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Pulmonary Function Studies in Healthy School Boys of West Bengal

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Abstract The establishment of normal standards of dynamic pulmonary function measurements in the form of prediction equations will serve as a remedial measure of different aspects of obstructive pulmonary diseases, especially in children. With a view to achieving the target, dynamic pulmonary function measurements were undertaken on 328 healthy school-going children of West Bengal having age ranging between 9 and 18 years. All the spirometric measurements except PEFR were taken with the help of a 9 *l* closed-circuit type expirograph following the methods and techniques of American Thoracic Society. PEFR was measured by Wright Peak Flow Meter. Prediction equations were derived on the basis of age and height for all the pulmonary function measurements except $FEV_{1\%}$ and FET. The prediction equations for FVC, FEV_1, MVV_F, and PEFR were reliable, but relative variability of predicted $FEF_{25-75\%}$ and $FEF_{75-85\%}$ was very large. A comparative study of FVC, FEV_1, and PEFR values of our subjects, standardized for age and height, was much closer to the boys of Delhi in FVC but higher than South Indian boys in FEV_1, North and South Indian boys in PEFR. In an attempt to compare FVC and FEV_1 values of our subjects with foreign populations, it is revealed that boys of our study were much lower than American (White), European, and Jordanian boys but comparable with those of Chinese and Libyan boys.

Key words: dynamic pulmonary function, boys, Indian.

Pulmonary function tests provide objective information about the extent of physiological impairment. Thus, techniques for estimating the severity of airway obstruction are useful in assessing functional derangement and for evaluating the results of various therapeutic regimens. The direct measurement of airway

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resistance is often used, but it is not practical for routine clinical use. However, lack of normal values for children may have delayed their acceptance. There are a number of reports on pulmonary function tests in children from various parts of the world and also from different segments of India. Multifarious factors like race, ethnic origin, habitat, sex, age, height, etc. may influence these measurements. Thus each laboratory should establish their own normal standard (SOBOL, 1966). The normal standards for different dynamic pulmonary function tests of children of eastern geographical region of India have not yet been reported.

The purpose of the present study is, therefore, to establish the normal standards of dynamic pulmonary function measurements in the form of prediction equations for boys of eastern geographical region of India.

MATERIALS AND METHODS

Three hundred twenty-eight healthy sedentary school children of the age range 9–18 years were investigated in this study. The subjects were taken from different schools of West Bengal, having middle-class family status. They were considered to be healthy non-smokers according to the criteria stated by MORRIS *et al.* (1971). Each subject answered a questionnaire which was a modification of the Medical Council Questionnaire, and was examined by a physician who specialized in pulmonary physiology.

Pulmonary function tests consisted of forced vital capacity (FVC), forced exiratory volume in 1 s (FEV_1), forced expiratory volume in 1 s as a percentage of forced vital capacity ($FEV_{1\%}$), forced expiratory time (FET), maximum voluntary ventilation, uncontrolled frequency (MVV_F), forced mid-expiratory flow ($FEF_{25-75\%}$), forced end-expiratory flow ($FEF_{75-85\%}$), and peak expiratory flow rate (PEFR).

All the measurements except PEFR were undertaken on a modified water-sealed Toshniwal Expirograph (9 *l* capacity) with soda lime canister removed. Expirographs were calibrated every fortnight with a palmer-respiratory hand pump. All the procedures were adequately explained to the subjects in order to allay apprehension and enlist their fullest cooperation. FVC and MVV_F were recorded using a standard spirometric technique (AMERICAN THORACIC SOCIETY, 1979) at a Kymograph speed of 1,200 mm/min. FVC curve was used to measure forced expiratory volume, flows and time. PEFR was recorded with Wright Peak Flow Meter. At least three satisfactory trials were given for each measurement, with at least 3 to 5 min rest between exhalations.

All the tests were performed in standing position of the subject and a nose-clip was used. All the volumes and flows were expressed at body temperature and pressure saturated with vapor (BTPS). Body height and body weight were measured without footwear and with light clothing. Body surface area was calculated using the DuBois and DuBois formula (DUBOIS and DUBOIS, 1916).

