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Predicted Equations of Pulmonary Function Indices for East Indian Adolescent Boys Aged 10-18 Years

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Abstract: *The prevalence of childhood pulmonary diseases is increasing worldwide. Reference standard for pulmonary function that is reported for Indian children and adolescent is mainly from Northern and Western part of the country. There is a paucity of data on pulmonary function of normal Eastern Indian adolescent. Therefore this study was planned to established reference standard for pulmonary function of Eastern Indian adolescents. Pulmonary function test was carried out in 1399 school boys aged 10-18 years in six schools in Hooghly District of west Bengal state. Subjects were grouped into three: pre pubertal (10-12 years), pubertal (13-14 years) and post pubertal (15-18 years). Anthropometric parameters such as height and weight were measured and body mass index and body surface area were derived. The lung function parameters studied were FVC, FEV1, PEFR and FEF25-75%. Correlation coefficients between pulmonary function parameters and anthropometric parameters were derived. Both simple and multiple regression equations were developed for pulmonary function. In adolescent boys aged 10-18 years positive correlation was noted between pulmonary function and age, height, weight, BSA and BMI. Maximum correlation was obtained with height followed by BSA and minimum with BMI. Both simple and multiple regression equations were predicted for very pulmonary function parameter. In view of the large sample size equations of the present study can be used largely to calculate lung functions in Indian adolescent boys particularly for Eastern Indian adolescent boys.*
Keywords*: Spirometry, FVC, FEV1, FEF25-75%, PEFR, Predicted equations for lung function*

I. Introduction

Spirometry is an invaluable tool for the assessment of lung function. Pulmonary function test (PFT) for lungs can be comparable to the ECG of heart (1). It is used to identify the underline cause of respiratory symptoms in children and adolescents and to monitor the status of those with chronic pulmonary diseases. The predictive normal values are essential for meaningful clinical interpretation of PFT. Pulmonary functions were known to vary with age, sex, height, weight, race and geographic locations (2, 3). India, being a subcontinent, changes in pulmonary functions can occur between children East Indian Origin and children of other region (4-6). Adolescent people constitute 25% of the world population of which 85% are in developing countries. In India the adolescent population is 243 million (7). Pulmonary function study of adolescent is very limited (8). The prevalence of childhood pulmonary diseases is increasing worldwide and this necessitates the need for establishing regression equations for predicting pulmonary functions in children. Reference standards for pulmonary function that are reported for Indian children are mainly from northern, Southern and western part of the country. And there is paucity of data on pulmonary function in normal East Indian Children and adolescent. Thus it is essential to have normal pulmonary function data for East Indian adolescents to interpret accurately the result of PFT. A study was therefore designed to obtain reference values for force vital capacity (FVC), Forced expiratory volume in one second (FEV1), peak expiratory flow rate (PEFR) and forced expiratory flow 25-75% (FEF25-75%) among adolescent boys aged 10-18 years in Eastern region of India.

II. Materials And Methods

Subject: The present study was conducted among normal healthy school children of 10-18 years studying in six schools at Chinsurah town in Hooghly district during their school hours. The prior written permission of school authority was taken. Written consent from the parents of the students experimented in the study was obtained. The subjects of this study were chosen at random irrespective of socioeconomic status and religion so that in can reflect an overall picture pulmonary function indices of study region. Every child in this study was given a predesigned questionnaire which was to be recorded by either parents to obtain the information regarding family history cardiovascular and respiratory diseases, food habit and physical activity. We excluded the students who did not complete the lung function test correctly, who reported being active smoker, who had allergic diseases and who had been hospitalized with respiratory or cardio vascular complaint. A total of 1518 students were selected first, out of which 119 children were debarred either due to exclusion criteria or due to unsatisfactory expiratory effort during the procedure. Adolescents were divided into three categories: pre puberty age group: 10-12 years; pubertal age group; 13-14 years and post p[pubertal age group: 15-18 years by considering classification process of Manna et al., 2014 (9).

Anthropometric measurement: Body weight was measured using bathroom scale and standing height was measured using anthropometric rod. Body mass index (BMI) was calculated from the height and weight using following equation: BMI (kg/m^2) = weight (kg) / height^2(m). Body surface area (BSA) was calculated from height and weight using Mosteller formula [18]. BSA=√ [Height (cm)*Weight (kg)/3600].

