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Establishing the normative values of spirometry in children of 5-18 years age range living in and around Solan district of Himachal Pradesh, India

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Abstract

Introduction: Pulmonary Function Tests (PFTs), especially spirometry is an established mode of assessing chronic lung diseases especially Asthma. Spirometric reference values are essential in assessing pulmonary function. Normative values of these tests differ from population to population and with difference in methods and apparatus used. The normal standards for pulmonary function measurements among the hilly areas of Himachal Pradesh is not reported yet.

Aim: To measure the normative values of spirometry (FEV1, FVC, FEV1/FVC, PEFR) in children of 5-18 years age range living in and around Solan district of Himachal Pradesh, India.

Material and Methods: This cross-sectional study was carried out at M.M Medical College and Hospital, Kumarhatti, Solan, HP, India and comprised school-going children and nearby community aged 5-18 years. After noting their gender, age, height and weight, the pulmonary function test measures, Forced vital capacity (FVC), Forced expiratory volume in 1 second (FEV1), FEV1/FVC%, FEF 25-75% and peak expiratory flow rate were taken. Simple and multiple regression models were used for the prediction of pulmonary function test values. SPSS 20 was used for statistical analysis

Results: Of the 200 participants, 110(55%) were boys and 90 (45%) were girls. The mean age was 12.47±3.27 years. The means height, weight, forced expiratory volume in 1 second, force vital capacity, peak expiratory flow rate FEV1/FVC% and FEF 25-75% were 147.39±16.07cm, 41.30±12.38kg, 2.54±0.70, 2.90±0.8, 5.42±1.30, 87.41±3.85% and 2.90±0.84 respectively. All the three variables - Age, Height and Weight-had significant linear relationship and positive correlation with the pulmonary function test values (p0.7). Among these three variables maximum correlation was found with height (r=>0.8).

Conclusion: Age, height and weight had statistically significant and positive correlation with the PFT values, both for boys and girls. Height was found to be most strongly and positively correlated with the PFT values. Overall significant difference was seen in FEV1/FVC and FEF 25-75 among boys and girls except FEV1, FVC and PEFR of the same age group. The fitted regression equations would help to predict the PFT values for the Indian children living in hilly areas at given age, height and weight. This study should be seen as a pilot study and will require data from a large population to establish normal values for our population.

Keywords: Forced expiratory volume in 1 second, Force vital capacity, Peak expiratory flow rate, Spirometry, forced expiratory flow 25-75%

Introduction

Respiratory disorders are a major group of illness affecting children. They are an important cause of childhood morbidity and mortality [1]. The national burden of asthma and Chronic bronchitis was estimated respectively 17.23 and 14.84 million in adults which poses an enormous health care burden in India [2]. Most of the associated risk factors are preventable. Pulmonary Function Tests (PFTs), especially spirometry is an established mode of assessing chronic lung diseases especially Asthma. Spirometric reference values are essential in assessing pulmonary function. Normative values of these tests differ from population to population and with difference in methods and apparatus used [3-5]. Spirometry has been studied extensively in adults but till date it's use in children has been limited primarily due to the erroneous belief that children cannot perform these tests and also due to lack of standardised local reference data. These tests are important in the initial evaluation of respiratory disorders and help in planning therapy as well as predicting prognosis with a reasonable accuracy [6]. There is an increasing requirement of these tests as air pollution is increasing worldwide and alarmingly in India. Air pollution has become a global health problem. Epidemiological evidence is showing association of prenatal or perinatal exposure to air pollutants with various adverse birth outcomes, such as preterm birth, lower birth weight, lung developmental defects, which further associated with respiratory diseases and reduced lung function in children and adults. Thus, it becomes imperative to establish base line values for a given population [7].

In 2012, European Task Force Society, derived continuous prediction equations and their lower limits of normal for spirometric indices, which are applicable globally [8]. These predication equations could not be derived for Indian sub-continent as one of the sets produced a pattern for FEV1, FVC and FEV1/FVC that differed quite significantly in comparison to other data sets. Hence data from Indian subcontinent were excluded, thus India lost the opportunity to be included among global reference ranges representing the large pool of world population. ERS task force also stated in end that additional data from Indian subcontinent and Arabic Polynesian and Latin American countries as well as Africa will further improve these equations in future. GLI task force has suggested a representative sample of at least 300 subjects to be used for this kind of study and data collected using standardised protocols [9].

Present study would be an attempt to build this representative sample from India, which will provide the much needed representation of India in the globally accepted database in near future. Although various studies have been conducted in India but there is paucity of normative values of spirometry for children residing in Himachal Pradesh. Moreover, several reference values for lung function indices of the children have been published from different parts of the globe. These values are influenced by age, sex, ethnicity and anthropometric profile of an individual [8, 10-17]. The normal standards for pulmonary function measurements among the hilly area of Himachal Pradesh is not reported yet. Since geography, height and environment plays important role in influencing pulmonary function and in view of dearth of pertinent data, it becomes paramount to provide age specific baselines estimates of spirometrical indices of local children.

PFTs are noninvasive tests that show how well the lungs are working. The tests measure lung volume, capacity, rates of flow and gas exchange. Pulmonary tests help in detecting airway obstruction, assessing severity and prognosis and determining risk factors [18]. To diagnose these diseases, different pulmonary function tests are used and among them the spirometry is the gold standard one [19]. They can be performed easily and provide objective information in adults as well as in children. Their interpretation is based on comparing measured variables with expected values, called reference values, obtained from studies conducted in healthy populations [20]. Another method for doing PFT is by Plethysmography. These two methods may be used together or separately, depending on the information one is looking for. Spirometry, the test which measures the volumes of lung as a function of time. It measures either volume or flow. Just like blood pressure provides important information about general cardiovascular health. Similarly, spirometry is an essential screen tool for respiratory health [21]. Spirometry can measure all the lung volumes except residual volume. Spirometry is done by Spirometer, which is a device with a mouthpiece hooked up to a small electronic machine. Spirometry is a simple, speedy and essential for the detection, diagnosis and monitoring of respiratory diseases. It is a physiological noninvasive test and is an invaluable screening test for general respiratory health [18]. Spirometry can be utilised for diagnostic as well as monitoring purpose and indicated as per ATS guidelines [22].

Aim & Objectives

To measure the normative values of spirometry (FEV1, FVC, FEV1/FVC, PEFR) in children of 5-18 years age range living in and around Solan district of Himachal Pradesh, India.

Materials and Method

The present study was undertaken in the Department of Paediatrics in collaboration with Department of Respiratory Medicine, M.M Medical College and Hospital, Kumarhatti, Solan.

Selection of patients

A sample size of 500 children was planned from age 5-18 years of both sex and with varied height and weight. However, because of the covid pandemic which occurred during the study and closure of schools during most of the study period, 200 cases were enrolled after taking due permission from the institutional research and ethical committees.

Source of subjects: Subjects was taken from nearby local community and schools.

Criteria in the study

Inclusion criteria

1. Children with age 5-18 years living in and around Solan.
2. Children whose parents give consent.

Exclusion criteria

1. Children having any illness at the time of testing.
2. Children with known disease and symptom of any disorder.
3. Children having any of the contraindications for spirometry as per ATS criteria.
4. Children who are not able to perform an acceptable spirometry.

Materials

Computerized spirometer Helios 401, RMS, India along with computer & printer.
Disposable Mouth piece.
Disposable nose clip.
Stadiometer.
Electronic weighing machine.

Method

Basic demographic data of subject including age sex and religion etc. was noted in a predesigned proforma. Age was recorded in year and completed months. Age was cross checked and recalculated from the date of birth provided by the parents. Anthropometric measurements were recorded as per standard technique. Weight was recorded on a digital weighing machine with minimum clothing and without foot wear. Height was be recorded by stadiometer, without foot wear and head cap while looking in Frankfurt plane.

Relevant information was also be entered in computer. Patients name age sex weight, height parameters were be added in spirometry software also. A detailed present and past history was elicited and clinical examination with focus on examination of respiratory system has been done to check suitability of subject as per inclusion and exclusion criteria.

Test procedure was explained to each child in their own native language using simple and easy to understand vocabulary.

Child was also shown a prerecorded video to understand the procedure as subject was relaxed by engaging in pleasant talk. Anxiety management was done by keeping parents nearby children. A good rapport with child was developed by investigator. Clothes were removed or loosened to allow for free chest and abdominal movement beforehand. Child was seated in an armed chair or mothers lap if needed. Feet were kept flat with legs uncrossed allowing no use of abdominal muscles for leg position. Supportive footrest was provided to children to keep foot flat along with appropriate size cushions to achieve proper position. Time of day, ambient temperature and barometric pressure was be noted.