RESULTS

The distribution of subjects in each age group (9–18 years) along with the mean±S.D. values of different physical characteristics are given in Table 1. The body height, weight and body surface area (BSA) are increased significantly up to the age of 16. Table 2 represents the mean and standard deviation values of different pulmonary function measurements. FVC, FEV_1, MVV_F, and PEFR values increase significantly (p varied from 0.05–0.001) with age up to 16 years. But significant increase in $FEF_{25-75\%}$ and $FEF_{75-85\%}$ values is observed in between their age 13 and 16 years.

Table 3 indicates the product momemnt correlation (r) among the physical characteristics and different pulmonary function measurements. All the correlation values are highly significant and positive except $FEV_{1\%}$ where age, height, and weight show consistently negative correlation. The underlying reason behind the same is that FVC and FEV_1 values are highly correlated with the above parameters. The slope of age regression of different pulmonary function measurements standardized for height at 146 cm is shown in Figs. 1 and 2. Figure 3 represents the relationship of FVC and FEV_1 with height standardized to an age of 13 years.

Since the age and height were more reliable indicators of pulmonary function measurements, the said (two) parameters were taken into consideration for the predication of different pulmonary function tests. The prediction equations are given in Table 4 with multiple correlation coefficients (R), coefficient of determination (R^2), and standard error of estimate (S.E.E.). The regression coefficients of age and height were highly significant in all the prediction equations except $FEV_{1\%}$ and FET.

Figures 4 and 5 represent the comparison of VC or FVC, FEV_1 and PEFR values in relation to height at the standardized age of 13 with those reported for boys by Pande and Deshpande (1984) of Southern India, Jain and Ramiah (1968) of Delhi, Northern India, Parmar *et al.* (1977) of Chandigarh, Northern

Table 1. Physical characteristics (mean and standard deviation) of healthy school-going boys of different ages.

		Age (years)									
		9	10	11	12	13	14	15	16	17	18
No. of subjects		30	36	41	32	31	30	38	30	30	30
Height	Mean	121.32	129.30	134.56	138.01	143.53	147.81	158.41	163.27	164.00	164.96
(cm)	S.D.	5.02	4.96	6.46	7.11	6.46	9.05	5.46	6.32	5.03	5.26
Weight	Mean	19.60	22.94	25.95	27.88	31.24	33.33	42.33	47.13	48.65	49.90
(kg)	S.D.	2.08	2.26	3.61	3.79	3.72	6.23	4.46	7.25	5.35	5.86
BSA	Mean	0.82	0.92	1.00	1.05	1.14	1.22	1.39	1.48	1.49	1.53
(m^2)	S.D.	0.06	0.06	0.09	0.09	0.08	0.20	0.09	0.13	0.40	0.10

Table 2. Spirometric lung functions (Mean±S.D.) of healthy school-going boys of different ages.

	Age (years)									
	9	10	11	12	13	14	15	16	17	18
FVC (l) BTPS										
Mean	1.28	1.61	1.78	1.94	2.16	2.39	3.06	3.46	3.58	3.68
S.D.	0.25	0.20	0.25	0.28	0.35	0.48	0.42	0.52	0.47	0.46
FEV_1 (l) BTPS										
Mean	1.19	1.48	1.61	1.75	1.93	2.15	2.77	3.11	3.24	3.31
S.D.	0.23	0.17	0.26	0.25	0.30	0.47	0.42	0.52	0.36	0.37
$FEV_{1\%}$										
Mean	93.85	91.98	90.46	90.45	89.47	90.59	91.14	90.25	90.86	89.20
S.D.	3.17	3.26	4.15	3.92	3.58	4.34	4.62	3.81	5.66	4.69
$FEF_{25-75\%}$ (l/min) BTPS										
Mean	122.53	136.81	139.29	148.82	153.26	176.06	222.66	248.84	256.10	263.90
S.D.	31.54	37.55	40.34	40.90	31.09	45.65	54.58	55.15	55.44	56.70
$FEF_{75-85\%}$ (l/min) BTPS										
Mean	50.03	52.94	54.07	57.32	60.85	67.42	88.77	103.20	113.92	118.58
S.D.	13.65	17.93	17.39	22.61	15.07	25.06	27.46	27.73	30.34	24.42
MVV_F (l/min) BTPS										
Mean	51.99	66.23	73.21	81.27	88.26	97.20	119.10	138.54	142.89	148.25
S.D.	15.60	8.98	15.35	12.76	13.32	16.92	17.58	23.56	19.01	19.17
PEFR (l/min)										
Mean	224.66	272.77	298.77	317.66	336.30	383.83	455.79	500.33	513.17	539.33
S.D.	44.37	36.57	41.94	46.40	53.77	68.30	52.74	67.15	66.37	62.98
FET (s)										
Mean	1.67	2.30	2.53	2.59	2.53	2.56	2.58	3.03	3.15	3.23
S.D.	0.51	0.69	0.77	0.60	0.63	0.74	0.70	1.01	0.97	0.92

