Spirometric Standards for Non-Smokers and Smokers of India (Eastern Region)

Satipati CHATTERJEE, Samir Kumar NAG,
and Swapan Kumar DEY

*Exercise Sports and Cardiorespiratory Physiology Laboratory,
Department of Physiology (Calcutta University),
University College of Science and Technology,
92, Acharya Prafulla Chandra Road,
Calcutta 700009, India*

Abstract Three hundred thirty-four healthy male non-smokers and 300 healthy male smokers of the age range 20–60 years were investigated for their spirometric lung functions by the method and technique recommended by American Thoracic Society. It was found that FVC, FEV₁, FEV₁%, FEF_{200–1,200}, FEF_{25–75}%, FEF_{75–85}%, MVV, and PEFR were significantly lower in smokers. When the subjects were blocked into several half decades these differences persisted. These functions deteriorated with age both in smokers and non-smokers, but in the former group the functions were reduced to a greater extent. Significant negative correlation was obtained between lung functions and smoking histories. Separate multiple regression equations were developed separately for non-smokers and smokers. The sensitivity of the tests was determined. The FEF_{25–75}% and FEV₁ were found to be most sensitive in detecting early airway obstruction. When comparison of lung function was made among American, European, Jordanian, Negro, and Pakistani subjects, it was found that the former three groups are superior to the remaining. Negroes and Pakistanis are comparable to Indians in respect to their lung function. These differences in these functions between the nations of developed countries and the underdeveloped or developing countries might be attributable to the differences in their life-style, physical activity status, nutritional status, environmental condition, and race and ethnicity. The spirometric functions of Indians in the Eastern region of India are comparable to North-West Indians and superior to Southern Indians.

Key words: spirometry, smoking, racial difference, regression equations.

In the assessment of lung function the spirometric measures are most commonly used. These values are influenced by a number of factors, particularly sex, height, age, usual habitat, geographic condition, and ethnic and racial origin. In different parts of the world several investigators have investigated the different lung function measurements and established the normal standards (KORY *et al.*, 1961; BERGLUND *et al.*, 1963; COTES and WARD, 1966; DaCOSTA, 1971; MORRIS *et al.*, 1971, 1975; OSCHERWITZ *et al.*, 1972; COTES *et al.*, 1973; SIDER and PETERS, 1973; WILLIAMS *et al.*, 1978; CRAPO *et al.*, 1981; SLIMAN *et al.*, 1981). In India such types of studies have been made for the north-west (JAIN and RAMIAH, 1969; VERMA *et al.*, 1983; MATHEW *et al.*, 1984) and the southern geographical region (KAMAT *et al.*, 1982; REDDY and SASTRY, 1944) of India. From these studies it was observed that the spirometric functions varied between these two populations. For the population of the eastern geographical region of India, normal standards have not yet been established. Some studies were, however, made recently on people of Calcutta, a part of Eastern Region by CHATTERJEE *et al.* (1988). This population differs from those of other regions of India in terms of ethnicity, environmental conditions, dietary habit, nutritional status, and other factors. Therefore, it is imperative to study these spirometric measures for this population. Moreover, the need for each laboratory to establish its own limits of "normal" is emphasized by SOBOL (1976).

Many investigators have been investigating the deleterious effect of cigarette smoking in different parts of the globe (ZWI *et al.*, 1964; PETERS and FERRIS, 1967; GRIMES and HANES, 1973; KRUMHOLZ and HEDRICK, 1973; MARCQ and MINETTE, 1976; TOCKMAN *et al.*, 1976; BECK *et al.*, 1981). Relatively little information is available in India in this respect (ISLAM *et al.*, 1970; JAIN *et al.*, 1972). Racial differences in smoking habits were documented (STEBBINGS, 1973). SELTZER *et al.* (1974) evidenced the differential effects of smoking habits on lung function in different racial groups. Therefore, it seemed appropriate to study the effect of smoking in this population and to develop separate prediction equation for smokers, if smoking effect on these subjects exists.

Therefore, the purposes of this study are a) to assess the role of cigarette smoking on spirometric lung functions measured by the method and instrument recommended by American Thoracic Society (1979) on smokers of different age groups, b) to establish standard norms in the form of prediction equations for the population of the eastern geographical region of India, and c) to compare these with the values reported on other geographical regions of India and abroad.

MATERIALS AND METHODS

Three hundred thirty-four healthy male sedentary non-smokers and 300 healthy male sedentary smokers of the age range 20–60 years were studied. Subjects included volunteer members of staff of the University, College and University students, research scholars, staff of different Government Offices. The subjects were drawn on the basis of random sampling procedure. No subject who was tested had

disabling respiratory, circulatory, or neuromuscular diseases. The criteria of MORRIS *et al.* (1971) were used to obtain the population of non-smokers who were free of disease or disability. An interview cross-checked the results of the questionnaire to eliminate subjects not fulfilling the criteria.

All these subjects were made familiar with the test procedures. Standing height was measured with subjects standing on bare feet, weight with the shoes and outer clothing removed. Body surface area (BSA) was calculated from the formula of DuBois and DuBois (1916).

During the testing, the subjects were observed for coughing or wheezing. All tests were done in the standing position and a noseclip was used. Most of the tests were done between 11:00 A.M. and 3:00 P.M. The spirometry was performed with a modified water-sealed Toshiwal Expirograph (9 l capacity) with sodalime cannister removed. The spirometer met the technical specifications of the American Thoracic Society (1979). The spirometric measures consisted of the vital capacity (VC), forced vital capacity (FVC), forced expiratory flow ($FEF_{200-1,200}$), forced mid expiratory flow ($FEF_{25-75\%}$), forced end expiratory flow ($FEF_{75-85\%}$), forced expiratory time (FET), maximum voluntary ventilation (MVV), and peak expiratory flow rate (PEFR). The terminology of the ventilatory function tests is in accordance with the recommendations of the American Thoracic Society (1979). From each subject at least three satisfactory spirograms were obtained. Performance of spirometry and selection of the best spirogram were made according to the method outlined by American Thoracic Society (1979). Measurement and calculations of spirometric results were made according to the techniques recommended by KORY *et al.* (1961) and Intermountain Thoracic Society (1975).