Strict hygiene and infection control were maintained. Separate disposable mouthpiece and nose clip was used for each child. Disposable inline filter was used to prevent equipment contamination. All the necessary precautions were taken while doing this procedure of all the subjects regarding covid-19.

Test was conducted by the investigator himself. ATS reference values was used for interpretation. Calibration was done daily. Leak was checked daily. It was also ensured that child has not been actively playing or doing vigorous exercise within last 30 minutes. Ah/o smoking and consuming alcohol was also be elicited in adolescents if suspected.

The test was carried out in designated spirometry room of the hospital (MMMC&H) in sitting position with nose clip put on nose. Spirometric measurements of each child was recorded using the precalibrated spirometer following standard procedure as per the American Thoracic Society (ATS) guidelines.

The flow, volume/timed graph was recorded including the following parameters (values) forced vital capacity (FVC); forced expiratory volume in first second (FEV1); forced expiratory volume in first second to forced vital capacity ratio (FEV1/FVC); peak expiratory flow rate (PEFR) and forced expiratory flow between 25-75% of vital capacity (FEF25-75%) and maximal voluntary ventilation (MVV). The maximum voluntary ventilation (MVV) was determined by fast, deep breathing for a 10 second period and reported as liters/minute.

Data interpretation was done by built in software of machine. A printout was taken and will be attached to proforma for future reference and statistical analysis. Data was also maintained in Excel sheet in computer.

BMI was measured with formula weight (kg)/height (m2). Compared with IAP BMI Charts 2015 BMI >23^{rd} adult equivalent line refers as overweight and more than 27^{th} adult equivalent line refers as obesity. Less than 3^{rd} adult equivalent line refers as underweight and 3^{th} to 23^{rd} adult equivalent line refers as normal weight.

Graph was accepted only if it meets the acceptability, reproducibility and end of test criteria as per ATS guidelines.

Statistical analysis

Normal descriptive statistics were used to describe various Spiro metric values, while to ascertain the effect of age, height and weight on the spirometric values among the study subjects, a simple and multiple regression models would be applied. The descriptive results were expressed as percentages and mean ± standard deviation (SD). Two-sample Student's t-test was used to compare the significant difference between mean PFT values of boys and girls. Pearson's correlation coefficient was applied to measure linear relationship of the PFT measures with age, height and weight. Statistical Package for Social Sciences, version 20 (SPSS 20) was used for statistical analysis.

Ethical consideration

Informed and written consent (in the language they best understand) was taken from each subject before collecting data and blood sample. The proposed study has been undertaken post approval by Institutional Ethical Committee.

Observations & Results

Among 200 participants, with breakup of 110 (55%) boys and 90 (45%) girls ranging from 5 to 18 years of age. Overall mean values of age, weight, height and BMI were 12.47 ± 3.275 yrs, 41.30 ± 12.38 kg, 147.39 ± 16.076 cm, 18.6007 ± 3.2 kg/m^2 respectively. Overall mean value of FVC, FEV1, FEV1/FVC, FEF25-75% and PEFR were 2.9 ± 0.81 lt, 2.5 ± 0.7 lt, 87.41 ± 3.8%, 2.9 ± 0.84 lt, and 5.4 ± 1.3 lt/sec respectively.

Mean values for girls age, weight, height and BMI were 13.3±3.03 yrs, 42.71±11.67 kg, 148.57±13.9 cm and 19.09±3.83kg/m^2. The mean value of dependant variables FVC, FEV1, FEV1/FVC, FEF25-75% and PEFR were 2.90±0.73 lt, 2.59±0.62 lt, 89.37±3.27%, 3.04±0.69 lt and 5.38±1.12lt. While, for boys mean values of age, weight, height and BMI were 11.7±3.286 yrs, 40.1±12.8 kg, 146.4±17.6 cm and 18.1±2.7 kg/m^2**.** The mean value of dependant variables FVC, FEV1, FEV1/FVC, FEF25-75% and PEFR were 2.89±0.8lt, 2.50±0.77lt, 85.81±3.5%, 2.79±0.92lt and 5.46±1.43lt/sec.

As far as relation with height, weight is concerned, all PFT values except FEV1/FVC were found significantly different among different height groups for both girls and boys ($p<0.05$). Normogram shows direct and linear relation between PFT values and height group. All PFT values tended to increase as height, weight and age increased.

Out of 200 participants, 13 were obese which accounted for 6.5% and 57 were overweight which accounted for 28.5%. But among all independent variables BMI was found to be least correlated with PFT values as r = 0.25.

As per socioeconomical categorization, out of 200 participants, 89 belonged to upper lower class (44.5%) followed by 70 in lower middle class (35%).

All the independent variables were correlated with Pearson correlation coefficient (r). It was found that age, weight, height and BMI had positive correlation with all PFT values. Among all influencing factors, height was maximally positive correlated as (r- 0.8).

Table 1: Age Group and gender wise distribution

Age (Years)	Girls		Boys		Total	
	Number	Percent	Number	Percent	Number	Percent
5 - 10 yr	15	14.4	44	38.2	59	29.5
11 - 15 yr	50	55.6	53	48.2	103	51.5
16 - 18 yr	25	27.8	13	11.8	38	19.0
Total	90	100.0	110	100.0	200	100.0

Table 2: Distribution according to BMI category

BMI Categories	Girls		Boys		Total	
	No.	Percent	No.	Percent	No.	Percent
Under weight	2	2.2	2	1.8	4	2
Normal weight	63	70.0	63	57.3	126	63
Overweight	17	18.9	40	36.4	57	28.5
Obesity	8	8.9	5	4.5	13	6.5
Total	90	100.0	110	100.0	200	100

Table 3: Descriptive statistics of various dependent and independent variables

	Girls		Boys		Total	
Parameters	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Age [years]	13.39	3.031	11.71	3.286	12.47	3.275
Weight [Kg]	42.71	11.675	40.15	12.876	41.30	12.386
Height [cm]	148.57	13.965	146.44	17.622	147.39	16.076
BMI [kg/m^2]	19.0981	3.83088	18.1938	2.73525	18.6007	3.29618
FVC [l]	2.9074	.73434	2.8963	.88549	2.9013	.81895
FEV1 [l]	2.5918	.62726	2.5049	.77070	2.5440	.70936
FEV1/FVC (%)	89.3733	3.27950	85.8192	3.55243	87.4185	3.85545
FEF25-75 (lt)	3.0486	.69851	2.7918	.92968	2.9074	.84144
PEFR [lt/sec]	5.3810	1.12334	5.4656	1.43301	5.4275	1.30036

Table 4a: Age group pattern of normative values of Pulmonary Function Tests in Girls

Age Groups		FVC [l]		FEV1 [l]		FEV1/FVC (%)		FEF25-75 (%)		PEFR [l/sec]	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
5 - 10 yr	15	1.8707	.34294	1.6933	.33232	90.2960	4.69210	2.0480	.54507	3.8500	.98613
11 - 15 yr	50	3.0628	.65784	2.7104	.53845	89.3250	3.02736	3.1782	.59090	5.6930	.96825
16 - 18 yr	25	3.2188	.47381	2.8936	.41714	88.9164	2.75223	3.3896	.37589	5.6756	.66330
Total	90	2.9074	.73434	2.5918	.62726	89.3733	3.27950	3.0486	.69851	5.3810	1.12334

Table 4b: Age group pattern of normative values of Pulmonary Function Tests in Boys

Age Groups		FVC [l]		FEV1 [l]		FEV1/FVC (%)		FEF25-75 (%)		PEFR [l/sec]	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
5 - 10 yr	44	2.0598	.60210	1.7516	.48805	85.2264	4.84304	2.0180	.04502	3.8500	.98613
11 - 15 yr	53	3.3228	.50671	2.9049	.43193	86.3249	2.33531	3.0924	.26091	5.6930	.96825
16 - 18 yr	13	3.9885	.22113	3.4238	.17628	85.7638	2.12795	3.1359	.11589	5.6756	.66330
Total	110	2.8963	.88549	2.5049	.77070	85.8192	3.55243	2.7918	.92968	5.4656	1.43301

