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Pulmonary Functions in Normal School Children in the Age Group of 6-15 Years in North India

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Abstract

Objective: Lung function tests have become an integral part of assessment of pulmonary disease. As few studies on pulmonary function tests have been carried out in young children in India, the study was carried out in normal urban and rural school children in Ludhiana district of North India to determine pulmonary functions in the age group 6-15 years and to find its correlation with regards to age, sex, height and weight.

Methods: The study group included 600 normal children between 6-15 years age from different urban and rural schools in the region. A preformed questionnaire was interviewed and detailed general physical and systemic examination was done. Pulmonary function tests were measured by using Micromedical Gold standard fully computerized portable auto spirometer (Superspiro Cat No. SU 6000).

Findings: The present study shows, all the three independent variables (age, weight and height) have linear positive correlation with lung function parameters, both for boys and girls. Lung function values in boys were significantly higher as compared to that of girls. Urban children had higher lung function parameters than rural children except IRV, $FEF_{25\%}$. Among all anthropometric parameters, height was the most independent variable with maximum coefficient of correlation.

Conclusion: Equations derived from the present study for estimation of the expected values of lung function will help to interpret the observed lung function values in children of North India.

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Key Words: Respiratory Function Tests; Pulmonary Function Test; Spirometry; Reference Values

Introduction

Lung function tests have been increasingly used for diagnosis, assessment and clinical management of respiratory disorders and have become an integral part of assessment of pulmonary disease. Pulmonary function values are influenced by race, age, sex, height, weight, as well as environmental, genetic, socio-economic and technical parameters.

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There is no single set of standard reference values. It is therefore, important to ensure that reference formulas in a PFT lab are applicable to the patient population being tested[1]. Spirometry is an important method for evaluating lung functions in children and can identify the type and the pattern of respiratory dysfunction, assess its severity, and help establish a prognosis. Moreover, it is of special importance in monitoring disease progression, response to treatment and in rating disability.

It is a known fact that Indian norms for spirometric test values are different from Western and other norms[2-4,17-19]. Even within the country the test values differ between different regional and ethnic groups[5-8,12]. Few studies have been carried out in younger age group children in India – especially in North India. There is a need to establish baseline lung function parameters in children of younger age group.

The present study, finds out the basic norms of pulmonary function tests in the normal urban and rural school children in the age group of 6 to 15 years. The study was carried out in normal urban and rural school children in Ludhiana district of North India to determine pulmonary functions in the age group 6-15 years and to find its correlation with regards to age, sex, height and weight.

Subjects and Methods

The study group included 600 normal children between 6-15 years age from different schools to obtain a representative cross section of normal subjects in the region. Equal numbers of urban and rural children in each age category were included. Informed consent was taken from the parents before enrolment of the child.

Permission for human studies from Institutional Review Board and Ethics Committee was duly taken.

The subjects with following history or examination were excluded.

1. History of respiratory symptoms within two weeks prior to test
2. History of smoking
3. History suggestive of cardiac illness like exertional dyspnea, orthopnea
4. History of chronic respiratory disease like pulmonary tuberculosis, bronchial asthma, bronchitis
5. Structural deformity of thoracic cage

Subjects who were not able to give desired cooperation for the procedure were also excluded from the study.

An Interview was taken and questions were asked as per the preformed questionnaire to rule out the above exclusion criteria. A detailed general physical and systemic examination was done to rule out cardiopulmonary and other illnesses. Age, sex, height and weight were recorded. Age was taken from the date of birth recorded in school register. Weight was recorded on a standard calibrated spring type weighing scale. Height was also recorded to nearest centimeter.

Pulmonary function tests had been measured as per standard guidelines by using Micromedical Gold standard fully computerized portable auto spirometer (Superspiro Cat No. SU 6000). It was designed to be used with electromechanical pneumotach and volume detection was done by this.

The measurements were performed in classroom of schools after selection of healthy children. Lung function was measured between 12 noon and 2 pm to keep the diurnal variation minimum. Lung function parameters, age, weight, height and sex of each child were recorded for statistical evaluation of the data.