The volumes and flow rates were corrected to body temperature and pressure, saturated with water vapour (BTPS). The spirometer was calibrated every week by using Palmer respiratory hand pump. Peak expiratory flow rate was measured with a calibrated Wright peak flow meter.

RESULTS

A total of 334 healthy male non-smokers and 300 healthy male smokers were studied. The subjects were blocked by age into eight groups of half decades from 20 to 60 years. The distribution of subjects in each group along with means and standard deviations for physical characteristics and smoking histories are listed in Table 1. The age, height, weight, and BSA of smokers and non-smokers of each age group were comparable. The body weight and BSA were significantly higher in non-smokers of all ages combined than those of smokers of the comparable group.

Results of spirometric pulmonary functions are summarized in Tables 2 and 3 and Figs. 1 to 4. Mean values of these spirometric measures (except FET) were significantly higher in non-smokers than in smokers. The magnitude of difference of these measures between these two groups gradually increased with age among both smokers and non-smokers. The rate of decline of these measures was relatively

Table 1. Physical characteristics and smoking histories of non-smokers and smokers.

Age group	Category	No. of subjects	Age (year)	Height (cm)	Weight (kg)	BSA (m ²)	No. of cig. smoked/day	No. of years smoked	Pack year*
20-24	Non-smoker Smoker Level of <i>p</i>	60	22.2 ± 1.44	165.7 ± 6.00	54.9 ± 7.11	1.600 ± 0.14	—	—	—
		45	23.00 ± 1.10 NS	166.85 ± 5.61 NS	53.30 ± 5.94 NS	1.590 ± 0.12 NS	13.84 ± 5.02	5.13 ± 1.60	3.54 ± 2.09
25-29	Non-smoker Smoker Level of <i>p</i>	42	26.5 ± 1.39	166.2 ± 5.76	54.6 ± 8.87	1.598 ± 0.13	—	—	—
		30	26.60 ± 1.27 NS	168.80 ± 6.54 NS	54.33 ± 5.55 NS	1.615 ± 0.13 NS	12.30 ± 4.55	7.26 ± 2.17	4.70 ± 2.78
30-34	Non-smoker Smoker Level of <i>p</i>	40	31.5 ± 1.47	166.1 ± 5.89	56.1 ± 7.29	1.616 ± 0.13	—	—	—
		36	31.47 ± 1.34 NS	167.00 ± 6.91 NS	53.40 ± 5.99 NS	1.619 ± 0.13 NS	13.07 ± 6.99	10.52 ± 3.99	7.58 ± 4.58
35-39	Non-smoker Smoker Level of <i>p</i>	41	37.0 ± 1.70	166.0 ± 6.05	56.6 ± 7.71	1.622 ± 0.09	—	—	—
		46	36.30 ± 3.01 NS	164.60 ± 6.04 NS	55.5 ± 8.17 NS	1.603 ± 0.11 NS	16.28 ± 9.79	13.55 ± 4.61	11.59 ± 8.40
40-44	Non-smoker Smoker Level of <i>p</i>	38	41.1 ± 1.31	165.8 ± 6.41	56.5 ± 7.93	1.621 ± 0.13	—	—	—
		49	41.42 ± 1.32 NS	163.10 ± 6.36 NS	53.69 ± 9.16 NS	1.567 ± 0.13 NS	16.47 ± 6.95	17.86 ± 5.47	15.15 ± 8.35
45-49	Non-smoker Smoker Level of <i>p</i>	45	46.6 ± 1.62	165.7 ± 5.56	57.5 ± 8.02	1.631 ± 0.14	—	—	—
		31	47.04 ± 1.69 NS	164.70 ± 4.44 NS	54.90 ± 7.73 NS	1.594 ± 0.12 NS	17.45 ± 4.91	20.50 ± 4.31	17.95 ± 4.04
50-54	Non-smoker Smoker Level of <i>p</i>	40	51.1 ± 1.28	165.4 ± 6.08	57.6 ± 7.17	1.630 ± 0.13	—	—	—
		32	51.65 ± 1.40 NS	164.70 ± 5.33 NS	55.18 ± 8.61 NS	1.596 ± 0.13 NS	16.00 ± 5.22	24.03 ± 6.42	19.05 ± 7.72
55-60	Non-smoker Smoker Level of <i>p</i>	28	56.7 ± 1.14	166.1 ± 5.66	56.2 ± 8.36	1.618 ± 0.15	—	—	—
		31	56.32 ± 1.35 NS	164.80 ± 6.68 NS	55.50 ± 6.32 NS	1.606 ± 0.12 NS	17.96 ± 5.49	26.06 ± 7.48	23.48 ± 12.10
20-60	Non-smoker Smoker Level of <i>p</i>	334	37.5 ± 10.85	165.9 ± 6.26	56.2 ± 8.96	1.619 ± 0.13	—	—	—
		300	38.47 ± 10.91 NS	165.36 ± 6.44 NS	54.40 ± 7.12 <0.01	1.599 ± 0.12 <0.05	15.53 ± 6.23	15.12 ± 5.15	12.57 ± 9.71

* Pack year = No. of packet of cigarettes (20's) consumed per day × No. of years through which smoked.