Table 3. Correlation coefficient of physical characteristics and pulmonary function measurements in healthy school-going boys having 9–18 years of age.

Test	Age (Year)	Height (cm)	Weight (kg)	BSA (m^2)
FVC (l)	0.88****	0.93****	0.94****	0.93****
FEV_1 (l)	0.87****	0.93****	0.94****	0.93****
$FEV_{1\%}$	−0.17***	−0.19****	−0.16***	−0.19****
$FEF_{25-75\%}$ (l/min)	0.72****	0.74****	0.76****	0.74****
$FEF_{75-85\%}$ (l/min)	0.70****	0.69****	0.72****	0.69****
MVV_F (l/min)	0.86****	0.89****	0.91****	0.89****
PEFR (l/min)	0.86****	0.90****	0.91****	0.90****
FET (s)	0.33****	0.33****	0.34****	0.34****

Level of significance of correlation coefficient (r) is given as asterisks; ***$p<0.01$, ****$p<0.001$.

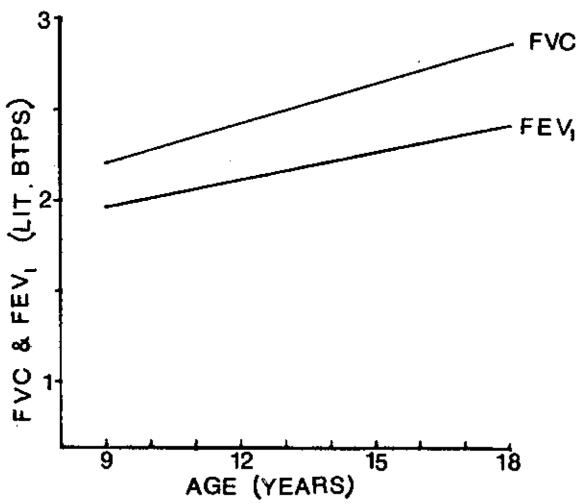

Fig. 1. Relationship of FVC and FEV_1 to age after standardization to a height of 146 cm in healthy school boys.

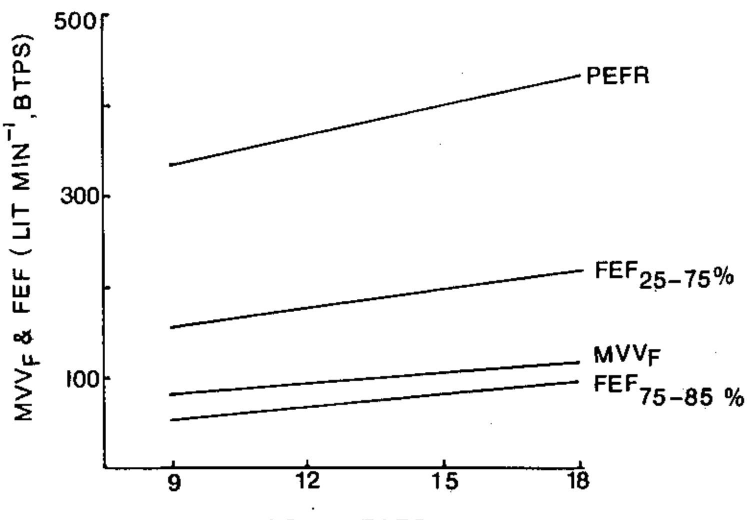

Fig. 2. Relationship of $FEF_{25-75\%}$, $FEF_{75-85\%}$, MVV_F, and PEFR to age after standardization to a height of 146 cm in healthy school boys.