Spirometry: Spirometry was done using a portable spirometer. The subjects were instructed to take a full breath in, then close the lips around the mouth piece and blow out as hard and fast possible in standing upright posture. Inspiration should be full and unhurried and expiration once begins should be continued without a pause. Three consecutive spirometric measurements were carried out. The highest values were recorded. FVC, FEV1, PEFR and FEF25-75% (mid expiratory flow) were the spirometric function tests that carried out.

Statistical analysis: Data obtained from the study were given as mean ± SD. The statistical significance was determined by student's t test. Two tailed p values were used throughout and p value less than 0.05 were judged as statistically significant. Pearson correlation was used to find the significant relationship between pulmonary function indices and anthropometric parameters. Prediction equations by regression analysis were carried out.

III. Results

Age wise distribution and physical characteristics of selected adolescent boys were as given in table-1. The height and weight consistently increased with age of the subjects. The relationship of height and weight with age was almost linear.

Table-1: Anthropometric measurement values by age of adolescent boys

Age (years)	Number of subjects	Height (cm)	Weight(kg)	BMI (kg/ m^2)	BSA
10	201	134.29 ± 8.91	29.87 ± 5.78	16.30 ± 4.02	1.045 ± 0.189
11	218	140.62 ± 8.53	34.73 ± 6.98	17.24 ± 4.02	1.154 ± 0.211
12	197	145.62 ± 10.06	37.36 ± 8.05	17.33 ± 2.81	1.220 + 0.205
13	257	153.34 ± 8.90	44.47 ± 10.03	18.68 ± 3.66	1.358 ± 0.240
14	232	158.59 ± 8.79	50.55 ± 11.26	19.82 ± 3.25	1.469 ± 0.271
15	112	161.21 ± 7.68	49.76 ± 10.06	18.81 ± 3.53	1.479 ± 0.263
16	50	163.26 ± 5.61	51.77 ± 10.04	19.14 ± 2.97	1.527 ± 0.163
17	70	166.29 ± 6.02	55.38 ± 11.14	19.96 ± 3.38	1.593 ± 0.175
18	62	168.41 ± 4.45	59.63 ± 9.76	20.73 ± 3.11	1.593 ± 0.147
10-12	616	140.15 + 9.93	33.99 ± 9.42	16.96 ± 3.21	1.140 ± 0.215
13-14	489	155.81 + 9.22	45.73 ± 10.37	18.60 ± 3.79	1.378 ± 0.218
15-18	294	164.32 + 6.97	53.35 ± 10.70	19.58 ± 3.38	1.553 ± 0.193

*Data represent mean ± SD

The observations for spirometric variables (FVC, FEV1, PEFR and FEF25-75%) have been summarized in table-2. All the above variables were observed to have been consistently increased with age

Table-2: Spirometric characteristic in normal East Indian adolescent boys by age

Age (years)	FVC(L)	FEV1(L)	PEFR(L/SEC)	FEF25-75% (L/Sec))
10	1.489 ± 0.441	1.438 ± 0.341	3.447 ± 0.601	2.514 ± 0.5.84
11	1.637 ± 0.378	1.600 ± 0.361	3.840 ± 0.726	2.786 ± 0.545
12	1.784 ± 0.423	1.746 ± 4.12	4.276 ± 0.948	3.095 ± 0.726
13	2.016 ± 0.423	1.988 ± 0.412	4.847 ± 0.981	3.568 ± 0.739
14	2.256 ± 0.491	2.222 ± 0.436	5.440 ± 0.989	4.060 ± 0.842
15	2.391 ± 0.508	2.370 ± 0.502	6.038 ± 1.177	4.553 ± 1.000
16	2.654 ± 0.404	2.606 ± 0.327	6.256 ± 1.022	4.590 ± 0.637
17	3.028 ± 0.499	2.931 ± 0.454	6.283 ± 0.721	4.722 ± 0.727
18	3.522 ± 0.601	3.196 ± 0.465	6.723 ± 0.790	5.021 ± 0.772
10-12	1.636 ± 0.446	1.597 ± 0.421	3.852 ± 1.021	2.797 ± 0.819
13-14	2.130 ± 0.546	2.099 ± 0.509	5.129 ± 1.160	3.801 ± 0.971
15-18	2.826 ± 0.670	2.718 ± 0.561	6.278 ± 1.023	4.699 ± 0.978
10-18	2.059 ± 0.70	2.008 ± 0.644	4.808 ± 1.429	3.541 ± 1.172