Fig. 1. FVC, FEV₁, and FEV₁% as a function of age in years. The regression shown is for subjects 166 cm tall; regression lines for smokers and non-smokers are shown.

higher in smokers than in non-smokers. The slope of the age regression standardized for height at 166 cm showed significant difference (Figs. 1 and 2).

Since age and height were found to show higher correlation with pulmonary function measurements than that of weight and BSA, these two parameters were considered for the prediction of different pulmonary function tests. The prediction equations for different pulmonary function measurements with multiple correlation coefficients (R), coefficient of determinations (R^2), and standard error of estimate (SEE) are given in Table 3. The values of regression coefficients for age and height and the coefficient of determination of all the equations were highly significant ($p < 0.001$). The relative variability of the predicted flow rates was comparatively large. Standard error of estimate varied between 23 to 37% of the predicted value for these functions.

The present study has determined the sensitivity of these spirometric tests. The lower limit of normal for each parameter was taken as the predicted value -1.645 SEE, i.e. the 95% confidence limit for one tail of the distribution curve (SNEDECOR and COCHRANE, 1967). The predicted values were calculated from the prediction equations for normal non-smoker subjects. The percentage of subjects with abnormal test results was calculated for the smokers and non-smokers. For all tests, except FET, result was counted as abnormal if the Z value was < -1.645 ; for EFT, abnormal results were those with a Z value $> +1.645$ (WALTER *et al.*, 1979). The Z value was calculated as follows:

Table 2. Spirometric lung functions (mean $\pm$ S.D.) of

Age group	Category	VC (l)	FVC (l)	FEV ₁ (l)	FEV ₁ %
20-24	Non-smoker	4.017 $\pm$ 0.52	4.011 $\pm$ 0.52	3.509 $\pm$ 0.50	87.5 $\pm$ 6.8
	Smoker	4.027 $\pm$ 0.58	3.997 $\pm$ 0.48	3.317 $\pm$ 0.45	83.0 $\pm$ 8.08
	Level of <i>p</i>	NS	NS	<0.05	<0.01
25-29	Non-smoker	4.013 $\pm$ 0.56	4.002 $\pm$ 0.56	3.432 $\pm$ 0.50	85.7 $\pm$ 6.86
	Smoker	3.932 $\pm$ 0.51	3.887 $\pm$ 0.50	3.220 $\pm$ 0.46	82.2 $\pm$ 7.21
	Level of <i>p</i>	NS	NS	NS	NS
30-34	Non-smoker	3.862 $\pm$ 0.57	3.852 $\pm$ 0.57	3.269 $\pm$ 0.50	84.8 $\pm$ 5.94
	Smoker	3.777 $\pm$ 0.64	3.714 $\pm$ 0.64	3.029 $\pm$ 0.52	81.2 $\pm$ 5.85
	Level of <i>p</i>	NS	NS	<0.05	<0.01
35-39	Non-smoker	3.731 $\pm$ 0.52	3.719 $\pm$ 0.52	3.078 $\pm$ 0.45	82.7 $\pm$ 5.82
	Smoker	3.594 $\pm$ 0.47	3.552 $\pm$ 0.47	2.819 $\pm$ 0.42	79.4 $\pm$ 5.82
	Level of <i>p</i>	NS	NS	<0.01	<0.01
40-44	Non-smoker	3.676 $\pm$ 0.44	3.666 $\pm$ 0.44	2.971 $\pm$ 0.42	81.0 $\pm$ 6.51
	Smoker	3.412 $\pm$ 0.55	3.367 $\pm$ 0.55	2.609 $\pm$ 0.38	77.3 $\pm$ 5.45
	Level of <i>p</i>	<0.02	<0.01	<0.001	<0.01
45-49	Non-smoker	3.570 $\pm$ 0.60	3.545 $\pm$ 0.60	2.821 $\pm$ 0.46	79.5 $\pm$ 5.57
	Smoker	3.375 $\pm$ 0.52	3.321 $\pm$ 0.51	2.521 $\pm$ 0.40	76.1 $\pm$ 5.88
	Level of <i>p</i>	NS	NS	<0.01	<0.02
50-54	Non-smoker	3.457 $\pm$ 0.51	3.436 $\pm$ 0.51	2.702 $\pm$ 0.42	78.6 $\pm$ 6.25
	Smoker	3.231 $\pm$ 0.53	3.171 $\pm$ 0.52	2.308 $\pm$ 0.38	73.5 $\pm$ 6.62
	Level of <i>p</i>	NS	<0.05	<0.001	<0.01
55-60	Non-smoker	3.374 $\pm$ 0.47	3.349 $\pm$ 0.47	2.571 $\pm$ 0.40	76.7 $\pm$ 6.12
	Smoker	3.137 $\pm$ 0.53	3.078 $\pm$ 0.53	2.209 $\pm$ 0.43	71.6 $\pm$ 5.14
	Level of <i>p</i>	NS	<0.05	<0.01	<0.01
20-60	Non-smoker	3.743 $\pm$ 0.61	3.728 $\pm$ 0.61	3.080 $\pm$ 0.60	82.6 $\pm$ 7.16
	Smoker	3.576 $\pm$ 0.61	3.523 $\pm$ 0.60	2.776 $\pm$ 0.63	78.4 $\pm$ 7.69
	Level of <i>p</i>	<0.001	<0.001	<0.001	<0.001

$$Z = \frac{\text{actual value} - \text{predicted value}}{\text{standard error of estimate}}$$

For smokers, 20% of the subjects had abnormal test results for FEF_{25-75%}; 10% for FEF_{75-85%}, PEFR, and FET; 13% for FEV₁, 9% for FEV₁% and FEF_{200-1,200}.