Testing procedures were quite simple from patient's point of view and had been carried out by using standard techniques. Results were calibrated in liters. Three acceptable recordings were obtained and best of three selected for analysis. A minimum exhalation time of 6 seconds was applied to obtain maximal FVC results.

The maneuvers required from the subject were tidal volume, forced vital capacity and a maximum voluntary ventilation. With these maneuvers auto spirometer was able to calculate the following parameters:

1. Tidal volume (TV)

2. Forced vital capacity (FVC)
3. Inspiratory reserve volume (IRV)
4. Timed vital capacity 1 second (FEV_1)
5. Timed vital capacity 3 seconds (FEV_3)
6. Maximum voluntary ventilation (MVV)
7. Forced Expiratory Flow $(FEF)_{25\%}$
8. $FEF_{50\%}$
9. $FEF_{75\%}$
10. Peak expiratory flow rate (PEFR)

Statistical considerations used in the study were Mean, Standard Deviation, Standard Error of Mean, Coefficient of Variance (CV).

Correlation of coefficient '*r*' was used to describe the linear relationship between two variables. Student 't' test was used in the study to describe the significance of difference between two means. Multiple step down regression analysis was used in the study.

Findings

Total of 600 subjects were studied in the age group of 6-15 years in which the mean age was 10.52 years (SD = 2.96 years). Of all subjects studied, male comprises 57.1% and female 42.9% with 55.09% belonging to urban region and 44.91% to rural area. While comparing the lung functions in different age groups it was observed that lung function values increase as the age increases (Table 1).

The height of subjects studied was in the range of 101-180 cm; mean height of studied group was 141.3 cm (SD = 15.73 cm). Effect of height on the lung function parameters was studied as individual variables. With an increase in height, lung function values increased.

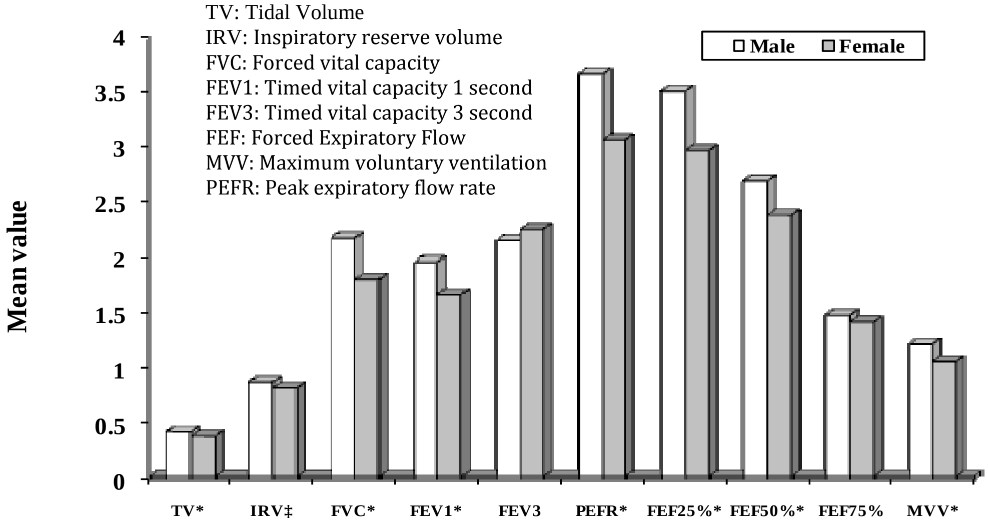
The weight was in the range of 15 to >65 kg, with the mean weight of 35.06 (SD=12.67) Kg.

