. MILIC-EMILI J., MEAD J., TURNER M. & GAENSER E.M.: Improved technique for estimating pleural pressure from oesophageal balloons. J Appl Physiol 19:20, 1964.

14. NIE N.H., HULL C.H., JENKINS J.G., STEINBRENNER K. & BENT D.H.: (eds) SPSS, Statistical package for the social sciences. 2nd ed. McGraw Hill, New York, 1975.

15. PERMUTT S. & MENKES H.A.: Spirometry analysis of forced expiration within the time domain. In: Lung biology in Health and Disease, vol 12: The lung in the transition between health and disease. P.T. Macklem and S Permutt eds. Dekker, New York. pp 113-151, 1979.

16. QUANJER Ph.H.: Standardized lung function testing. Clin Resp Phys suppl 5, vol 19, 1983.

17. SALORINNE Y.: Single-breath pulmonary diffusing capacity. Reference values and application in connective tissue diseases and in various lung diseases. Scand J Resp Dis suppl 9, 1976.

18. SIXT R., BAKE B. & OXHØJ H.: The single-breath N2-test and spirometry in healthy non-smoking males. Eur J Resp Dis 65:296-304, 1964.

19. VAN GANSE W.F., FERRIS JR B.G. & COTES J.E.: Cigarette smoking and pulmonary capacity (Transfer factor). Am Rev Resp Dis 105:30-41, 1972.

20. VILJANEN A.A., HALTTUNEN P.K., KREUS K-E. & VILJANEN B.C.: Spirometric studies in non-smoking, healthy adults. Scand J Clin Lab Invest 41: suppl 159, 5-20, 1981.

21. VILJANEN A.A., VILJANEN B.C., HALTTUNEN P.K. & KREUS K-E.: Pulmonary diffusing capacity and volumes in healthy adults measured with the single breath technique. Scand J clin Lab Invest 41: suppl 159, 21-34, 1981.

22. VILJANEN A.A., VILJANEN B.C., HALTTUNEN P.K. & KREUS K-E.: Body plethysmographic studies in non-smoking, healthy adults. Scand J Clin Lab Invest 41:suppl 159, 35-50, 1981.

23. WOITOWITZ H-J., BUCHHEIM F.W. & WOITOWITZ R.: Zur Theorie und Praxis der Ganzkörperplethysmographie in der Lungenfunktionsanalyse. Prax Pneumol 21:449-471, 1967.