India and AUNDHAKAR *et al.* (1985) of West Maharasthra, Southern India. It is observed that boys of the present study are much closer to the boys of Delhi (JAIN and RAMIAH, 1968) in FVC but higher than the South Indian boys (PANDE and DESHPANDE, 1984) in FEV_1, North and South Indian boys in PEFR (PARMAR *et al.*, 1977; AUNDHAKAR *et al.*, 1985).

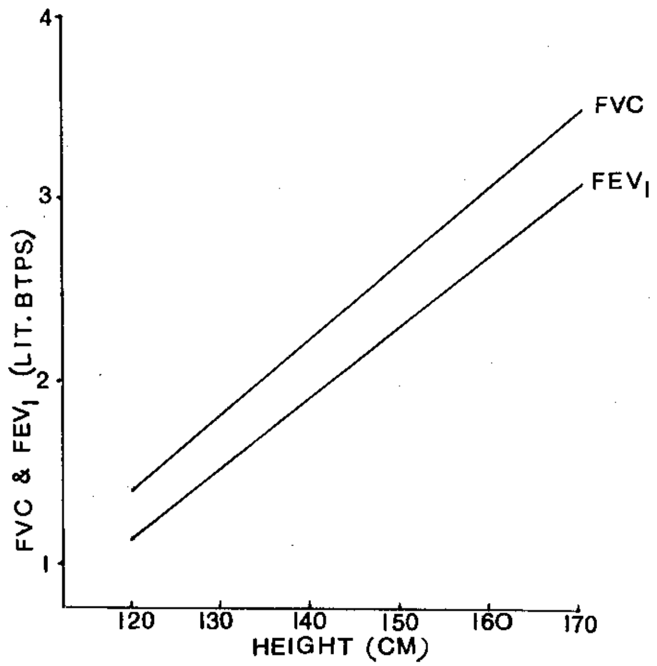

Fig. 3. Relationship of FVC and FEV_1 to height after standardization to age of 13 years in healthy school boys.

DISCUSSION

The present study shows that dynamic lung functions, mainly FVC, FEV_1, MVV_F, and PEFR values, increase progressively with the advancement of age from 9 years up to 16 years. These changes in measures of ventilatory capacity provide information about the size and muscular strength of the chest and the potency of the large airways (COTES *et al.*, 1979). In children the increase in the variables during growth is broadly proportional to the changes in indices of body size.

Comparison of pulmonary function measurements of boys of the present study with those of foreign populations and those of different Indian populations is difficult due to variation in their physical stature. For this reason, at standardized age and height the values were considered for valid comparison. As in normal healthy subjects FVC values were not found significantly different from vital capacity (VC) (JAIN and RAMIAH, 1968), an attempt was made to compare the FVC or VC and FEV_1 of boys of our study with those of other states of India. This comparative analysis revealed that boys of the present study had higher values of these functions than boys of Maharasthra studied between the age 8 and 10 years (DESHPANDE *et al.*, 1983). But boys of Tamilnadu, Southern India (SINGH *et al.*, 1971) were almost comparable with those of our subjects up to the age of 14;

Table 4. Regression equations for different pulmonary function measurements in healthy school-going boys having 9–18 years of age based on age and height as independent variable.