Table 1: Comparison of physical parameters and lung functions between urban and rural residents according to age

Parameters	Age group (years)									
	6 – 7		8 – 9		10 – 11		12 – 13		14 – 15	
	Urban N=75	Rural N=62	Urban N=25	Rural N=68	Urban N=94	Rural N=16	Urban N=73	Rural N=66	Urban N=63	Rural N=58
Height (cm) Mean (SD)	121.59* (5.4)	119.98 (4.84)	130.48 (6.52)	131.62 (6.16)	142.77 (7.83)	141.31 (5.63))	154.48† (8.4)	150.17 (6.72)	159.63* * (8.42)	156.74 (6.89)
weight (kg) Mean (SD)	21.88† (3.9)	20.58 (2.84)	26.6 (5.42)	26.66 (4.91)	37.24 (10.93)	34.88 (6.69)	44.93† (9.71)	39.68 (7.98)	48.40* (9.34)	45.45 (9.38)
TV (l) Mean (SD)	0.25 (0.07)	0.26 (0.08)	0.35 (0.08)	0.34 (0.09)	0.41 (0.09)	0.38 (0.06)	0.48* (0.1)	0.45 (0.08)	0.51† (0.12)	0.47 (0.09)
IRV (I) Mean (SD)	0.59† (0.14)	0.54 (0.13)	0.83† (0.21)	0.73 (0.18)	0.92 (0.25)	1.00 (0.17)	1.09 (0.23)	1.07 (0.18)	1.10† (0.28)	1.22 (0.26)
FVC (l) Mean (SD)	1.18* (0.25)	1.11 (0.24)	1.51 (0.29)	1.48 (0.23)	2.02 (0.38)	2.08 (0.68)	2.66† (0.53)	2.31 (0.46)	2.86 (0.62)	2.73 (0.56)
FEV_1 (l) Mean (SD)	1.12 (0.23)	1.07 (0.22)	1.43 (0.27)	1.41 (0.22)	1.80 (0.33)	1.84 (0.64)	2.34† (0.51)	2.09 (0.38)	2.60 (0.56)	2.45 (0.55)
FEV_3 (l) Mean (SD)	1.17 (0.25)	1.12 (0.23)	1.50 (0.28)	1.47 (0.23)	1.99 (0.38)	2.02 (0.67)	2.61† (0.53)	2.29 (0.45)	2.86 (0.60)	2.72 (0.56)
PEFR(l/min) Mean (SD)	131.95† (31.29)	119.05 (26.81)	189.20† (50.3)	166.16 (45.92)	214.28* (51.05)	190.31 (56.6)	256.53† (74.42)	222.6 (54.83)	278.02 (78.89)	260.26 (91.58)
$FEF_{25\%}$ (l/s) Mean (SD)	2.15† (0.54)	1.95 (0.60)	3.03* (0.86)	2.69 (0.79)	3.44† (0.84)	2.94 (0.93)	4.04† (1.25)	3.59 (0.94)	4.41 (1.44)	4.14 (1.50)
$FEF_{50\%}$ (l/s) Mean (SD)	1.75 (0.48)	1.66 (0.46)	2.38 (0.68)	2.20 (0.57)	2.44 (0.68)	2.27 (0.78)	3.08† (0.99)	2.72 (0.72)	3.62† (1.03)	3.19 (1.19)
$FEF_{75\%}$ (l/s) Mean (SD)	1.07 (0.36)	1.03 (0.34)	1.33 (0.39)	1.29 (0.31)	1.25 (0.43)	1.36 (0.73)	1.64 (0.64)	1.54 (0.48)	2.11* (0.81)	1.83 (0.77)
MVV (l/min) Mean (SD)	42.27 (8.59)	40.98 (7.78)	53.77 (10.05)	52.83 (8.31)	67.5 (12.45)	63.82 (11.25)	88.00‡ (18.85)	77.04 (14.3)	97.61 (20.64)	90.65 (20.99)

‡ P <0.01
† P <0.05
* P <0.10; No asterisk P >0.10

SD: Standard Deviation; TV: Tidal Volume; IRV: Inspiratory reserve volume
FVC: Forced vital capacity; FEV1: Timed vital capacity 1 second;
FEV3: Timed vital capacity 3 second; FEF: Forced Expiratory Flow
MVV: Maximum voluntary ventilation; PEFR: Peak expiratory flow rate



* *P*<0.01; ‡ *P*<0.05; No asterisk *P*>0.10

Fig. 1: Lung function parameters in relation to sex

Effect of weight either as individual or combined variable on the lung function parameters was studied. The present study also shows the positive correlation of lung function with weight.