Age-related changes of lung function in the population of the Eastern region of India were compared with the population of the North-Western (VERMA *et al.*, 1983) and the Southern region of India (KAMAT *et al.*, 1982), standardized to a height of 166 cm (Fig. 3). It was observed that for the same height the absolute value of VC is

non-smokers and smokers of different age groups.

FEF _{200-1,200} (l/min)	FEF _{25-75%} (l/min)	FEF _{75-85%} (l/min)	PEFR (l/min)	MVV _F (l/min)	FET (s)
421 ± 126.3	294 ± 69.3	87.2 ± 27.0	616 ± 61.4	146 ± 17.6	3.32 ± 1.01
374 ± 13.40	233 ± 64.2	77.5 ± 30.2	597 ± 62.2	138.1 ± 20.8	3.42 ± 1.26
NS	<0.001	NS	NS	<0.05	NS
401 ± 112.3	276 ± 64.5	85.8 ± 31.7	604 ± 71.8	143.0 ± 19.3	3.40 ± 0.89
354 ± 120.3	218 ± 57.2	70.1 ± 31.3	587 ± 76.9	134.3 ± 16.8	4.45 ± 1.67
NS	<0.001	<0.05	NS	<0.05	<0.01
380 ± 106.4	266 ± 63.8	74.8 ± 26.2	578 ± 58.2	138.0 ± 16.9	3.50 ± 1.15
337 ± 114.0	210 ± 58.8	62.3 ± 26.5	560 ± 64.1	127.3 ± 17.8	4.64 ± 1.39
NS	<0.001	<0.05	NS	<0.01	<0.001
363 ± 116.2	240 ± 60.6	70.9 ± 25.5	569 ± 54.3	127.0 ± 17.7	4.04 ± 0.98
307 ± 113.0	171 ± 51.2	54.5 ± 21.8	547 ± 60.3	115.3 ± 19.5	6.20 ± 1.43
<0.05	<0.001	<0.01	NS	<0.01	<0.001
353 ± 112.9	224 ± 44.8	61.1 ± 20.5	542 ± 56.6	119.5 ± 16.5	4.14 ± 1.47
278 ± 97.4	157 ± 40.4	45.1 ± 18.0	518 ± 54.8	107.0 ± 17.2	5.77 ± 2.05
<0.01	<0.001	<0.001	NS	<0.01	<0.001
325 ± 120.2	208 ± 45.7	52.0 ± 20.1	529 ± 62.4	112.0 ± 13.4	4.60 ± 1.28
266 ± 107.0	141 ± 45.2	35.2 ± 15.8	500 ± 59.2	99.2 ± 14.9	5.97 ± 2.10
<0.05	<0.01	<0.001	<0.05	<0.001	<0.001
315 ± 107.0	196 ± 51.1	49.2 ± 19.6	515 ± 48.6	106.0 ± 16.8	5.37 ± 1.62
261 ± 104.1	127 ± 37.3	27.5 ± 13.1	487 ± 53.5	89.8 ± 21.0	6.41 ± 2.11
<0.05	<0.001	<0.001	<0.05	<0.001	NS
294 ± 97.0	186.2 ± 37.2	39.6 ± 15.4	496 ± 47.2	99.0 ± 12.8	5.30 ± 1.75
248 ± 89.5	111 ± 29.5	18.8 ± 8.8	470 ± 51.7	81.8 ± 16.5	6.68 ± 2.12
NS	<0.001	<0.001	<0.05	<0.001	NS
362 ± 106.3	241 ± 70.6	67.2 ± 25.3	562 ± 71.6	126.0 ± 23.3	4.15 ± 1.36
305 ± 113.4	178 ± 68.6	50.3 ± 28.0	536 ± 80.6	112.8 ± 28.6	5.40 ± 1.96
<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

higher in the population of North-Western India and much lower in the population of Southern India. The VC declined gradually in these populations as age advanced, ultimately leading to a drop of 11.4, 24, and 21.5 ml/year for Southern, North-Western, and Eastern populations respectively.

The FEV₁ was also found to be much lower in the population of Southern India in respect to the population of Eastern India. Absolute value of FEV₁ for the same standardized height was identical between the population of Eastern and North-Western India. The FEV₁ declined with an annual drop of 28.5 ml/year in these latter two groups. A drop of 21.25 ml/year in FEV₁ was observed for the

Table 3. Regression equations for ventilatory functions of non-smokers and smokers.

Ventilatory norms	Regression coefficients* of		Constant	Multiple correlation coefficient (<i>R</i>)	Coefficient of deter- mination* (<i>R</i> ²)	Standard error of estimate (SEE)
	Age (year)	Height (cm)				
Non-smoker (<i>n</i> = 334)						
FVC (<i>l</i>)	−0.0214	0.0522	−4.129	0.72	0.52	0.422
VC (<i>l</i>)	−0.0214	0.0522	−4.114	0.72	0.52	0.422
FEV ₁ (<i>l</i>)	−0.0286	0.0533	−4.6899	0.84	0.70	0.326
FEV ₁ %	−0.3093	0.2136	58.76	0.54	0.29	6.019
FEF _{200–1,200} (<i>l</i> /min)	−3.6710	5.0558	−338.69	0.53	0.28	90.37
FEF _{25–75%} (<i>l</i> /min)	−2.7877	3.6742	−263.62	0.59	0.35	56.89
FEF _{75–85%} (<i>l</i> /min)	−1.4098	0.6777	7.637	0.66	0.44	14.29
PEFR (<i>l</i> /min)	−3.6350	2.0460	358.80	0.62	0.38	56.46
MVV _F (<i>l</i> /min)	−1.3287	1.2050	−24.14	0.76	0.57	15.18
FET (s)	0.0673		1.637	0.53		1.15
Smokers (<i>n</i> = 300)						
VC (<i>l</i>)	−0.0288	+0.0536	−4.179	0.84	0.70	0.331
FVC (<i>l</i>)	−0.0290	+0.0480	−3.312	0.81	0.65	0.354
FEV ₁ (<i>l</i>)	−0.0371	+0.0390	−2.378	0.83	0.69	0.346
FEV ₁ %	−0.339	+0.291	43.301	0.58	0.34	6.25
FEF _{200–1,200} (<i>l</i> /min)	−3.878	+6.790	−668.27	0.59	0.35	91.81
FEF _{25–75%} (<i>l</i> /min)	−3.710	+2.687	−123.22	0.69	0.47	49.98
FEF _{75–85%} (<i>l</i> /min)	−1.807	+0.826	−16.72	0.75	0.56	18.65
PEFR (<i>l</i> /min)	−4.265	+5.191	−157.95	0.76	0.58	52.47
MVV _F (<i>l</i> /min)	−1.782	+1.574	−78.85	0.81	0.65	16.8
FET (s)	0.103		1.322	0.59		1.58