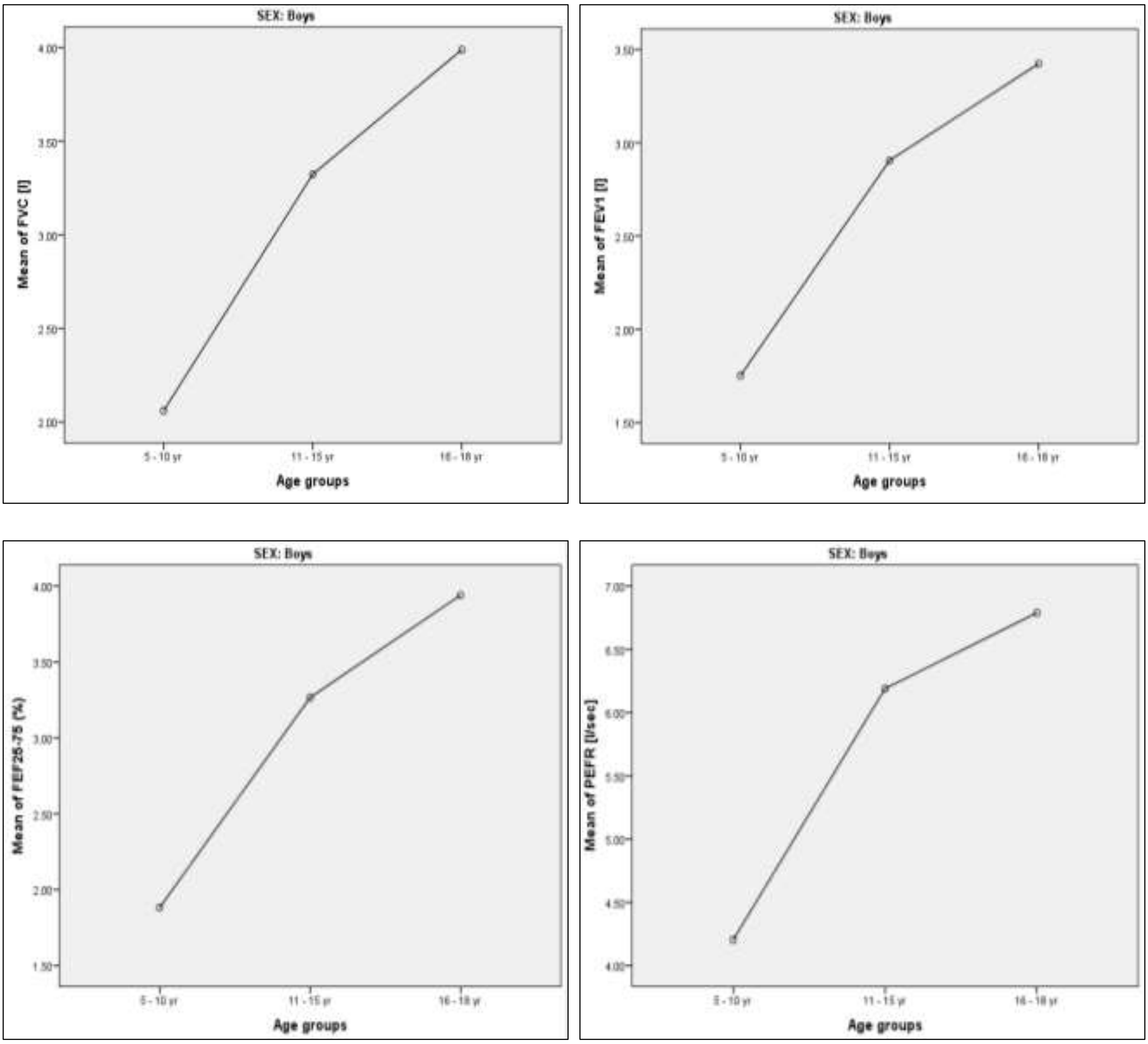
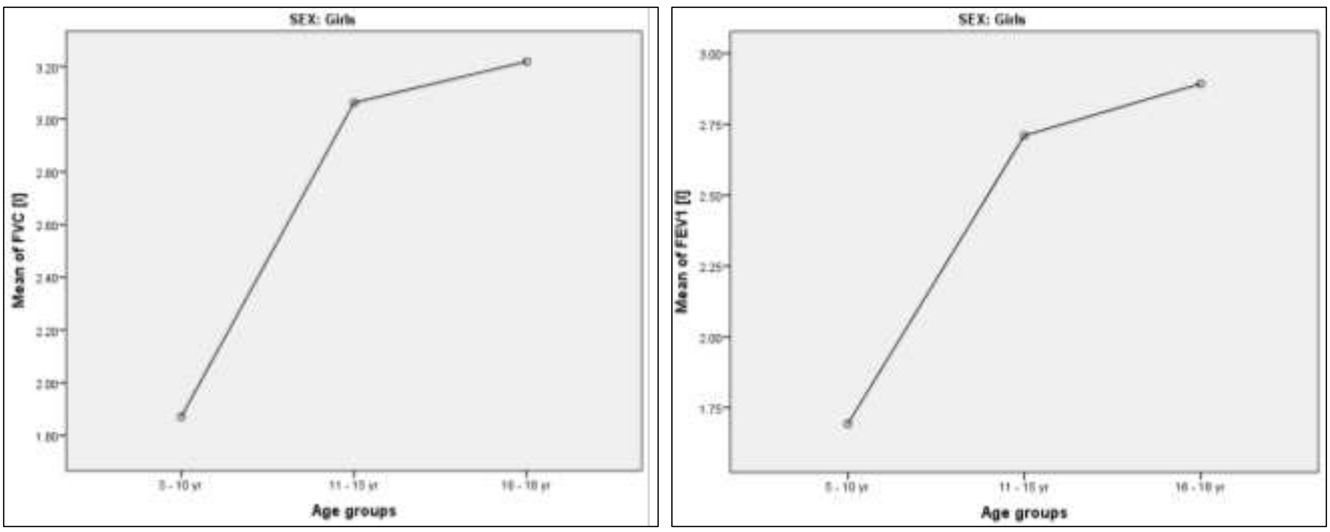


Fig 1: Showing Normogram of PFT in relation to age of boys



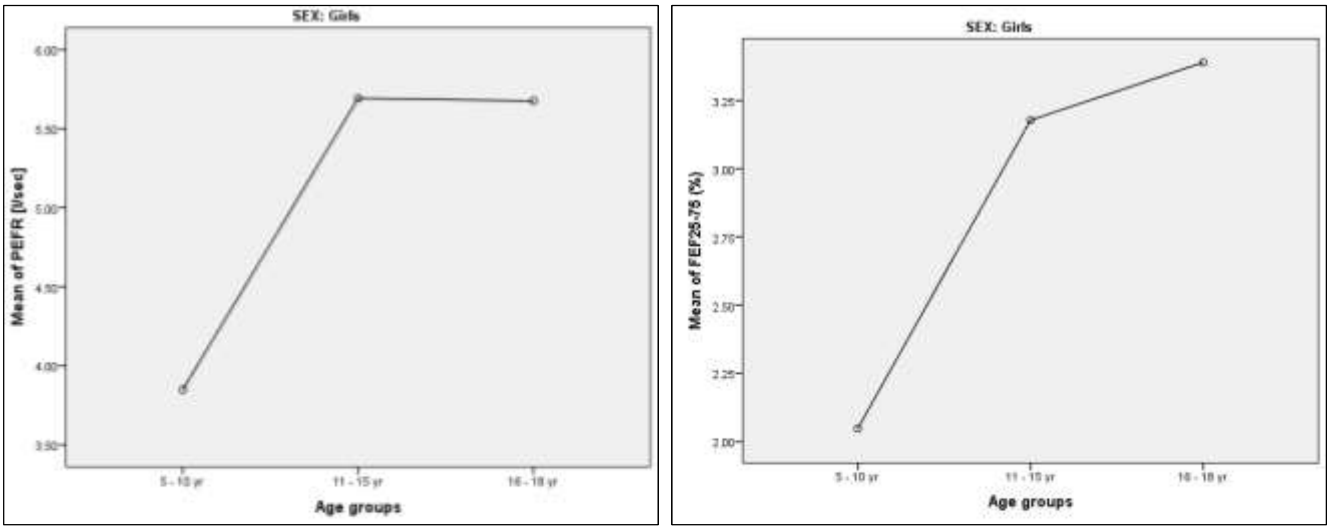
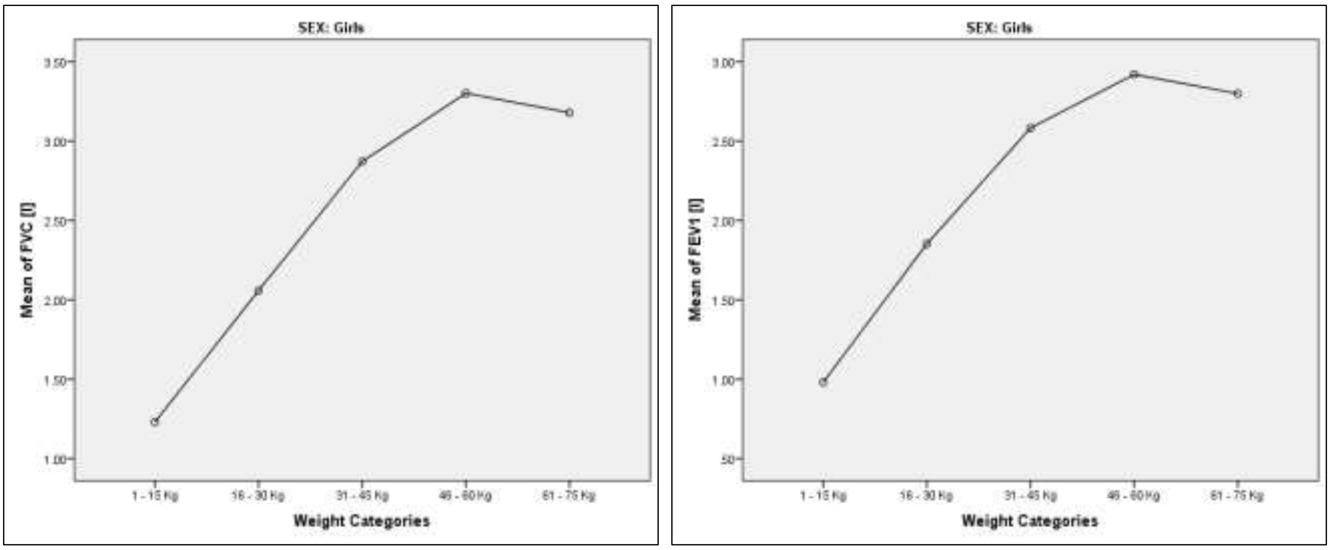