Comparing the lung function parameters with sex, most of these parameters were significantly higher in males as compared to females except FEV_3 and $FEF_{75\%}$ in which P-value was not significant (Fig. 1). Lung function parameters were also compared in relation to place of residence. People living in the urban areas had higher values than living in rural areas except IRV, $FEF_{25\%}$ in which *P*-value was non significant (Fig. 2). Mean level of different lung function parameters are depicted in Table 2.

Comparison of physical parameters and lung functions between urban and rural residents according to age and height was also studied (Table 1 and Table 3). With an increase in height, lung function values increased in both urban and rural children but in the same height group there was no statistically significant difference in

Table 2: Mean level of different pulmonary function parameters

Parameters	Mean	SD	SEM	CV
TV(I)	0.39	0.13	0.01	32.37
IRV(I)	0.90	0.31	0.01	34.17
FVC(I)	2.01	0.76	0.06	38.10
FEV_1(I)	1.83	0.67	0.03	36.50
FEV_3(I)	1.99	0.75	0.03	37.86
PEFR(l/min)	204.17	79.80	3.26	39.08
$FEF_{25\%}$ (l/s)	3.27	1.30	0.05	39.88
$FEF_{50\%}$ (l/s)	2.54	0.99	0.04	39.12
$FEF_{75\%}$ (l/s)	1.44	0.63	0.03	43.70
MVV(l/min)	68.65	26.13	1.07	38.07

SD: Standard Deviation; TV: Tidal Volume; IRV: Inspiratory reserve volume
FVC: Forced vital capacity; FEV1: Timed vital capacity 1 second;
FEV3: Timed vital capacity 3 second; FEF: Forced Expiratory Flow
MVV: Maximum voluntary ventilation; PEFR: Peak expiratory flow rate

Table 3: Comparison of physical parameters and lung functions between urban and rural residents according to height

Parameters	Height (cm)											
	< 120		121 – 130		131– 140		141 – 150		151 – 160		> 160	
	Urban (33)	Rural (45)	Urban (59)	Rural (43)	Urban (50)	Rural (50)	Urban (66)	Rural (53)	Urban (83)	Rural (60)	Urban (39)	Rural (19)
Height (cm) Mean (SD‡)	6.48 (0.57)	6.38 (0.72	7.39 (1.53)	7.63 (1.13)	9.82† (1.38)	9.26 (1.34)	11.38‡ (1.49)	12.32 (1.53)	12.83‡ (1.4)	13.58 (1.21)	13.87* (1.00)	14.32 (0.82)
weight (kg) Mean (SD)	19.3 (2.78)	19.6 (2.56)	23.54 (2.9)	23.42 (2.86)	30.66 (5.92)	29.06 (5.45)	41.38‡ (10.35)	36.43 (6.68)	44.47 (7.10)	43.75 (6.94)	55.26 (7.80)	53.05 (7.54)
TV (l) Mean (SD)	0.22 (0.06)	0.24 (0.07)	0.30 (0.08)	0.30 (0.08)	0.37 (0.08)	0.37 (0.08)	0.43† (0.08)	0.40 (0.07)	0.49 (1.00)	0.47 (0.08)	0.54 (0.09)	0.55 (0.06)
IRV (l) Mean (SD)	0.54 (0.14)	0.53 (0.13)	0.66 (0.16)	0.65 (0.16)	0.89* (0.22)	0.81 (0.22)	0.95 (0.21)	1.00 (0.19)	1.06** (0.24)	1.15 (0.19)	1.23† (0.29)	1.41 (0.38)
FVC (l) Mean (SD)	1.04 (0.19)	1.04 (0.20)	1.31 (0.25)	1.31 (0.22)	1.79* (0.31)	1.65 (0.44)	2.18* (0.28)	2.08 (0.34)	2.57 (0.40)	2.56 (0.36)	3.38 (0.46)	3.34 (0.38)
FEV_1 (l) Mean (SD)	0.99 (0.18)	1.02 (0.21)	1.24 (0.22)	1.26 (0.21)	1.62 (0.25)	1.55 (0.42)	1.95 (0.29)	1.88 (0.28)	2.27 (0.34)	2.29 (0.36)	3.06 (0.47)	3.00 (0.43)
FEV_3 (l) Mean (SD)	1.04 (0.19)	1.05 (0.2)	1.30 (0.24)	1.32 (0.22)	1.77* (0.29)	1.64 (0.43)	2.15 (0.28)	2.06 (0.34)	2.54 (0.38)	2.54 (0.36)	3.35 (0.46)	3.33 (0.35)
PEFR(l/min) Mean (SD)	119.94 (32.73)	108.6 (32.24)	153.51 (36.25)	154.63 (41.34)	195.84† (51.81)	172.92 (46.12)	230.09‡ (50.95)	205.11 (49.4)	245.94 (63.59)	238.03 (70.27)	323.18 (79.02)	325.84 (90.76)
$FEF_{25\%}$ (l/s) Mean (SD)	1.96 (0.54)	1.79 (0.59)	2.49 (0.66)	2.55 (0.69)	3.15† (0.87)	2.77 (0.79)	3.61† (0.83)	3.24 (0.85)	3.925 (1.12)	3.79 (1.17)	5.16 (1.43)	5.27 (1.43)
$FEF_{50\%}$ (l/s) Mean (SD)	1.6 (0.37)	1.57 (0.47)	1.96 (0.59)	2.06 (0.54)	2.34 (0.72)	2.25 (0.63)	2.63 (0.81)	2.44 (0.66)	3.03 (0.79)	2.96 (0.96)	4.17 (0.93)	3.97 (0.95)
$FEF_{75\%}$ (l/s) Mean (SD)	1.00 (0.27)	0.98 (0.36)	1.12 (0.38)	1.18 (0.23)	1.27 (0.44)	1.32 (0.35)	1.39 (0.68)	1.39 (0.51)	1.67 (0.53)	1.81 (0.71)	2.33 (0.78)	2.02 (0.61)
MVV (l/min) Mean (SD)	37.66 (6.44)	38.75 (7.29)	46.49 (8.19)	47.84 (6.89)	61.81† (9.48)	56.17 (8.63)	73.49† (10.95)	69.46 (10.55)	85.48 (12.64)	84.52 (13.25)	114.41 (17.3)	112.74 (13.95

