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PULMONARY FUNCTION BETWEEN 40 AND 80 YEARS OF AGE

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Spirometry is the most frequently performed lung function test. To determine a normal range of spirometry results, reference formulas are used. Predicted values play an important role in establishing whether the volumes measured in an individual fall within a range to be expected in a healthy person of the same gender, height, and age. Such standards enable to assess the development of the respiratory system in the youth, the early recognition of the influence of a disease on the respiratory system and the influence of environmental factors on lung function. The objective of the present study was to estimate lung function prediction equations and to identify appropriate normal reference values for the Lublin Region local population of adults. We addressed the issue by analyzing the data from a lung function screening program conducted in the Lublin Region of Poland. Pulmonary function of adults aged 40-80 years was assessed from the measurements of forced vital capacity (FVC) and forced expired volume in the first second (FEV_1) in 136 adults. Reference values of FVC and FEV_1 for females and males were calculated by linear multiple regressions with age and height used as predictors. Different equations were compared to show their reliability when applied to the local population. The results were as follows. In females, the mean FEV_1 was 2.856 ±0.534 (L) (113.7 ±14.3%) and the mean FVC was 3.517 ±0.662 (L) (118.5 ±14.1%), in males, 3.913 ±0.773 (L) (110.9 ±15.1%), 4.922 ±0.941 (L) (112.1 ±14.1%), respectively. The estimated prediction equations were: for the FVC - for females - FVC (L) = 0.0528 (height) - 0.0262 (age) - 3.676 and for males - FVC = 0.0756 (height) - 0.0649 (age) - 4.904; and for the FEV_1 - for females - FEV_1 (L) = 0.0378 (height) - 0.0282 (age) - 1.799 and for males - FEV_1 (L) = 0.0553 (height) - 0.0553 (age) - 2.874. Units are years for age and centimeters for height. In conclusion, the analysis of the lung function data showed that there were significant difficulties in determining the appropriate reference values of FEV_1 and FVC. The predicted FEV_1 and FVC values derived from equations based on the ECSC (1) reference populations are considerably lower than those calculated in the present study, re-emphasizing the need to be cautious when applying the ECSC reference values for the local Lublin population. There seems to be a need for a constant refinement of spirometric standards.

Key words: *FEV_1, FVC, lung function, predicted values, spirometry*

INTRODUCTION

Spirometry is the most frequently performed lung function test. Pulmonary function variables depend on height, age, and gender. There is evidence of considerable variations in pulmonary function in different ethnic groups and across generations (2, 3, 4). Reference formulas are used to determine a normal range of spirometry results. Reference values play an important role in establishing whether the volumes measured in an individual fall within a range to be expected in a healthy person of the same gender, leight and age. Lung function declines slowly throughout the adult life, even in healthy persons. After attaining the maximum level of forced expired volume in one second (FEV_1) and forced vital capacity (FVC), there comes a period with merely small fluctuations in these indices, called 'plateau phase' (5, 6). The plateau phase ends when FEV_1 and shortly afterward also FVC start to decline. Cross-sectional analyses have suggested that the decline may accelerate after the age of 70 (7).

The aim of the present study was to construe the spirometric reference formulas for the populations of adult and elderly persons from the local Lublin Region in Poland and to compare the measurements of pulmonary function in those populations with other available standards.

MATERIAL AND METHODS

The study was approved by a local Ethics Committee and each subject gave his informed consent prior to the investigation. Spirometry was performed in a total of 149 subjects (F/M - 91/58), randomly selected from a local population of the Lublin Region in Poland. The participants completed a questionnaire that gathered the information on age, sex, health, and the smoking habit. Body measurements were taken, including the standing height and weight.

Forced expiratory maneuvers were recorded with a Jaeger pneumotachograph (Master Screen Body Apparatus; Erich Jaeger, Höchberg, Germany). Calibration was done with a 3 L syringe once a day. During testing, flow vs. volume tracings were displayed. After the explanation of the test procedure, every subject attempted to perform FVC maneuvers. A minimum of 3 acceptable and reproducible maneuvers were obtained, according to the standards recommended by the American Thoracic Society (8).

Statistical analyses were performed using Statistica 6 for Windows. Independent variables considered for inclusion in the models were age and the standing height and weight. The form of a model and the choice of independent variables were based on a combination of statistical significance and multiple regression coefficients (R^2). On that basis, the standing height and age were finally chosen as the independent variables.