Fig 2: Showing Normogram of PFT in relation to age of girls

Table 5: Weight group wise normative values of Pulmonary Function Tests in Girls

Age [Years]		FVC [l]		FEV1 [l]		FEV1/FVC (%)		FEF25-75 (%)		PEFR [l/sec]	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1 - 15 Kg	1	1.2300	.	.9800	.	79.6700	.	.9600	.	2.2100	.
16 - 30 Kg	13	2.0577	.5757	1.8515	.51340	90.1208	3.52481	2.1685	.63889	4.1354	1.32155
31 - 45 Kg	38	2.8713	.7071	2.5818	.57827	90.4768	3.28336	3.0976	.60928	5.5921	.97991
46 - 60 Kg	31	3.3010	.4217	2.9197	.39137	88.2319	2.35063	3.3619	.41188	5.7268	.67151
61 - 75 Kg	7	3.1786	.6599	2.7986	.50492	88.4357	2.86471	3.3271	.51497	5.4700	1.04984
Total	90	2.9074	.7343	2.5918	.62726	89.3733	3.27950	3.0486	.69851	5.3810	1.12334



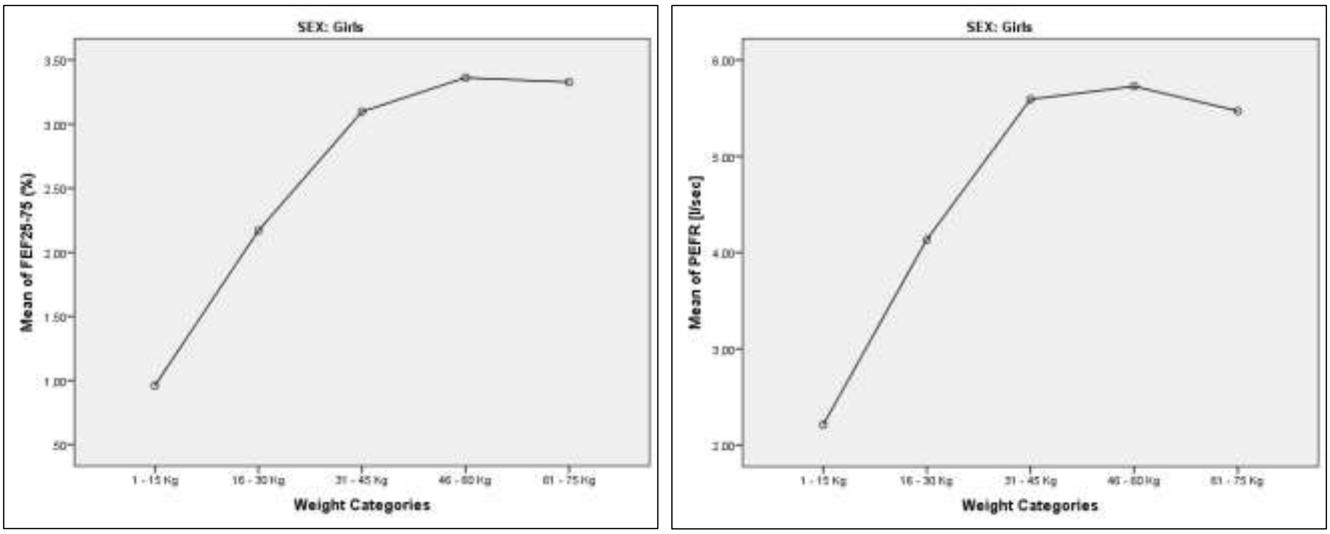
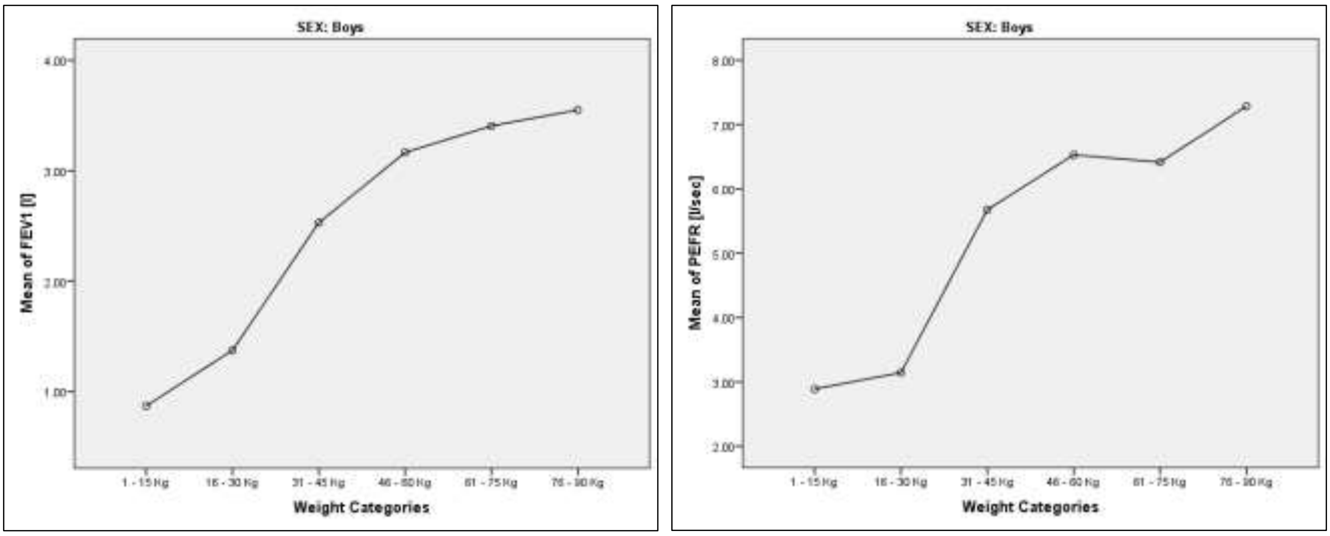


Fig 3: Showing Normogram of PFT in relation to weight group of girls

Table 6: Weight group wise pattern of normative values of Pulmonary Function Tests in Boys

Age [Years]		FVC [l]		FEV1 [l]		FEV1/FVC (%)		FEF25-75 (%)		PEFR [l/sec]	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1 - 15 Kg	1	.8700	.	.8700	.	100.0000	.	.9600	.	2.8900	.
16 - 30 Kg	19	1.600	.4717	1.3737	.38409	85.4047	5.86584	2.1685	.63889	3.1437	1.15143
31 - 45 Kg	59	2.937	.6033	2.5290	.52596	85.1853	2.54731	3.0976	.60928	5.6768	.82575
46 - 60 Kg	27	3.620	.4118	3.1648	.36291	87.0033	2.03353	3.3619	.41188	6.5285	.59862
61 - 75 Kg	2	3.930	.2545	3.4050	.17678	86.6800	1.11723	3.3271	.51497	6.4150	.67175
76 - 90 Kg	2	4.210	.0707	3.5500	.07071	84.5200	.55154	3.0486	.69851	7.2850	.16263
Total	110	2.896	.8854	2.5049	.77070	85.8192	3.55243	2.7918	.92968	5.4656	1.43301