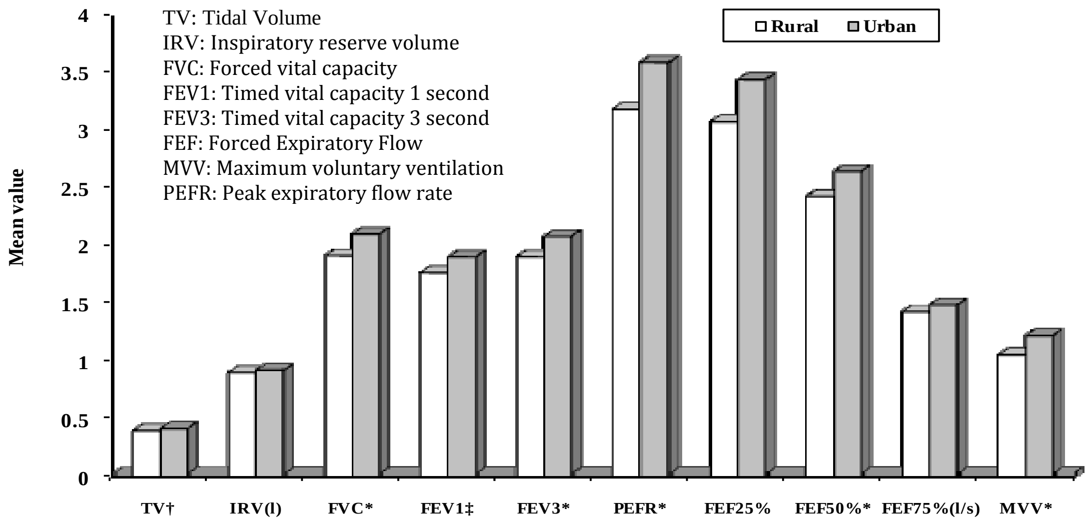
‡ $P < 0.01$; † $P < 0.05$; * $P < 0.10$; No asterisk $P > 0.10$