* Regression coefficients and coefficients of determinations are significant ($p < 0.001$).

Southern population.

The present data of FVC and FEV₁ have also been compared with American White (KORY *et al.*, 1961), Negro (OSCHERWITZ *et al.*, 1972), European (COTES *et al.*, 1973), Pakistani (WILLIAMS *et al.*, 1978), and Jordanian (SLIMAN *et al.*, 1981) subjects to evaluate racial differences for a standardized height at 166 cm (Fig. 4). The figure shows that absolute values of FVC and FEV₁ of Jordanian, European, and American White subjects are much higher than those of the present study. The FVC and FEV₁ are found to be comparable among the Negroes, Pakistanis, and the present study. The FVC declined with a rate of 21.5, 22, 24, 27, and 32 ml per year in the population of the present study, American White, Jordanian, Negro, and European subjects, respectively. In these populations, FEV₁ dropped at a rate of 28.5, 36, 27, 31, and 33 ml per year, respectively.

Fig. 2. $FEF_{200-1200}$, $FEF_{25-75\%}$, $FEF_{75-85\%}$, $PEFR$, and MVV_F as a function of age in years. The regression shown is for subjects 166 cm tall. Regression lines for smokers and non-smokers are shown.

DISCUSSION

The present study is based on two very similar groups of people. The smokers and non-smokers are comparable regarding their physical characteristics, physical activity, socioeconomic status, and environmental conditions. The subjects were of similar race and ethnic origin. Nevertheless, there were some marked differences in the results in these two groups. In general, the lung capacities, volumes, and ventilatory flow rates have shown significant difference between smokers and non-smokers; lower values are obtained in the former group. When the subjects were blocked into several half decades these differences persisted both in the young and older subjects. In age groups where significant differences were not obtained, a definite trend of higher spirometric lung function values was seen among non-smokers. These observations are in accordance with those of others. WALTER *et al.* (1979) showed significant changes in lung function in young smokers. Moreover, in this study these changes were dose-related, similar to our finding. SEELY *et al.* (1971) and LIM (1973) also observed similar results in teenagers with smoking histories of 1 to 2 years. Thus, changes in lung function appear to occur early after starting to smoke. KRUMHOLZ and HEDRICK (1973) obtained significantly lower values of FVC,

Fig. 3. VC and FEV₁ as a function of age in years in North-West Indian, Southern Indian, and Eastern Indian subjects. The regression shown is for subjects 166 cm tall. Regression lines for non-smokers are shown.

FEV₁, FEV₁%, expiratory flow rates and MVV in middle-aged smokers than their non-smoking counterpart. JAIN *et al.* (1972) also reported significant difference in pulmonary function between smokers and non-smokers of young and older ages.

The findings of an increasing difference between smokers and non-smokers with increasing age in the spirometric measures possibly reflect chronic effects of smoking which develop over time in response to repeated insults to the lung. It is possible that the observed changes in pulmonary function with increasing age among smokers merely reflected the result of an increase in cigarette consumption, both in terms of pack years and number of cigarettes smoked per day, with increasing age (Table 1). Significant negative correlations of these smoking variables with pulmonary functions also suggest this view. It may be that these effects are related to the gradual development of paranchymal destruction and increased compliance, development of bronchoconstriction, inflammation, or mucus production (TOCKMAN *et al.*, 1976).

As shown in the Table 2, FEV₁, FEF_{25-75%}, and FEF_{75-85%} decreased more extensively than other flow rates. The chief determinants of flows at low lung volumes are the elastic recoil of the lung and the resistance of the small airways (MEAD *et al.*, 1967). Thus, narrowing and resultant increase in resistance in the small airways and/or a decrease in elastic recoil pressure of the lung can cause decreased flows at these lung volumes. According to DOSMAN *et al.* (1975), early changes in smokers are probably due to narrowing of the small airways. The present

Fig. 4. FVC and FEV₁ as a function of age in years in American, European, Jordanian, Negro, Pakistani, and Indian subjects. The regression shown is for non-smoker subjects 166 cm tall.

observations are in accordance with this view which also coincide with WALTER *et al.* (1979). However, alterations in the elastic recoil pressure are not ruled out.

SELTZER *et al.* (1974) reported important racial distinctions between smokers and non-smokers with respect to spirometric measures. For Whites, larger mean values of these measures were found among non-smokers in comparison to smokers virtually in every age grouping. For Negroes and Orientals no such differences between smokers and non-smokers were noted. Our results do not corroborate the findings of SELTZER *et al.* (1974). Our Indian subjects being oriental showed significant difference between smokers and non-smokers.