Spirometric 'norms'	Regression equations: Regression coefficients of Age (year)	Height (cm)	Constant	Multiple correlation coefficient (R)	Coefficient of determination (R^2)	Standard error of estimate (S.E.E.)
FVC (l) BTPS	0.07****	0.04****	−4.59	0.95	0.89	0.30
FEV_1 (l) BTPS	0.05**	0.04****	−4.19	0.93	0.87	0.29
$FEF_{25-75\%}$ (l/min) BTPS	6.86**	2.07****	−208.63	0.75	0.56	45.22
$FEF_{75-85\%}$ (l/min) BTPS	4.73****	0.64****	−81.50	0.71	0.51	22.58
MVV_F (l/min) BTPS	3.99****	1.39****	−157.57	0.90	0.81	15.86
PEFR (l/min)	10.87****	4.86****	−473.75	0.91	0.82	49.22

**$p < 0.02$, ***$p < 0.01$, ****$p < 0.001$.

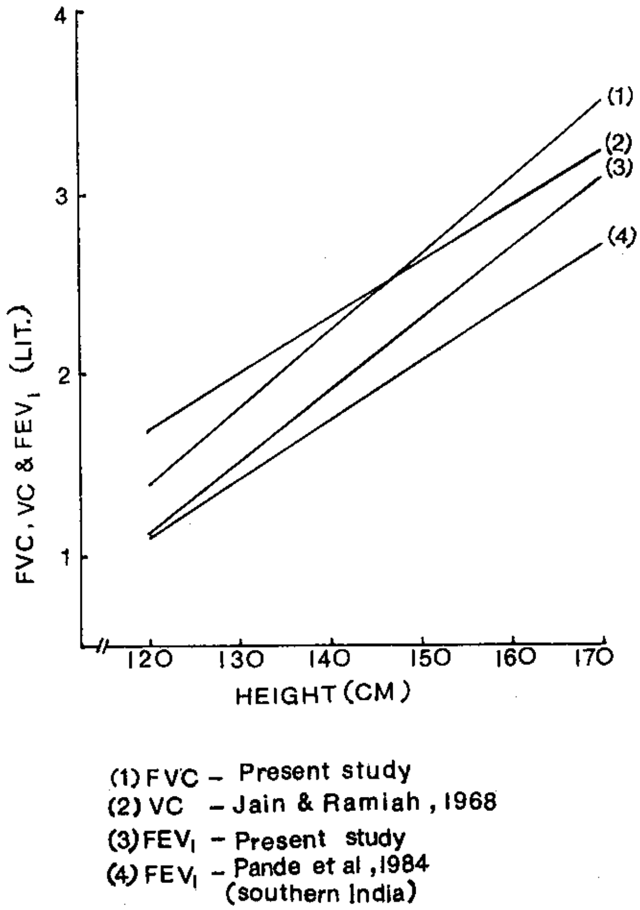

Fig. 4. Comparison of FVC or VC and FEV_1 in relation to height, at 13 years of age, with those of other Indian workers.

thereafter, boys of our study exceeded the boys of Tamilnadu. Besides, VC of Rajasthani boys (BHATTACHARYA and BANERJEE, 1966) was almost similar to the boys of this study up to the age of 13; thereafter, Rajasthani boys showed higher values than boys of the present study. MALIK and JINDAL (1985) reproduced slightly higher values of VC and FEV_1 for boys of Chandigarh compared with boys of our study. These differences might be due to the nutritional status, socio-economic condition, ethnic and racial variation (PATRICK and PATEL, 1986) of boys of different regions of India. But boys of our study are almost similar to those of Delhi from higher socio-economic group studied by JAIN and RAMIAH (1968). Though the economic status of the two populations is different, the result might be due to the difference in the procedure: we studied the subject in standing position while JAIN and RAMIAH (1968) investigated in sitting position. For the same