*Data represent mean ± SD

The correlation with age, height, weight and BSA are given in table-3. All the correlation were significant ($p<0.05$) indicating that there is linear relationship between spirometric functions and anthropometric parameters. The correlation of the functions was highest with height. The height can be considered the best predictor of spirometric variables.

Table-3: Correlation between various anthropometric and lung function variables in adolescent boys

Variable	Pre puberty (10-12 years)	Puberty (13-14 years)	Post puberty (15-18 years)	Adolescent (10-18 years)
FVC				
Age	+0.265	+0.219	+0.644	+0.709
Height	+0.663	+0.620	+0.566	+0.768
Weight	+0.546	+0.308	+0.469	+0.682
BSA	+0.611	+0.498	+0.517	+0.733
FEV1				
Age	+0.310	+0.230	+0.584	+0.721
Height	+0.720	+0.649	+0.569	+0.801
Weight	+0.592	+0.306	+0.453	+0.697
BSA	+0.662	+0.500	+0.505	+0.754
PEFR				
Age	+0.326	+0.256	+0.233	+0.686
Height	+0.610	+0.519	+0.402	+0.755
Weight	+0.450	+0.232	+0.264	+0.606
BSA	0.522	+0.376	+0.311	+0.674
FEF25-75%				
Age	+0.285	+0.253	+0.172	+0.650
Height	+0.505	+0.452	+0.406	+0.701
Weight	+0.374	+0.151	+0.216	+0.548
BSA	+0.430	+0.280	+0.271	+0.613

The prediction equations were derived based upon the correlation coefficients of anthropometric variables with lung functions. Group wise simple and multiple regression equations were predicted using age, standing height, weight and BSA as independent variables (table-4 to7).

Table-4: Regression equations for pulmonary function of pre pubertal boys aged 10 to 12 years

Parameters	Simple regression equations	Multiple linear regression equations
FVC (lit)	0.1477 x Age(year) + 0.0123	0.0307 x Height (cm) – 0.0276 x Age (year) – 0.3696
	0.0297 x Height (cm) – 2.5332	0.0257 x Height (cm) + 0.0048 x Weight (kg) – 2.1230
	0.0213 x Weight (kg) + 0.9112	0.0231 x Height (cm) + 0.3606 x BSA (kg/ m^2) – 2.0130
	0.4480 x BSA (sq. m) + 1.1252	
FEV1 (Lit)	0.1596 x Age(year) - 0.1575	0.03033 x Height (cm) - 0.0134 x Age(year) - 2.578
	0.0298 x Height (cm) – 2.5855	0.02586 x Height (cm) + 0.0047 x Weight (kg) – 2.1863
	0.0214 x Weight (kg) + 0.8710	0.02345 x Height (cm) + 0.3481 x BSA (kg/m^2) -2.0864
	1.2686 x BSA (sq. m) + 0.1508	
PEFR (Lit/sec)	0.4161 X Age (year) – 0.7204	0.0599 x Height (cm) + 0.0744 X Age (year) – 5.3618
	0.0626 x Height (cm) – 4.929	0.0629 x Height (cm) – 0.0004 x Weight (kg) – 4.9634
	0.040 x Weight (kg) +2.4850	0.0614 x Height (cm) + 0.0699 x BSA (kg/m^2) – 4.8291
	2.4789 x BSA (sq. m) + 1.0261	
FEF 25-75% (Lit/sec)	0.2918 X Age (year) – 0.4095	0.0390 x Height (cm) - 0.01336 X Age (year) –2.5078
	0.0416 x Height (cm) – 3.0345	0.04164 x Height (cm) – 0.00003 x Weight (kg) – 3.0373
	0.0268 x Weight (kg) + 1.8853	0.0413x Height (cm) + 0.0171 x BSA (sq. m^2) – 3.0099
	1.6380 x BSA (sq. m) + 0.9297	