The present study illustrates the usefulness of the forced expiratory spirogram in evaluating the early changes in lung function in smokers. Judging by the number of smokers who had abnormal results, FEF_{25-75%} was found to be the most sensitive indicator for this purpose, whereas FEV₁, FEV₁%, FEF_{75-85%} also appeared to be sensitive but not to the extent of FEF_{25-75%}. This parameter is a sensitive indicator for the detection of expiratory flow obstruction. SOBOL *et al.* (1973) also designated this variable as the most sensitive indicator for the detection of early airway obstruction.

The age-related change in pulmonary functions of non-smokers of this study are in agreement with those found in many other studies (BERGLUND *et al.*, 1963; MORRIS *et al.*, 1971). The degenerative change in lung, respiratory muscle and spines are probably the most important factor that limit the ventilatory function and thus cause a reduction in the total lung capacity, limit maximum respiration thereby reducing VC. The marked decline in ventilatory function with increasing age may also be due to impairment of pulmonary elasticity and decreased mobility of the chest cage (MITTMAN *et al.*, 1965). Decrease in the power of the respiratory muscle and loss of elasticity of the lungs with advancing age are reported (TURNER *et al.*, 1968). As a result of these changes, the static intra-thoracic pressure becomes less negative for any given level of lung inflation and the pressure volume diagram becomes curvilinear and the lungs become more compliant (KENNY, 1982). Resistance to air flow is caused by two mechanisms viz. intrinsic airway narrowing and airway collapse. Airway closure has been shown to occur at higher lung volume with advancing age (ANTHONISEN *et al.*, 1970). All these factors contribute to the decline of ventilatory functions with advancing age in non-smokers. Among smokers the age-related change on ventilatory functions is augmented due to smoking-induced airway resistance developed in smokers. Higher negative correlations of lung functions with age in smokers obtained in this study (Figs. 1 and 2) support this view.

Owing to this significant difference between smokers and non-smokers, separate regression equations for non-smokers and smokers were derived. The different regression equations developed for prediction of spirometric lung functions are reliable and reproducible. The separate regression equations developed for smokers were also derived from age and height without incorporating the smoking variables. This is because when the smoking variables were incorporated, the multiple correlation though increased slightly and SEE reduced to some extent, the absolute predicted value obtained was comparable with those regression equations derived from age and height only.

The pulmonary functions of American White, European White, and Jordanian subjects, standardized for age and height, are superior to those of the Indians of the present study. These functions are well comparable among Indians, Pakistanis, and Negroes. It indicates that in more economically developed countries these functions are superior to those of the underdeveloped or developing countries like India, Pakistan, and Africa where problems of malnutrition and frequent childhood respiratory infections are common. Other studies on Americans (MORRIS *et al.*, 1971; SCHMIDT *et al.*, 1973; CRAPO *et al.*, 1981) also reported much higher values for these tests in them than those of our subjects.

Racial and ethnic variation might be the major factor behind these differences. A number of studies revealed difference in pulmonary function among subjects of different ethnic and racial origin (COTES and MALHOTRA, 1965; ROSSITER and WEILL, 1974; OSCHERWITZ *et al.*, 1972). Better economic status, nutritional standards, and more active habits among the subjects of more economically developed countries

are also important factors in such differences. The differences in pulmonary function between Whites and Negroes were also explained as due to smaller chest size perhaps due to socioeconomic factors or lower physical activity (COTES *et al.*, 1973, 1975; ROSSITER and WEILL, 1974). A large portion of American subjects examined by KORY *et al.* (1961) is military personnel performing manual duties which might contribute to enhanced development of the musculoskeletal system of the thoracic cage and lung tissues resulting in better function in them as compared to our subjects inspite of standardization for differences in physical measurements. The excellent values of FVC and FEV₁ observed in Jordanians in comparison to other populations could be the result of strict criteria observed in choosing a sample of non-smokers. Another reason may be the lack of atmospheric pollution. Amman, where the tests were carried out, is a non-industrial, mountainous city, 774 m above sea level, so high altitude and physical activity (COTES *et al.*, 1973) might also have produced a favourable effect on FVC and FEV₁. Similar ecological and tropical conditions, nutritional and socioeconomic status of the subjects in both India and Pakistan are possibly the reason for obtaining comparable values in Indians and Pakistanis.

Racially, Indians are smaller in structure compared to Whites and Jordanians. Taller individuals have a different ratio of upper extremities (leading to a larger thoracic cavity and larger lung volumes) compared to total body length. Climatic factors are complex and cannot be simplified. People in tropical India pursue more sedentary occupations than in the temperate and cold climates in Europe and America. These factors combined with poor nutrition and repeated and untreated respiratory infections in childhood among Indians perhaps are the reasons for poor lung function in Indians. WOOLCOCK *et al.* (1972) have stressed that respiratory infections in childhood may predispose to chronic respiratory disease in adults and to a lower lung function. COTES *et al.* (1965, 1973) though that all Asians had smaller lungs than those of Europeans. The differences, they argued, were possibly genetic or environmental relating to physical activity during childhood or as a result of inhospitable tropical living (an effect of malnutrition or frequent infections).

The age-related changes of pulmonary functions of these Indians were similar to those of American Whites and Jordanians. There was a greater fall of forced expiratory volume as a result of aging in Europeans and Negroes. The age-related changes in Pakistanis were close to Indians. The significance of these changes cannot be appreciated without statistical analysis. It is possibly associated with ethnic and environmental factors.