RESULTS AND DISCUSSION

The objective of the study was to construe the reference equations appropriate for a local adult population of the Lublin Region. Appropriate reference values are vital for the assessment of lung function. The practice of functional testing dictates the qualification of a degree of functional impairment depending on the level of FEV_1 estimated as a percent of the reference value. Improper predicted values can delay the recognition of an illness developing or lead to inadequate rating of the impairment observed. That is why we decided to examine a group of healthy adults over the age of 40 years to create the reference values for a population of the Lublin Region. During many years of laboratory work we have observed that a substantial part of our patients have FEV_1 and FVC exceeding 120-130% of the ECSC (1) reference values. To set our own standards, we have begun the examination of healthy adults, both men and women. To this end, we used a program of prevention of circulatory system diseases being conducted in the city of Lublin. Subjects with symptoms of airways obturation (FEV_1%VC <70%) were excluded from the analysis. We did not exclude smokers and ex-smokers. These subjects had higher FEV_1 and FVC levels, even height correlated, than non-smokers (the effect of a healthy smoker). *Table 1* presents the characteristics of the examined group. *Table 2* presents the indices examined, FEV_1, FVC, separately for females and males.

The analysis of frequency distribution of the investigated FEV_1 and FVC, expressed as a percent of the ECSC (1) reference values showed a shift to the

Table 1. Anthropometric data.

	Females	Males
Number of subjects	87	49
Non-smokers (%)	57.3	32.7
Ex-smokers (%)	11.2	20.4
Smokers (%)	31.5	46.9
Age (yr)	51.6 ±7.2	52.2 ±7.1
Range (yr)	43 - 77	45 - 79
Height (cm)	161.4 ±5.9	174.9 ±6.4
Range (cm)	147 - 177	161 - 194
Weight (kg)	71.8 ±14	83.8 ±13.2
Range (kg)	46 - 124	61 - 115

Table 2. Lung function data in the cohorts evaluated.

Slow Vital Capacity (SVC)	Females	Males
Mean ±SD (L)	3.586 ± 0.66	5.019 ± 0.95
Range (L)	2.310 - 5.600	2.720 - 7.380
Forced Vital Capacity (FVC)		
Mean ±SD (L)	3.517 ± 0.66	4.922 ± 0.94
Range (L)	2.260 - 5.510	2.660 - 7.350
Forced Expiratory Volume in the First Second (FEV_1)		
Mean ±SD (L)	2.856 ± 0.53	3.914 ± 0.77
Range (L)	1.800 - 4.280	2.040 - 5.400

right, in both sexes. The FEV_1 and FVC exceeded 100%, respectively in 82% and 87% of women and in 80% and 80% of men. That unequivocally showed that the ECSC standards are not suitable for the Lublin population studied.

Taking into account the regression patterns for the calculation of reference values, we chose other than ECSC (1) formulas to calculate the FEV_1 and FVC reference values for women and men of our study. These formulas are shown in the *Table 3* and *Table 4* and are compared with those given by ECSC (1), Knudson et al (7), and Roca et al (9), Crapo et al (10). The outcome of the corresponding calculations of the predicted values for FEV_1 and FVC is presented in *Table 5*. The greatest differences between the reference values of our own patterns were observed in comparison against the ECSC values (1). The FEV_1 was underestimated by over 13% and FVC

Table 3. Comparison of different FEV_1 and FVC prediction equations used for females.

FEV_1 (L)	Formula	R^2	RSD
Ostrowski	0.0378h - 0.0282a - 1.799	0.41	0.43
ECSC (1)	0.0395h - 0.0250a - 2.600	-	0.38
Knudson (7)	0.0665h - 0.0292a - 6.515	0.74	0.52
Crapo (10)	0.0342h - 0.0255a - 1.578	0.79	0.32
Roca (11)	0.0326h - 0.0253a - 1.286	0.67	0.32
FVC (L)			
Ostrowski	0.0528h - 0.0262a - 3.676	0.41	0.57
ECSC (1)	0.0395h - 0.0250a - 2.600	-	0.38
Knudson (7)	0.0444h - 0.0169a - 3.195	0.49	0.48
Crapo (10)	0.0342h - 0.0255a - 1.578	0.67	0.32
Roca (9)	0.0454h - 0.0211a - 2.825	0.56	0.40

h - height in cm; a - age in years; R^2 - multiple regression coefficient; RSD - residual standard deviation

Table 4. Comparison of different FEV_1 and FVC prediction equations used for males.

FEV_1(L)	Formula	R^2	RSD
Ostrowski	0.0553h - 0.0553a - 2.874	0.61	0.52
ECSC (1)	0.0430h - 0.0290a - 2.490	-	0.51
Knudson (7)	0.0665h - 0.0292a - 6.515	0.74	0.52
Crapo (10)	0.0414h - 0.0244a - 2.190	0.64	0.49
Roca (11)	0.0514h - 0.0216a - 3.995	0.56	0.45
FVC (L)			
Ostrowski	0.0756h - 0.0649a - 4.904	0.66	0.62
ECSC (1)	0.0576h - 0.0260a - 4.340	-	0.61
Knudson (7)	0.0844h - 0.0298a - 8.782	0.72	0.64
Crapo (10)	0.0600h - 0.0214a - 4.650	0.53	0.64
Roca (9)	0.0678h - 0.0147a - 6.055	0.52	0.53

h - height in cm; a - age in years; R^2 - multiple regression coefficient; RSD - residual standard deviation

Table 5. Mean FEV1 and FVC values, as % of predicted, by different authors.