Table-5: Regression equations for pulmonary function of pubertal boys aged 13 to 14 years

Parameters	Simple regression equations	Multiple linear regression equations
FVC (lit)	0.2391 x Age(year) – 1.0920	0.0359 x Height (cm) + 0.0510 x Age (year) –4.1558
	0.0367 x Height (cm) – 3.5914	0.04705 x Height (cm) - 0.01099 x Weight (kg) – 4.6994
	0.0134 x Weight (kg) + 1.5083	0.0369 x Height (cm) - 0.0079 x BSA (kg/ m^2) – 3.6036
	1.2530 x BSA (sq. m) + 0.3782	
FEV1 (Lit)	0.2341 x Age(year) - 1.0556	0.0350 x Height (cm) + 0.0506 x Age(year) - 4.0442
	0.0358 x Height (cm) – 3.4842	0.0472 x Height (cm) - 0.01205 x Weight (kg) – 4.6992
	0.0126 x Weight (kg) + 1.5232	0.0387 x Height (cm) + 0.1496 x BSA (kg/m^2) -3.7167
	1.1728 x BSA (sq. m) + 0.4594	
PEFR (Lit/sec)	0.5939 X Age (year) – 2.8729	0.0611 x Height (cm) + 0.2741 X Age (year) – 8.0802
	0.0653 x Height (cm) – 5.0463	0.0882 x Height (cm) – 0.0243 x Weight (kg) –7.4968
	0.0217 x Weight (kg) + 4.1341	0.0773 x Height (cm) - 0.6348 x BSA (kg/m^2) – 6.0329
	2.0099 x BSA (sq. m) + 2.3191	
FEF 25-75% (Lit/sec)	0.5107 X Age (year) – 3.0800	0.0436 x Height (cm) + 0.2632 X Age (year) –6.5312
	0.0476 x Height (cm) – 3.6168	0.07168 x Height (cm) – 0.0256 x Weight (kg) – 6.1977
	0.0118 x Weight (kg) + 3.2589	0.0678 x Height (cm) – 1.0661 x BSA (sq. m^2) – 5.2740
	1.2529 x BSA (sq. m) + 2.0494	

Table-6: Regression equations for pulmonary function of post pubertal boys aged 15 to 18 years

Parameters	Simple regression equations	Multiple linear regression equations
FVC (lit)	0.3663 x Age(year) – 3.1367	0.0348 x Height (cm) + 0.2814 x Age (year) –7.4740
	0.0544 x Height (cm) – 6.1115	0.0445 x Height (cm) + 0.0085 x Weight (kg) – 4.9408
	0.0268 x Weight (kg) + 1.3920	0.0401 x Height (cm) + 0.6575 x BSA (kg/ m^2) – 4.7848
	1.7948 x BSA (sq. m) + 0.0387	
FEV1 (Lit)	0.2781 x Age(year) - 1.8090	0.0318 x Height (cm) + 0.2005 x Age(year) - 5.776
	0.0458 x Height (cm) – 4.8047	0.0394 x Height (cm) + 0.0055 x Weight (kg) – 4.0523
	0.0217 x Weight (kg) + 1.5586	0.0362 x Height (cm) + 0.4418 x BSA (kg/m^2) -3.9137
	1.4679 x BSA (sq. m) + 0.4388	
PEFR (Lit/sec)	0.2023 X Age (year) + 2.9841	0.0541 x Height (cm) + 0.0705 X Age (year) – 3.7555
	0.0590 x Height (cm) – 3.4143	0.0617 x Height (cm) – 0.0023 x Weight (kg) –3.7306
	0.0231 x Weight (kg) + 5.0454	0.0604 x Height (cm) - 0.0631 x BSA (kg/m^2) – 3.5417
	1.6484 x BSA (sq. m) + 3.7179	
FEF 25-75% (Lit/sec)	0.1428 X Age (year) + 2.3740	0.0566 x Height (cm) + 0.0048 X Age (year) –4.6820
	0.0570 x Height (cm) – 4.4595	0.0689 x Height (cm) – 0.0135 x Weight (kg) – 6.0752
	0.0180 x Weight (kg) + 3.7345	0.0707 x Height (cm) – 0.6300 x BSA (sq. m^2) – 5.9302
	1.3723 x BSA (sq. m) + 2.5659	