It has been reported earlier that the lung functions among Indians also show regional and ethnic variation (COTES *et al.*, 1975; JAIN and RAMIAH, 1969; VERMA *et al.*, 1983). In these studies the lung functions of North Indians were reported to be higher than South Indians. But these functions were not evaluated for the population of the Eastern region of India. In this study when the comparisons of these functions of Eastern Indians were made with other regions, it was found that the functions of Eastern Indians are similar to those of North-Western Indians and

higher than South Indians. The procedural and technical anomalies may be responsible in part for such differences in lung function between South Indians and Eastern Indians. As the socioeconomic and environmental conditions are comparable in between these two regions, the difference in lung function might be associated with ethnic variation and genetic factors. The difference in dietary habit may also be associated. Though the values of the Eastern region of India are apparently comparable with those of North-West Indians there are some shortcomings in the report made on them by VERMA *et al.* (1983), particularly of instrument, procedure, and characteristics of the subjects. It was not explained whether the subjects, from which the regression formulae were derived by them, were smokers, non-smokers, or both.

The spirometric standards presented in this study for the male Eastern Indian subjects might be helpful for the estimation of lung function of a given subject for detection of chronic obstructive pulmonary diseases, for the assessment of severity of these diseases, and for the assessment of degree of pulmonary disfunction as a result of industrial hazards on industrial workers. The standard values provided will also serve as a reference standard of this population for comparison.

The authors are indebted to Indian Council of Medical Research for providing financial assistance.

REFERENCES

- American Thoracic Society (1979) ATS-statement—Snowbird workshop on standardization of spirometry. *Am. Rev. Respir. Dis.*, **119**: 831–838.
- ANTHONISEN, N. R., DANSON, J., ROBERTSON, P. C., and ROSS, W. R. D. (1970) Airway Closure as a function of age. *Respir. Physiol.*, **8**: 58–65.
- BECK, G. J., ROYLE, C. A., and SCHACHTER, E. N. (1981) Smoking and lung function. *Am. Rev. Respir. Dis.*, **123**: 149–155.
- BERGLUND, E., BIRATH, G., BJURE, J., GIRIMBY, G., KJELLMER, I., SANDGUST, L., and SODERHOLM, B. (1963) Spirometric studies in normal subjects. I. Forced expirogram in subjects between 7 and 70 years of age. *Acta Med. Scand.*, **173**: 185–192.
- CHATTERJEE, S., SAHA, D., and CHATTERJEE, B. P. (1988) Pulmonary function studies in healthy non-smoking men of Calcutta. *Ann. Human Biol.*, in press.
- COTES, J. E., DABBS, J. M., HALL, A. M., LAKHERA, S. C., SAUNDERS, M. J., and MALHOTRA, M. S. (1975) Lung function in healthy young men in India—Contributory roles of genetic and environmental factors. *Proc. R. Soc. Lond.*, **191**: 413–425.
- COTES, J. E. and MALHOTRA, M. S. (1965) Differences in lung functions between Indians and Europeans. *J. Physiol. (Lond.)*, **177**: 17–18.
- COTES, J. E., SAUNDERS, M. J., ADAM, J. E. R., ANDERSON, H. R., and HALL, A. M. (1973) Lung function in coastal and highland New Guineans. Comparison with Europeans. *Thorax*, **28**: 320–330.
- COTES, J. E. and WARD, M. P. (1966) Ventilatory capacity in normal Bhutanese. *J. Physiol. (Lond.)*, **163**: 36–37.
- CRAPO, R. O., MORRIS, A. H., and GARDNER, R. M. (1981) Reference spirometric values using techniques and equipment that meet ATS recommendations. *Am. Rev. Respir.*

- Dis.*, **123**: 659–664.
- DACOSTA, J. L. (1971) Pulmonary function studies in healthy Chinese adults in Singapore. *Am. Rev. Respir. Dis.*, **104**: 128–131.
- DOSMAN, J., BODE, F., URBANETTI, J., MARTIN, R., and MACKLEM, P. T. (1975) The use of a helium-oxygen mixture during maximum expiration flow to demonstrate obstruction in small airways in smokers. *J. Clin. Invest.*, **55**: 1090.
- DUBOIS, D. and DUBOIS, E. P. (1916) Clinical calorimetry: A formula to estimate the approximate surface area if height and weight be known. *Arch. Intern. Med.*, **17**: 863–871.
- GRIMES, C. A. and HANES, B. (1973) Influence of cigarette smoking on the spirometric evaluation of employees of a large Insurance Company. *Am. Rev. Respir. Dis.*, **108**: 273–282.
- Intermountain Thoracic Society (1975) Clinical pulmonary function testing. *In*: A Manual of Uniform Laboratory Procedures for an Intermountain Area, Intermountain Thoracic Society, Salt Lake City.
- ISLAM, M. S., DATTA, P. K., MITRA, D. K., and CHAKRABORTY, M. K. (1970) Changes of ventilations function amongst smokers and non-smokers. *Indian J. Physiol. Pharmacol.*, **14**: 165–173.
- JAIN, B. L., ABRAHAM, S., and KOKAU, A. K. (1972) A study of ventilatory lung functions in smokers from a tropical area. *J. Trop. Med. Hyg.*, **75**: 103–108.
- JAIN, S. K. and RAMIAH, T. J. (1969) Normal standards of pulmonary function tests for healthy Indian men 25–40 years old. Comparison of different regression equations (prediction formula). *Indian J. Med. Res.*, **57**: 1453–1463.
- KAMAT, S. R., TYAGI, N. K., and RASHID, S. S. A. (1982) Lung function in Indian adult subjects. *Lung India*, **1**: 11–21.
- KENNY, R. A. (1982) *Physiology of Aging*, Year Book, Medical Publishers Inc., Chicago, p. 42.
- KORY, R. C., CALLAHAN, R., BOREN, H. G., and SYNER, J. C. (1961) The veterans administration co-operative study of pulmonary function: Clinical spirometry in men. *Am. J. Med.*, **30**: 243–258.
- KRUMHOLZ, R. A. and HEDRICK, E. C. (1973) Pulmonary function differences in normal smoking and non-smoking, middle aged, white collar workers. *Am. Rev. Respir. Dis.*, **108**: 225–230.
- LIM, T. P. K. (1973) Airway obstruction among high school students. *Am. Rev. Respir. Dis.*, **108**: 985.
- MARCQ, M. and MINETTE, A. (1976) Lung function changes in smokers with normal conventional spirometry. *Am. Rev. Respir. Dis.*, **114**: 723–738.
- MATHEW, L., SENGUPTA, J., LAKHURA, S. C., and RAMAN, C. V. (1984) Age related changes in lung functions in Indian servicemen. *Indian J. Med. Res.*, **79**: 529–537.
- MEAD, J., TURNER, J. M., MACKLEM, P. T., and LITTLE, J. B. (1967) Significant of the relationship between lung recoil and maximum expiratory flow. *J. Appl. Physiol.*, **22**: 95–108.
- MITTMAN, C., EDELMAN, N. H., MORRIS, A. H., and SHOCK, N. W. (1965) Relationship between chest wall and pulmonary compliance and age. *J. Appl. Physiol.*, **20**: 1221.
- MORRIS, J. F., KOSKI, A., and BREESE, J. D. (1975) Normal values and evaluation of forced end expiratory flow. *Am. Rev. Respir. Dis.*, **111**: 755–762.
- MORRIS, J. F., KOSKI, A., and JOHNSON, L. C. (1971) Spirometric standard for healthy non-smoking adults. *Am. Rev. Respir. Dis.*, **103**: 57–67.