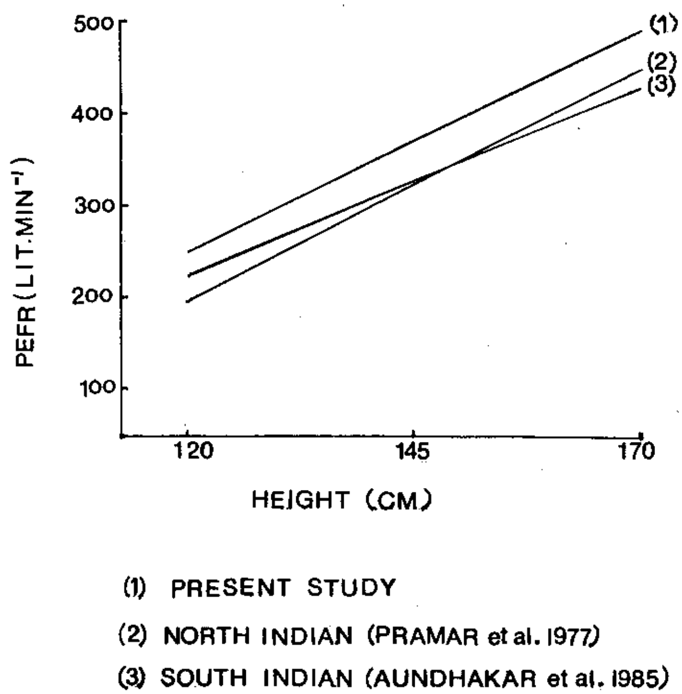

Fig. 5. Comparison of PEFR in relation to height, at 13 years of age, with those of other Indian workers.

reason, PEFR values of boys of the present study were higher than those of Chandigarh (PARMAR *et al.*, 1977) of North India and the boys of West Maharasthra, South India (AUNDHAKAR *et al.*, 1985).

Besides, occupational habits have a tremendous influence on the growth of the body, thereby influencing the pulmonary capacities. KRISHNAN and VAREED (1932) showed in a selected group of South Indians known to be engaged in a regular physical activity, a VC of 3.72 *l*, which was roughly 12 percent higher than the average values for South Indians.

For comparison of our result with those of foreign populations, FVC and FEV_1 values, standardized for age and height, were considered. The comparative study revealed lower values in our subject than those of American White (BINDER *et al.*, 1976), European (LUNN *et al.*, 1965; BJURE, 1963; STRANG, 1959), Polish (PALKA, 1979) and Jordanians (SLIMAN *et al.*, 1982). Better economic condition, nutritional status, environmental, and genetic factors might be responsible for this difference. Racially, Indian children are smaller in structure compared to American (White) and Jordanian; that influences the ratio of upper extremities of the body compared to total body length. So the larger body size leads to a larger thoracic cavity and larger lung volumes. Furthermore, COTES *et al.* (1965, 1973) thought that all Asians had smaller lungs than those of Europeans. Again people in tropical

India pursue more sedentary occupation than the people in temperate and cold climates in Europe and America. This sedentary life-style also influences their ventilatory capacities to some extent.

The values of FVC and FEV_1 in our study were much higher than those of Americans (Black) (BINDER *et al.*, 1976) and Europeans (DICKMAN *et al.*, 1971; ENGSTROM *et al.*, 1962). This is possibly due to their low nutritional standard (BHATTACHARYA and BANERJEE, 1966) and also to the difference in the instruments used for measurements.

But Chinese boys (WU and YANG, 1962) and Libyan boys (SHAMSSAIN *et al.*, 1988) were comparable to our subjects. The factors underlying the same, we assume, are the same ecological and topographical conditions, nutritional status, and socio-economic condition in both the countries.

The prediction equations for FVC, FEV_1, MVV_F, and PEFR are reliable, as the standard errors of estimate of these equations are small (approximately 12–16% of the mean values). But relative variability of predicated $FEF_{25-75\%}$ and $FEF_{75-85\%}$ is very large. This indicates that the equations are not reliable. This variation might be due to the irregularities and fluctuations in lung functions accompanying rapid differential growth during this age period (between 9–18 years), which coincides with their pubertal age period (JAIN and RAMIAH, 1968). Similar observations were made by SCHMIDT *et al.* (1973) and CHATTERJEE *et al.* (1988) for adult population.

Thus normal standards of different dynamic lung function measurements of school-going children of Eastern India might be helpful in diagnosis, management, and treatment of children with large and small airway obstructive pulmonary diseases. Besides, it may give indication about the degree of respiratory disfunction owing to industrial hazards and also the status of physical working capacity.

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