Table-7: Regression equations for pulmonary function of adolescent boys aged 10 to 18 years

Parameters	Simple regression equations	Multiple linear regression equations
FVC (lit)	0.2266 x Age(year) – 0.8803	0.0283 x Height (cm) + 0.0946 x Age (year) –3.4314
	0.0400 x Height (cm) – 3.9735	0.02215 x Height (cm) + 0.0210 x Weight (kg) – 2.1665
	0.0338 x Weight (kg) + 0.6356	0.0291 x Height (cm) + 0.5743 x BSA (kg/ m^2) – 3.0858
	1.9074 x BSA (sq. m) - 0.4531	
FEV1 (Lit)	0.2120 x Age(year) - 0.7419	0.0288 x Height (cm) + 0.0779 x Age(year) – 3.3341
	0.03840 x Height (cm) – 3.7804	0.02125 x Height (cm) + 0.0202 x Weight (kg) – 2.0465
	0.0317 x Weight (kg) + 0.6696	0.0301 x Height (cm) + 0.4354 x BSA (kg/m^2) -3.1074
	1.8051 x BSA (sq. m) - 0.3693	
PEFR (Lit/sec)	0.4476 X Age (year) - 0.9977	0.0589 x Height (cm) + 0.1728 X Age (year) – 6.3082
	0.0803 x Height (cm) – 7.2984	0.0445 x Height (cm)+ 0.0442 x Weight (kg) –3.6720
	0.0612 x Weight (kg) + 2.2260	0.0800 x Height (cm) + 0.0132 x BSA (kg/m^2) – 7.2780
	3.5805 x BSA (sq. m) + 0.0925	
FEF 25-75% (Lit/sec)	0.3478 X Age (year) – 0.9647	0.0428 x Height (cm) + 0.1482 X Age (year) –4.8227
	0.0611 x Height (cm) – 5.6720.	0.03385 x Height (cm) + 0.03215 x Weight (kg) – 2.9104
	0.0454 x Weight (kg) + 1.6320	0.0659 x Height (cm) – 0.2465 x BSA (sq. m^2) – 6.0530
	2.6708 x BSA (sq. m) + 0.0296	

IV. Discussion

Pulmonary function test (PFT) is an invaluable tool for the assessment of lung function. For the diagnosis and follow-up of respiratory diseases, PFT is essential. Predictive reference values are essential for meaningful clinical interpretation of PFT. Reference value describes the level of an index for a group of healthy persons (reference population) in term of definite variable called reference variable. Commonly used reference variables include ethnic group, age, gender and one or more indices of body size. Thus reference values are generated from an equation and the result of an individual subject is obtained by inserting values of subject's features into equation.

In India several studies were carried out on school children using anthropometric variables to predict different type of regression equation for lung functions in Indian children (10-14). Some of the studies had used age, height and weight (12), age and height (13), age and BSA (10) or height alone (14) as independent variable for prediction of lung function. These studies have shown that there were differences in the lung function values due to difference in ethnicity among these subjects (15). Present study done on Bengali students has used age, height, weight and BSA as independent variables.

The present study has shown significant correlation for pulmonary function indices with age, height, weight and BSA as reported by other studies (15, 16). Correlations were in general highest with height, in adolescent, prepubertal, pubertal and post pubertal boys. Vijayan et al., (16) showed highest correlation of FVC and FEV1 with body height. Simple regression equations were drawn using all four anthropometric variables. For prediction of multiple regression equations two independent variables were selected: age and height, height and weight and age and BSA.

V. Conclusion

Region specific and age specific predicted equations for PFT are generated from this study. In view of the large sample size in the age group 10-18 years the equations of the present study can be used largely to calculate lung function of adolescent boys in India particularly in Eastern region in both urban and rural populations for epidemiological survey and also as referral standards against measured values.

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