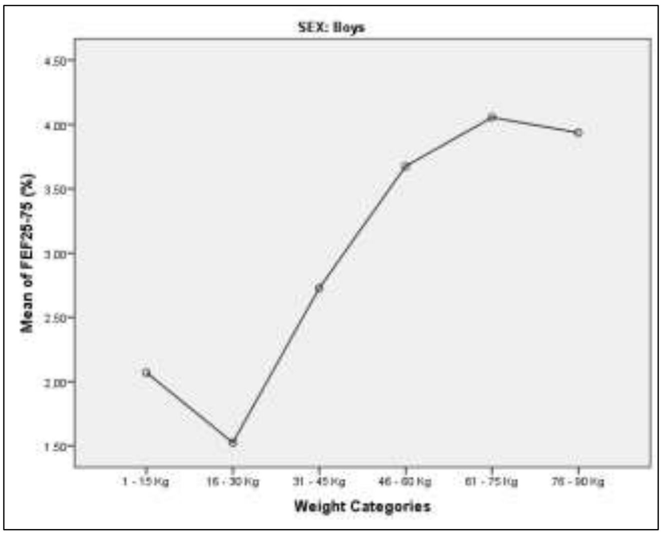
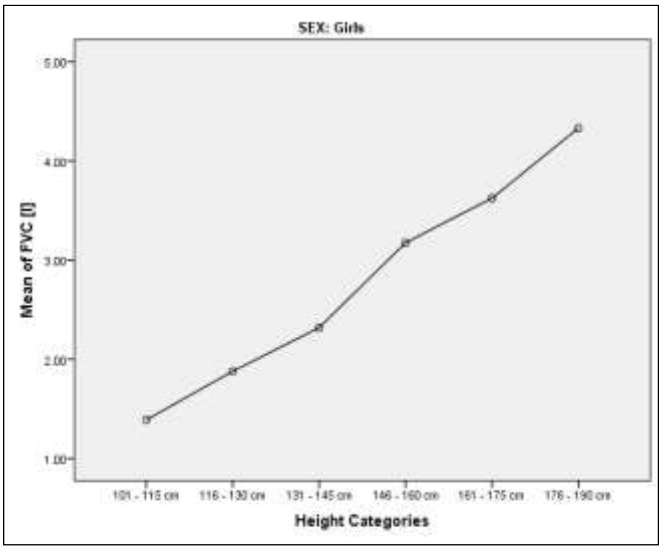
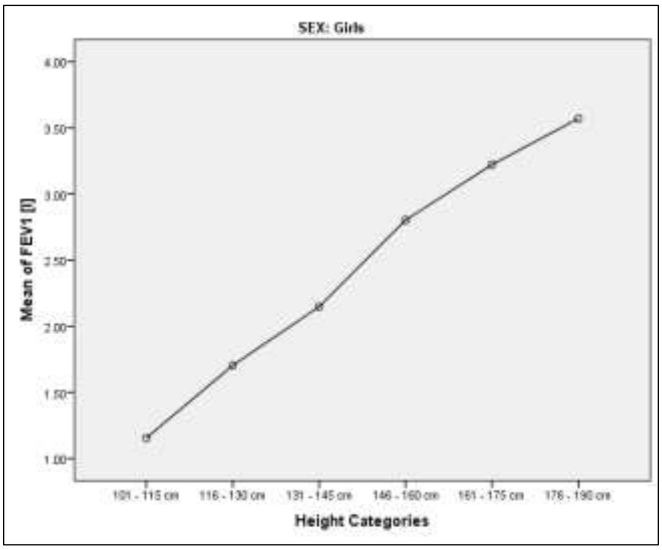


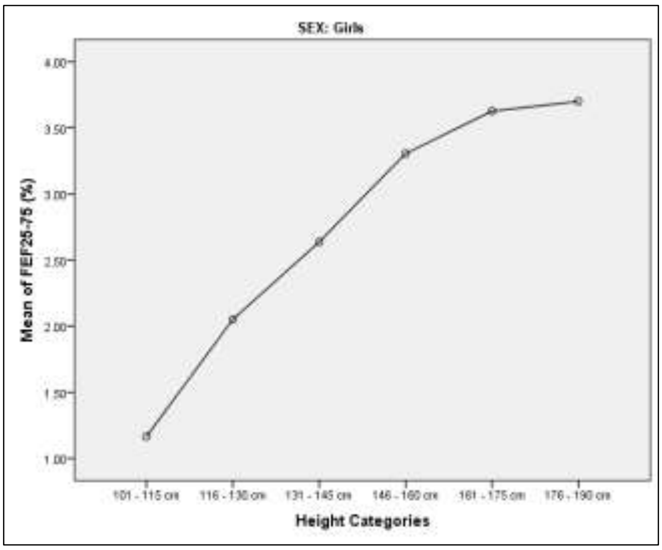
Fig 4: Showing Normogram of PFT in relation to weight group of boys

Table 7: Height wise pattern of normative values of Pulmonary Function Tests in Girls

Height Categories	N	FVC [l]		FEV1 [l]		FEV1/FVC (%)		FEF25-75 (%)		PEFR [l/sec]	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
101 - 115 cm	2	1.3900	.22627	1.1550	.24749	82.7400	4.34164	1.1650	.28991	2.4750	.37477
116 - 130 cm	8	1.8788	.35835	1.7037	.26619	91.2700	5.36803	2.0513	.37574	3.7200	1.00419
131 - 145 cm	20	2.3190	.49489	2.1480	.44998	92.2020	2.26769	2.6375	.49889	4.9870	.82587
146 - 160 cm	46	3.1748	.45609	2.8024	.39472	88.9796	1.97286	3.3052	.47570	5.7422	.79981
161 - 175 cm	13	3.6238	.29576	3.2215	.29902	86.8008	1.95535	3.6262	.31840	6.0185	.68874
176 - 190 cm	1	4.3300	.	3.5700	.	82.4500	.	3.7000	.	7.4600	.
Total	90	2.9074	.73434	2.5918	.62726	89.3733	3.27950	3.0486	.69851	5.3810	1.12334







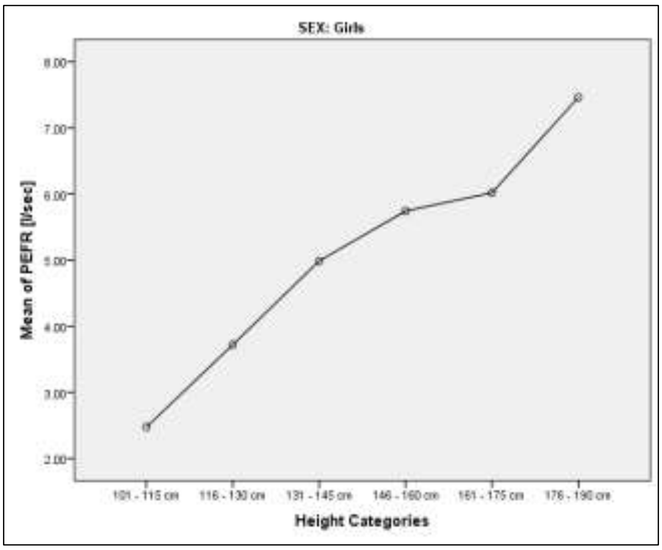
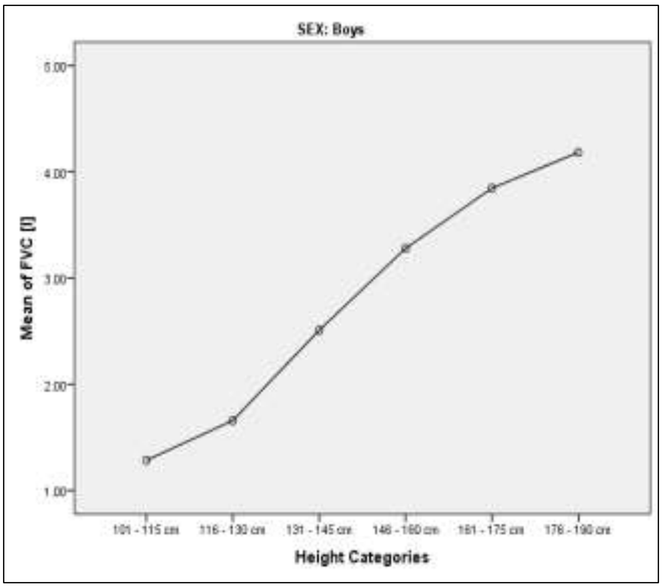
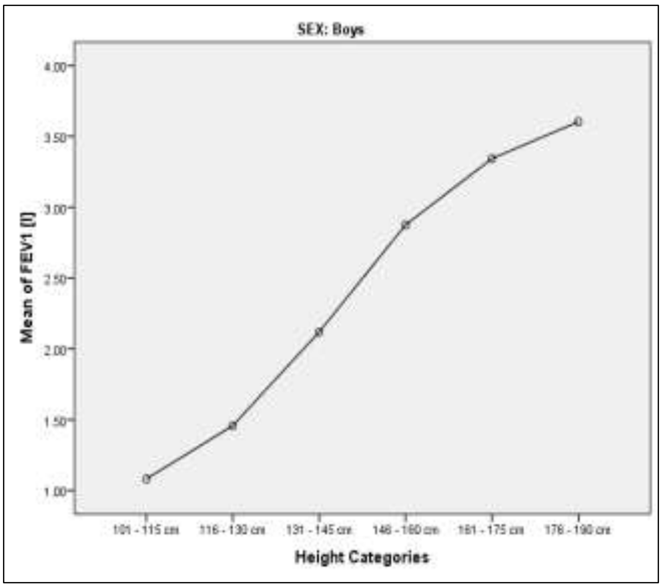