- OSCHERWITZ, M., EDLAVITCH, S. A., BAKER, T. R., and JARBOE, T. (1972) Difference in pulmonary function in various racial groups. *Am. J. Epidemiol.*, **96**: 319–327.
- PETERS, J. M. and FERRIS, B. G., Jr. (1967) Smoking pulmonary function and respiratory symptoms in a college age group. *Am. Rev. Respir. Dis.*, **95**: 774–782.
- REDDY, D. V. S. and SASTRY, P. B. (1944) Studies in vital capacity. *Indian J. Med. Res.*, **32**: 237–246.
- ROSSITER, C. E. and WEILL, M. (1974) Ethnic differences in lung function evidence for proportional differences. *Int. J. Epidemiol.*, **3**: 55–61.
- SCHMIDT, C. D., DICKMAN, M. Z., GARDNER, R. M., and BROUGH, F. K. (1973) Spirometric standards for healthy elderly men and women. *Am. Rev. Respir. Dis.*, **108**: 933–939.
- SEELY, J. E., ZUSKIN, E., and BOUHUYS, A. (1971) Cigarette smoking: Objective evidence for lung damage in teenagers. *Science*, **172**: 741.
- SELTZER, C. C., SIEGELAUB, A. B., FRIEDMAN, G. D., and COLLEN, M. F. (1974) Differences in pulmonary function related to smoking habits and race. *Am. Rev. Respir. Dis.*, **110**: 598–608.
- SIDER, R. and PETERS, J. M. (1973) Difference in ventilatory capacity of Irish and Italian fire fighters. *Am. Rev. Respir. Dis.*, **108**: 669–671.
- SLIMAN, N. A., DAJANI, B. M., and DAJANI, H. M. (1981) Ventilatory function test values of healthy adult Jordanians. *Thorax*, **36**: 546–549.
- SNEDECOR, G. W. and COCHRANE, W. G. (1967) Statistical Methods, 6th ed., Oxford and IBH Publishing Co., Calcutta.
- SOBOL, B. J. (1976) The early detection of airway obstruction. Another perspective. *Am. J. Med.*, **60**: 619.
- SOBOL, B. J., PARK, S. S., and EMIRGIL, C. (1973) Relative value of various spirometric tests in the early detection of chronic obstructive pulmonary disease. *Am. Rev. Respir. Dis.*, **107**: 753–762.
- STEBBINGS, J. H. (1973) A survey of respiratory disease among New York City postal and transit workers. *Environ. Res.*, **6**: 147.
- TOCKMAN, M., MONKES, H., COHEN, B., PERMUTT, S., BUJAMIN, J., BALL, W. C., Jr., and TONAECIA, J. (1976) A comparison of pulmonary function in male smokers and non-smokers. *Am. Rev. Respir. Dis.*, **114**: 711–722.
- TURNER, J. M., MEAD, J., and WOHL, N. E. (1968) Elasticity at human lungs in relation to age. *J. Appl. Physiol.*, **25**: 664–671.
- VERMA, S. S., KISHORE, N., RAMAN, C. V., LAKHERA, S. C., and DASS, S. K. (1983) Prediction of some ventilatory norms in healthy Indian males 21–69 years age. *Indian J. Physiol. Pharmacol.*, **27**: 45–49.
- WALTER, S., NANCY, N. R., and COLLIER, C. R. (1979) Changes in the forced expiratory spirogram in young male smokers. *Am. Rev. Respir. Dis.*, **119**: 717–724.
- WILLIAMS, D. E., MILLER, R. D., and TAYLOR, W. F. (1978) Pulmonary function studies in healthy Pakistani adults. *Thorax*, **33**: 243–249.
- WOOLCOCK, A. J., COLMAN, M. H., and BLACKBURN, C. R. B. (1972) Factors affecting normal values for ventilatory lung function. *Am. Rev. Respir. Dis.*, **106**: 692–709.
- ZWI, S., GOLDMAN, H. I., and LEVIN, A. (1964) Cigarette smoking and pulmonary function in healthy young adults. *Am. Rev. Respir. Dis.*, **89**: 73–81.