SD: Standard Deviation; TV: Tidal Volume; IRV: Inspiratory reserve volume

FVC: Forced vital capacity; FEV1: Timed vital capacity 1 second;

FEV3: Timed vital capacity 3 second; FEF: Forced Expiratory Flow

MVV: Maximum voluntary ventilation; PEFR: Peak expiratory flow rate



* *P*<0.01; ‡ *P*<0.05; † *P*<0.10; No asterisk *P*>0.10

Fig. 2: Lung function parameters in regional distribution

urban and rural children except in TV, PEFR, $FEF_{25\%}$ in height range 141-150 cm.

Coefficient of correlation of different parameters with age, height and weight was calculated. All the lung function parameters significantly correlated with age, height and weight except IRV (Table 4).

Discussion

This study determines the normal values of lung function in children of North India who are in the age group of 6-15 years. The aim of the study was to see the correlation of lung functions with age, height, weight and sex in both urban and

Table 4: Coefficient of correlation of different parameters with age, height and weight

	Age		Height		Weight	
	r value	*P* value	*r* value	*P* value	*r* value	*P* value
TV(I)	0.714	<0.01	0.773	<0.01	0.747	<0.01
IRV(I)	0.069	<0.10*	0.073	<0.10*	0.070	<0.10*
FVC(I)	0.828	<0.01	0.910	<0.01	0.864	<0.01
FEV_1(I)	0.808	<0.01	0.887	<0.01	0.840	<0.01
FEV_3(I)	0.121	<0.05	0.112	<0.05	0.083	<0.05
PEFR (l/min)	0.667	<0.01	0.727	<0.01	0.679	<0.01
$FEF_{25\%}$ (l/sec)	0.632	<0.01	0.694	<0.01	0.652	<0.01
$FEF_{50\%}$ (l/sec)	0.607	<0.01	0.669	<0.01	0.651	<0.01
$FEF_{75\%}$ (l/sec)	0.497	<0.01	0.543	<0.01	0.510	<0.01
MVV (l/min)	0.738	<0.01	0.815	<0.01	0.774	<0.01

* Non significant
All the lung function parameters significantly correlated with age, height and weight except IRV
TV: Tidal Volume; IRV: Inspiratory reserve volume; FVC: Forced vital capacity;
FEV1: Timed vital capacity 1 second; FEV3: Timed vital capacity 3 second;
FEF: Forced Expiratory Flow; MVV: Maximum voluntary ventilation; PEFR: Peak expiratory flow rate

rural subjects. While comparing the lung function in different age groups it has been observed that lung function values increase as the age increases.

With an increase in height, lung function values increase in both urban and rural children but in the same height group there is no statistically significant difference in urban and rural children except in TV, PEFR, $FEF_{25\%}$ in height range 141-150 cm. Other studies show similar results[15]. Malik et al in their study of PEFR in school children from North India observed higher mean values of PEFR in the urban as compared to that of the rural boys[9]. However, when the measurements of lung functions were standardized for height, most of the values of rural and urban boys came out to be similar except in height range of 130-150 cm in which TV, PEFR and $FEF_{25\%}$ were higher. So, higher values of these in urban subjects can be explained on the basis of their better height and weight as well.

The present study also shows the positive correlation of lung function with weight. Among all anthropometric parameters height is the most independent variable and is shown to have maximum coefficient of correlation. The study conducted by Rajkapoor et al, Chowgule et al showed similar relationship of lung function with physical parameters of growth, namely age, weight, height and sex[10,15]. Present study found a statistically significant difference in lung function between both sex groups. Lungs functions were higher in boys as compared to that of girls ($P<0.05$) except in FEV_3 and $FEF_{75\%}$ in which there was no statistical difference. These results were comparable with the study done by Rajkapoor et al in which they found that mean lung function test was higher in boys than in girls except $FEF_{50\%}$, $FEF_{75\%}$ which were higher in girls[10]. There was no significant difference in MVV in the study conducted by Rajkapoor et al(10). In the present study $FEF_{50\%}$ and MVV were higher in boys than in girls, while there was no statistical difference seen with $FEF_{75\%}$.