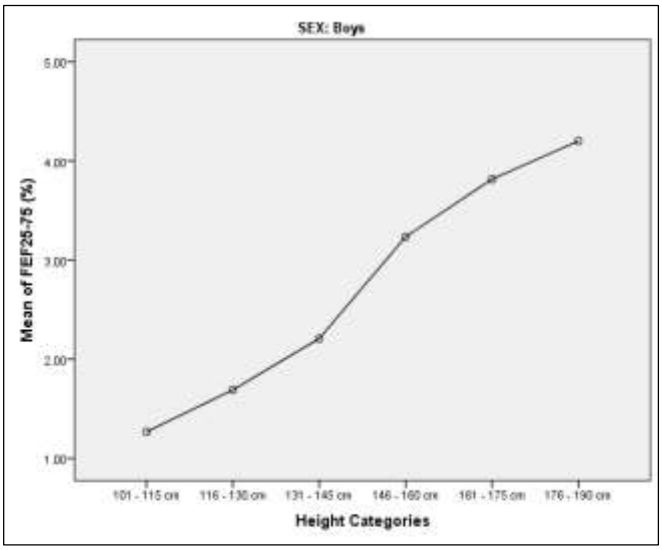
Fig 5: Showing Normogram of PFT in relation to height categories of girls

Table 8: Height wise pattern of normative values of Pulmonary Function Tests in Boys

Height Categories		FVC [l]		FEV1 [l]		FEV1/FVC (%)		FEF25-75 (%)		PEFR [l/sec]	
	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
101 - 115 cm	8	1.2838	.34777	1.0813	.20979	86.0550	10.03030	1.2675	.42281	2.1287	.55008
116 - 130 cm	11	1.6582	.38856	1.4573	.31629	86.4800	3.25716	1.6909	.31198	3.7000	.84356
131 - 145 cm	32	2.5084	.29528	2.1188	.23503	84.5678	2.61837	2.2091	.30400	5.1166	.59975
146 - 160 cm	32	3.2797	.40800	2.8753	.31395	86.4547	2.06228	3.2341	.46944	6.1409	.50766
161 - 175 cm	24	3.8462	.24913	3.3433	.17512	86.2000	2.37111	3.8158	.26891	6.7188	.48476
176 - 190 cm	3	4.1833	.06807	3.6033	.10504	86.2900	3.09044	4.2000	.48135	7.3333	.14224
Total	110	2.8963	.88549	2.5049	.77070	85.8192	3.55243	2.7918	.92968	5.4656	1.43301







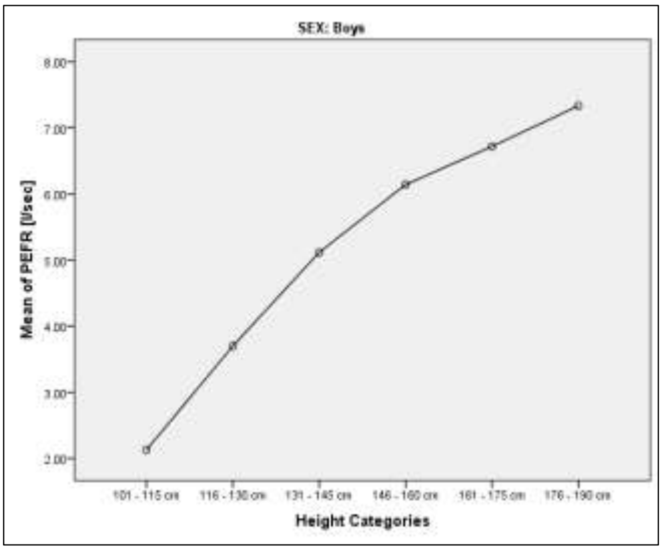


Fig 6: Showing Normogram of PFT in relation to height categories of boys

Table 9: Association of sex with PFT's values through Independent sample T-Test

Group Statistics						
Parameters	**SEX**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Sig. (2-tailed)**
FEV1 [l]	Boys	110	2.5049	.77070	.07348	.381
	Girls	90	2.5918	.62726	.06612	
FVC [l]	Boys	110	2.8963	.88549	.08443	.922
	Girls	90	2.9074	.73434	.07741	
FEV1/FVC (%)	Boys	110	85.8192	3.55243	.33871	.000
	Girls	90	89.3733	3.27950	.34569	
FEF25-75 (%)	Boys	110	2.7918	.92968	.08864	.027
	Girls	90	3.0486	.69851	.07363	
PEFR [l/sec]	Boys	110	5.4656	1.43301	.13663	.640
	Girls	90	5.3810	1.12334	.11841	

Table 10: Association of age groups with PFT's values through One-way ANNOVA test

Descriptive						
Parameters	**Age groups**	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Sig.**
FVC [l]	5 - 10 yr	59	2.0117	.55141	.07179	.000
	11 - 15 yr	103	3.1966	.59653	.05878	
	16 - 18 yr	38	3.4821	.54627	.08862	
	Total	200	2.9013	.81895	.05791	
FEV1 [l]	5 - 10 yr	59	1.7368	.45156	.05879	.000
	11 - 15 yr	103	2.8105	.49390	.04867	
	16 - 18 yr	38	3.0750	.43352	.07033	
	Total	200	2.5440	.70936	.05016	
FEV1/FVC (%)	5 - 10 yr	59	86.5153	5.25930	.68470	.100
	11 - 15 yr	103	87.7813	3.07463	.30295	
	16 - 18 yr	38	87.8379	2.94606	.47791	
	Total	200	87.4186	3.85545	.27262	
FEF25-75 (%)	5 - 10 yr	59	1.9241	.49877	.06493	.000
	11 - 15 yr	103	3.2232	.58284	.05743	
	16 - 18 yr	38	3.5779	.44761	.07261	
	Total	200	2.9074	.84144	.05950	

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PEFR [l/sec]	5 - 10 yr	59	4.1136	1.24827	.16251	.000
	11 - 15 yr	103	5.9483	.86582	.08531	
	16 - 18 yr	38	6.0563	.81938	.13292	
	Total	200	5.4275	1.30036	.09195	

Table 11: Association of weight categories with PFT's values through One-way ANNOVA test

Parameters	Weight Categories	N	Mean	Std. Deviation	Std. Error	Sig.
FVC [l]	1 - 15 Kg	2	1.0500	.25456	.18000	.000
	16 - 30 Kg	32	1.7859	.55650	.09838	
	31 - 45 Kg	97	2.9114	.64323	.06531	
	46 - 60 Kg	58	3.4495	.44356	.05824	
	61 - 75 Kg	9	3.3456	.66675	.22225	
	76 - 90 Kg	2	4.2100	.07071	.05000	
	Total	200	2.9013	.81895	.05791	
FEV1 [l]	1 - 15 Kg	2	.9250	.07778	.05500	.000
	16 - 30 Kg	32	1.5678	.49452	.08742	
	31 - 45 Kg	97	2.5497	.54469	.05530	
	46 - 60 Kg	58	3.0338	.39485	.05185	
	61 - 75 Kg	9	2.9333	.51636	.17212	
	76 - 90 Kg	2	3.5500	.07071	.05000	
	Total	200	2.5440	.70936	.05016	
FEV1/FVC (%)	1 - 15 Kg	2	89.8350	14.37548	10.16500	.005
	16 - 30 Kg	32	87.3206	5.50692	.97349	
	31 - 45 Kg	97	87.2582	3.84927	.39083	
	46 - 60 Kg	58	87.6600	2.27520	.29875	
	61 - 75 Kg	9	88.0456	2.62875	.87625	
	76 - 90 Kg	2	84.5200	.55154	.39000	
	Total	200	87.4185	3.85545	.27262	
FEF25-75 (%)	1 - 15 Kg	2	1.5150	.78489	.55500	.000
	16 - 30 Kg	32	1.7859	.60769	.10743	
	31 - 45 Kg	97	2.8720	.66454	.06747	
	46 - 60 Kg	58	3.5076	.49003	.06434	
	61 - 75 Kg	9	3.4889	.54946	.18315	
	76 - 90 Kg	2	3.9350	.20506	.14500	
	Total	200	2.9074	.84144	.05950	
PEFR [l/sec]	1 - 15 Kg	2	2.5500	.48083	.34000	.000
	16 - 30 Kg	32	3.5466	1.30029	.22986	
	31 - 45 Kg	97	5.6436	.88531	.08989	
	46 - 60 Kg	58	6.1000	.75068	.09857	
	61 - 75 Kg	9	5.6800	1.02795	.34265	
	76 - 90 Kg	2	7.2850	.16263	.11500	
	Total	200	5.4275	1.30036	.09195	