	Female*		Male**	
	FEV_1(%)	FVC(%)	FEV_1(%)	FVC(%)
Ostrowski	100	100	100	100
ECSC (1)	113.7	118.6	110.9	112.1
Knudson (7)	105.3	110.3	109.1	111.5
Crapo (10)	108.5	109.2	103.6	104.1
Roca (9)	107.0	103.0	100.2	97.8

*age 51.6 yr, height 161 cm; **age 52.2 yr, height 174.9 cm

by 18% in females, and by 10 % and over 12% in men, respectively. Smaller differences were observed when the reference values were calculated after Knudson et al (7) and Roca et al (9). Here, for the group of men, the reference values for both FEV_1 and FVC were close to the values calculated with our own patterns, the respective differences amounted to -0.2% and +2.2%. For the group of women, the closest to our own reference values for FEV1 were those of Knudson et al (7), the difference of +3%, and of Roca et al (9), the difference of -5.3%. All formulas were constructed on the basis of the multiple regression method and they consider the same independent factors. With the exception of the ECSC (1) formula all the others give the R^2 value. The scatter of R^2 between 41% and 79% means that the strength of each formula varies. Taking that into consideration, it can be stated that none of the authors have managed to create a strong, universal formula.

Establishing the predicted values is not easy. According to the presently accepted method of establishing of predicted values for lung function indices, it is assumed that the value of FEV_1 depends more on height. This assumption is true, as it has been confirmed in several examinations in the up-growth period and in subjects who outgrew this period. A second assumption is that the efficiency of ventilation measured with FEV_1 or FVC decreases constantly after it has reached its maximum level.

An important problem for such procedures is the cohort effect. Variation inside the reference group, such as overrepresentation of people with average anthropometric parameters and a simultaneous lack of people with extreme height and weight, very short and tall and very thin and obese, are responsible for the falsification of estimation. The vital influence on the final regression result has the deviation of physical development in successive generations. Ventilatory function in oldest cohorts is substantially lower than might have been expected from the longitudinal change in younger cohorts (4). In the investigated cohort we observed a negative correlation between the height and age. Thus, the cohort's elderly subjects' changes in FEV_1 and FVC depended, in part, on the age and on the fact that they were shorter.

In our group of men the estimated annual change of FEV_1 and FVC, which was 55.3 ml and 64.9 ml, respectively, was noticeably different from those stemming from the formulas presented in *Table 4*, which amounted to 21.6-29.2 ml/year for FEV_1 and 14.9-27.8 ml/year for FVC. Probably, the yearly variation of FEV_1 and FVC we noted results from the fact than we examined males over 40 years of age. At this point of age, most people have their developmental and plateau phases completed. Comparing the yearly drop in FEV_1 and FVC between the non-smokers and smokers, no significant differences were observed. This observation requires further research to establish whether it is characteristic for men, or an outcome of the cohort effect, or specific for the group examined. In the women examined, the estimated yearly declines of FEV_1 and FVC were similar to those observed in the reference groups of other authors.

Our analysis revealed differences in estimates of the predicted values for spirometric indices. In accordance with the study by Roca et al (11), which revealed significant differences between the observed and predicted values for FEV_1 and FVC in subjects aged 20-40 years, based on the ECSC formula (1), we now presented such differences in subjects aged 40-80 years.

Modifications of spirometric equipment and technique that have occurred during the last decade could additionally factor in the differences between the presently measured and long ago established predicted values of pulmonary function. However, using the current ATS quality criteria (8) for performing the forced expiration maneuver we obtain repeatable and reliable outcomes and factual maximum values of FEV1 and FVC.

In conclusion, we submit that there are significant difficulties in determining the appropriate reference values for FEV_1 and FVC. Predicted FEV_1 and FVC values derived from the equations based on the ECSC reference populations (1) are considerably lower than the mean values measured in the present study study, re-emphasizing the need to be cautious when applying the ECSC for the local Lublin population. In our opinion, constant research should be conducted to refine the pulmonary function standards and maintain them up to date. Such standards will enable to assess correctly the development of the respiratory system in the youth, the early recognition of the influence of a disease on the respiratory system, and the influence of environmental factors on lung function.

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