Lung function values in urban were significantly higher than in rural children ($P<0.05$). Glew et al found no statistical difference in pulmonary function between children living in rural and urban areas in North Nigeria[13], but in the present study we found significant statistical difference in lung functions between rural and urban school children probably because of environmental factors and better height in urban subjects.

The values of lung function in present study are slightly more than the study conducted by Rajkapoor et al in Rohtak[11] probably because of regional variation but are comparable with the study conducted by others[12,15,16]. The values obtained by Rosenthal et al while studying the lung function in white children were higher than those obtained in the present study probably because of better height and weight in white children than North Indians. The environmental factors and regional variation too could have contributed to this significant difference. The present study in comparison to other studies is shown in Table 5.

The present study intended to derive the prediction formula for estimation of the expected values of lung function in children between 6-15 years based on height, weight, age and sex. In the present study due to observed

Table 5: Predicted pulmonary values from various studies in boys and girls of specified age, height and weight

Study	FVC(I)		FEV_1(I)		PEFR(l/s)		$FEF_{50\%}$(l/s)		MVV(l/min)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Rosenthal et al	2.82	2.17	2.36	1.91	497	4.27	3.09	2.71	-	-
Shamssain	2.29	1.88	1.82	1.59	3.82	2.92	-	-	-	-
Chowgule et al	2.54	1.94	2.26	1.77	5.40	4.33	3.16	2.87	80.9	82.8
Vijayan et al	2.59	2.05	2.24	1.79	5.11	3.64	2.48	2.32	94.0	68.0
Rajkapoor et al	1.63	1.47	1.49	1.37	3.845	3.633	2.44	2.77	59.94	58.60
Present study	2.16	1.80	1.95	1.66	3.3663	3.056	2.68	2.37	72.91	62.97

FVC: Forced vital capacity; FEV1: Timed vital capacity 1 second; PEFR: Peak expiratory flow rate; FEF: Forced Expiratory Flow; MVV: Maximum voluntary ventilation variation in lung function tests with sex, prediction formula is separately formulated for both boys and girls. Regarding sex, girls were designated as 0 and boys as 1. The prediction equations of present study were comparable to those in study conducted by Rajkapoor et al[10].

FVC: -2.8916 + 0.0254 (Age years) + 0.1257 (Sex) + 0.0271 (Ht cm) + 0.0172 (Wt kg)

FEF1: -2.3666 + 0.021 (Age years) + 0.0906 (Sex) + 0.0236 (Ht cm) + 0.0141 (Wt kg)

PEFR: -214.587 + 3.2039 (Age years) + 17.451 (Sex) + 2.2489 (Ht cm) + 1.1375 (Wt kg)

MVV: -90.2014 + 2.3332 (Sex) + 0.966 (Ht cm) + 0.5332 (Wt kg)

The present study also intended to derive the prediction equation for TV and IRV, though no other studies have derived the prediction equation for these parameters as per our best knowledge. So the comparison of these parameters with other studies could not be made out.

TV: -0.225 + 0.005 (Age years) + 0.0032 (Ht cm) + 0.0031 (Wt kg)

IRV: -0.4443 + 0.0283 (Age years) + 0.0871 (Sex) + 0.0048 (Ht cm) + 0.0068 (Wt kg)

These equations derived can be used to predict the lung function of children from North India. Pulmonary function test depends on many factors; regional variation is one of them. No study has been conducted in this region of India, so the present study was done to know the baseline pulmonary function test in the healthy school children of North India.

The limitation of the study was more children could have been included in each subgroup.

Conclusion

The present study shows, all the three independent variables (age, weight and height) have linear positive correlation with lung function parameters, both for boys and girls.

Lung function values in boys were found to be significantly higher as compared to girls. Height is the most important and reliable single independent variable.

Measurement of lung function is an integral part of modern management of both restrictive and obstructive lung disease. A wider application of this instrument, both by the doctor and patient, will help to improve the quality of life in patients suffering from asthma and other pulmonary disease. The present study will definitely help to interpret the observed lung function values in local children of North India.

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