Table 12: Association of height categories with PFT's values through One-way ANNOVA test

Descriptive						
Parameters	**Height Categories**	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Sig.**
FVC [l]	101 - 115 cm	10	1.3050	.31900	.10088	.000
	116 - 130 cm	19	1.7511	.38253	.08776	
	131 - 145 cm	52	2.4356	.39102	.05423	
	146 - 160 cm	78	3.2178	.43736	.04952	
	161 - 175 cm	37	3.7681	.28355	.04661	
	176 - 190 cm	4	4.2200	.09201	.04601	

	Total	200	2.9013	.81895	.05791	
	101 - 115 cm	10	1.0960	.20495	.06481	.000
	116 - 130 cm	19	1.5611	.31427	.07210	
	131 - 145 cm	52	2.1300	.33048	.04583	
	146 - 160 cm	78	2.8323	.36337	.04114	
	161 - 175 cm	37	3.3005	.22994	.03780	
	176 - 190 cm	4	3.5950	.08737	.04368	
	Total	200	2.5440	.70936	.05016	
FEV1/FVC (%)	101 - 115 cm	10	85.3920	9.07181	2.86876	.091
	116 - 130 cm	19	88.4968	4.79623	1.10033	
	131 - 145 cm	52	87.5040	4.48864	.62246	
	146 - 160 cm	78	87.9437	2.35570	.26673	
	161 - 175 cm	37	86.4111	2.22507	.36580	
	176 - 190 cm	4	85.3300	3.17074	1.58537	
	Total	200	87.4186	3.85545	.27262	
FEF25-75 (%)	101 - 115 cm	10	1.2470	.38762	.12257	.000
	116 - 130 cm	19	1.8426	.37734	.08657	
	131 - 145 cm	52	2.3738	.43954	.06095	
	146 - 160 cm	78	3.2760	.47139	.05337	
	161 - 175 cm	37	3.7492	.29735	.04888	
	176 - 190 cm	4	4.0750	.46580	.23290	
	Total	200	2.9074	.84144	.05950	
PEFR [l/sec]	101 - 115 cm	10	2.1980	.52179	.16500	.000
	116 - 130 cm	19	3.7084	.88746	.20360	
	131 - 145 cm	52	5.0667	.69050	.09576	
	146 - 160 cm	78	5.9058	.71873	.08138	
	161 - 175 cm	37	6.4727	.65048	.10694	
	176 - 190 cm	4	7.3650	.13229	.06614	
	Total	200	5.4276	1.30036	.09195	

Table 13: Correlation of all PFTs with Age, Weight, Height and BMI

Correlations						
		FVC [l]	**FEV1 [l]**	**FEF25-75 (%)**	**PEFR [l/sec]**	**Calculated BMI**
Pearson Correlation	Age [years]	.762	.796	.782	.677	.420
	Weight [Kg]	.726	.740	.732	.642	.764
	Height [cm]	.891	.869	.869	.854	.283
	BMI	.251	.293	.263	.181	1.000

Discussion

Respiratory disorders are a major group of illness affecting children which attributed to morbidity and mortality. The lung functions are an objective way of quantifying the disturbances in pulmonary physiology occurring in any respiratory disorder. Pulmonary function tests, especially spirometry have been studied extensively in adult age groups but till date it's use in children is limited comparatively. Pulmonary function tests were performed using computerized spirometer based on ATS criteria.
Normal descriptive statistics were used to describe various Spiro metric values, while to ascertain the effect of age, height and weight on the spirometric values among the study subjects, the descriptive results were expressed as percentages and mean ± standard deviation (SD). Normality of all parameters were also assessed to apply suitable statistical tests for getting better approximation of statistically significant difference. Appropriate statistical tests were used to compare the significant difference between mean PFT values of boys and girls. Pearson's correlation coefficient was applied to measure linear relationship of the PFT measures with age, height and weight. As evident in previous studies, various parameters'

plays influential role in spirometry results like age, height, weight and sex; in this current study we studied their effects on Pulmonary Function tests.

This present found overall mean values of age, weight, height and BMI were 12.47 ± 3.275 yrs, 41.30 ± 12.38 kg, 147.39 ± 16.076 cm, 18.6007 ± 3.2 kg/m^2 respectively. These values of pulmonary function tests were found higher than research [43] done in north eastern state of our country in 640 tribal and non-tribal children ranging from 10-14 years which concluded that FVC, FEV1, FEV1/FVC%, FEF25-75 and PEFR were 1.7 ± 0.08 lt, 1.5 ±0.09 lt, 88.51 ±6.06%, 2.8 ±0.43 lt, and 4.7 ± .63 lt/sec respectively. Similarly, another study by Thakare *et al*. [45] also present lower PFTs values on same lines in a total of 440 rural and urban children of age group 5-15 years with FVC, FEV1 and PEFR were maximum upto 1.89 ± 0.93 lt, 1.7 ±0.80 lt and 3.96 ± 1.76 lt/sec respectively. Results of our present study showed that mean values of pulmonary function test are higher than study conducted in neighboring country by M Asif *et al*. [24] in 2017 in 5-14 years age group of 3275 children (FEV = 1.56± .58, FVC = 1.72±.50 and PEFR = 3.66± 1.00). Increase in spirometric values in comparable age groups irrespective of gender, height and weight may be possibly due to our study conducted in children residing in hilly terrain with better environmental conditions (less pollution) and due to better socioeconomic profiling.

In the present study, sex wise descriptive analysis with focus on mean values with standard deviations of age group, weight categories, height categories, BMI categories and socio-economic status was also estimated.

PFTs in relation to height

Overall, height of subjects participating in this present study ranged from minimum of 103 cm and maximum of 184 cm. Girls ranged from 104-184 cm while boys ranged from 103-184 cm. The maximum number of girls recorded under 140-160 cm category and boys recorded under 131-145 cm and 146-160 cm with 32 participants each.

Among the independent variables height was found to be maximum correlated with outcome variables The correlation coefficient (r) for FVC, FEV1, FEF25-75% and PEFR with height were .891, .869, .869, .854 respectively which were near to +1. Height had maximum correlation with FVC among all outcome variables. These results are well supported by previous studies [44, 49, 50, 51].

Our study presented height wise estimation of all PFTs as at height. FEV and FVC values of same height from current study are higher than study conducted by Kim DH *et al*. [37] with a total, 5590 healthy children aged 4 to 17 years old were recruited from Korea as at height of 120 cm FEV1 were 1.26 and 2.705 at 160 cm while FVC at 120 cm were 1.346 and 2.984 at 160 cm. Similarly, another study by Park *et al*. also followed the same lines as previous study with height of 120 cm FEV1 were 1.207 and 2.527 at 160 cm while FVC at 120 cm were 1.302 and 2742 at 160 cm.

Our present study provided evidence that Lung functions have direct and linear relationship with the height of subject thereby means as height increases PFT's values increases irrespective of sex. These results are in accordance with the results of study [26] conducted in Greek Gypsy children where a total of 152 children as in 112-135 cm FEV1 and FVC were around 1.47 Lt and 1.6 Lt. respectively while at 136-164 cm FEV1 and FVC were around 1.93 Lt and 2.14 Lt. respectively. Another study where 233 healthy, young adolescence, Indian and Nepalese medical students of 18 to 20 years of age participated in the study. Results of this Nepalese study are in accordance to the observations of present study as height remained the most important predictor influencing Mean expiratory flows irrespective of gender. Singh HD *et al*. [5] conducted a study where 4-15 years children were included and a nomogram was constructed relating PEFR to height. Prediction equations for PEFR using height alone or height, age and weight were determined for both sexes. Similarly, another national study Pulickal AS *et al*. [49] was undertook a study to establish normograms for PEFR in healthy school going children from rural area of south India and to derive prediction equations for PEFR with height. PEFR was measured in 1403 children aged 5 to 17 years in which significant linear correlation was seen of PEFR with height in males ($p < 0.001$, $r = 0.856$) and in females ($p < 0.001$, $r = 0.762$).

In terms of international evidence, a study was conducted in Hong kong by Ip MS *et al*. [11] in age group of 7 to 19 yr, where children were recruited from seven schools in Hong Kong. Prediction equations for FVC, FEV(1) and maximal expiratory flow at 50% of the FVC (MEF(50)) for both sexes are presented, with standing height as the dependent variable. Similar results were shown by Facchini F *et al*. [12] with aged 7-18 years who found that height explained almost all the variance of forced vital capacity (FVC) and forced expiratory volume in 1s (FEV1) for both sexes. Another study by Trabelsi Y *et al*. [16] in 1,114 asymptomatic, nonsmoking Tunisian children 6-16 years of age with peak expiratory flow (PEF) for both sexes were presented with standing height as the dependent variable. This study also showed that significant increase in lung function with standing height in both sexes.

In a research conducted by Dickman ML *et al*. [35], with participation of aged 5-18 years. In children less than 60 inches tall, values of the spirometric measurements were very similar for boys and girls, but in the taller subjects marked differences were observed. In a Nigerian study [38], 155 children were studied. The mean age (±SD) of the males was 10.5+2.95 years while that of the females was 10.7 + 3.19 years. Height was the significant predictor of PEFR (p=0.04), while the height and sitting height were the important predictors of log FVC and FEV1 for the males respectively (p= 0.007 and 0.02; 0.004 and 0.027). For the female subjects, age was a significant predictor of log PEFR and Log FVC (p=0.047 and 0.003), while Age and Sitting height were the significant predictors of log FEV1 (p=0.02 and 0.03 respectively). The values obtained were statistically highly significant at a P-value of .000 suggested a linear impact height on FVC, FEV1, FEF25-75% and PEFR.

To conclude relationship of height with spirometric parameters shows that all PFT values except FEV1/FVC were found to be the most significant dependent parameter irrespective of age and weight in both girls and boys (p<0.05). Normogram shows direct and linear relation between PFT values and height group. All PFT values tended to increase as height increased.

PFTs in relation to age

In this present study, almost half of participants belonged to 11-15 years of age group with similar distribution among both sexes. In current study, we found that the mean values of FEV1, FVC and PEFR increased when children got older. Age had positive correlation with all outcome variables. The correlation coefficient (r) for FVC, FEV1, FEF25-75% and PEFR with age were 0.726, 0.740, 0.732 and 0.677 respectively with a P-value = .000 for all, which was highly statistically significant. However, girls showed a slightly greater mean values of all pulmonary function tests values than boys on age group wise matching but not statistically significant different. This may be attributed to random selection of number of boys and girls in the study therefore matching of sex couldn't be done. Additionally, it was observed in our study that means of PFT's with age, boys showed more consistent linear relationship than girls which is in line with various national [5, 15, 27, 34, 41, 45, 47] and international studies [16, 23, 24, 36, 37, 38].

Our study presented age wise and age group wise estimation of all PFTs to ease the comparative quotient of results as at age of 5 years and 14 years respectively. These spirometric values on comparing with a result of recently conducted study in Pakistan found on greater side as at age of 5 years, FEV1 is around 0.97 lt., FVC is 0.98 lt. and PEFR (lt/min) is 2.12 and at age of 14 years FEV1 is around 2.22 lt., FVC is 2.45 lt. and PEFR (lt/min) is 4.63. Another Indian study by Raju PS *et al*. [15] with 1555 normal healthy schoolboys from Hyderabad city who were in the age group of 5 to 15 years also produced similar kind of results as at age of 5 years, FEV1 was around 0.76 lt., FVC was 0.78 lt. and PEFR (lt/min) was 155.31 and at age of 14 years FEV1 was around 2.82 lt., FVC was 2.69 lt. and PEFR (lt/min) was 465.59. These studies showed lower PFTs which may be probably due to our study conducted in different geographic location one of the hilly (less pollution) and prosperous (better SES) state of our country and different kind of population.

The present study showed that in girls, PFT values are at peak in age of 12 years of age while in boys gradual consistent increase was seen across increasing ages. Interestingly, in adolescent ages, PFT values of boys are greater than of girls especially after age of 9 years which is in accordance to a study by

Dickman ML *et al*. [35] where in boys, pulmonary function increased dramatically at adolescence, peaked at age 18 years, then decreased with increasing age. In girls, the values increased until age 16 years, then leveled off hence proving spikes in PFT values during adolescence period in both genders. Similarly, another study by Wang X *et al*. [6] studied spirometric parameters of children aged 6-18 years with FVC, FEV1 and FEF25-75% from 11,630 white children and 989 black children. For the same height, boys have greater lung function values than girls, and whites have greater ones than blacks. Lung function increases linearly with age until the adolescent growth spurt at about age 10 years in girls and 12 in boys. The pulmonary function vs. height relationship shifts with age during adolescence.
These results may be explained by the fact that especially in later ages or adolescence, the boys have larger lungs, more muscularity and different growth pattern so there should be a gender-based reference equation[51]. One study mentioned sex hormone or the intracellular signalling pathway as a reason behind the gender difference in pulmonary function values [56].
On the other hand, a Pakistani study by M Asif *et al*. [24] concluded that although the mean PFT values increased with age for both genders but the increase was slow in the age group of 7 to 9 years, but a sharper and more variable increase was reported at the age of 10 years or after. FEV1, FVC and PEFR for boys (of age 13 and 14 years) were found to be significantly higher than those of girls.
To summarize, all PFT values except FEV1/FVC were found significantly different among different weight groups for both girls and boys ($p<0.05$). Normograms also showed direct and linear relation between PFT values and weight group. All PFT values tended to increase as age increased.

PFTs in relation to Weight

Overall, weight of subjects participating in this present study ranged from minimum of 14 kg and maximum of 81 kg. Girls ranged from 14-72 kg while boys ranged from 15-81 kg. The maximum number of girls and boys were recorded under 31-45 kg category. In Girls, PFTs were maximum in 46 to 60 kg category while in boys under 61-75 kg category.
In this current study, we tried to assess the effect of weight while keeping other components constant and we found that weight is also in direct and linear relationship with the values of pulmonary function tests. Weight had positive correlation with all outcome variables. The correlation coefficient (r) for FVC, FEV1, FEF25-75% and PEFR with weight were 0.762, 0.796, 0.782 and 0.642 respectively with a P-value = .000 for all, which was highly statistically significant. These results are in accordance to several studies [9, 11, 13, 14] (Wang X *et al*., Ip M S *et al*., Towsend MC *et al*., Karlberg E M *et al*.,) which has also recorded direct co relation between weight and lung functions.
All PFT values except FEV1/FVC were found significantly different among different weight groups for both girls and boys ($p<0.05$). Normograms show direct and linear relation between PFT values and weight group. All PFT values tended to increase as weight increased.

PFTs in relation to gender/sex

In present study, authors tried to estimate separate mean values of age, weight, height and BMI as per gender. On comparing observed values of our study with GLI reference values (FVC=3.6±0.19 lt. in boys and 2.1±0.23 lt, in girls, FEV1=2.7±0.13 lt. in boys and 2.07±0.19lt. in girls, FEF25-75=3.2±.67 in boys and 7.7.± .70 in girls) given by Qunajer PH *et al*. [8] in a multicentric study, it was seen that FVC and FEV1 are less than reference values in boys while more among girls except FEF25-75, which is contrary to other Asian studies [5, 32, 33, 34, 45, 54 ,55]. There is differential performance of lung function tests in boys and girls, which is already a well-established fact through various national and international studies. Contrarily, this present study showed that there is no significant difference in pulmonary function values among boys and girls. This kind of results of our research are in accordance with the study conducted in healthy children aged 6 to 11 years in Taiwan by Tsai MC *et al*. [25] including 214 children 109 boys and 105 girls showed no significant differences in lung function variables between the genders. However most of the national evidences [5, 45, 54, 55] (Singh *et al*. [5] in age group of 10-14 years with FVC=2.53 lt. in boys and 2.31 lt, in girls, FEV1=2.39 lt. in boys and 2.18 lt. in girls, PEFR=5.8 lt./s in boys and 5.29 lt./s in girls; Thakare *et al*. [45] in age group of 5-15 years with FVC=1.89 lt. in boys and 1.6 lt, in girls, FEV1=2.39 in boys and 2.18 in girls, PEFR=5.8 lt./s in boys and 5.29 lt./s in girls; Vijayan *et al*. [54] studied spirometric values in 7-19 years with FVC=2.05 lt. in boys and 1.87 lt, in girls, FEV1=1.79 in boys and 1.47 in girls, PEFR=3.64 lt./s in boys and 3.45 lt./s in girls, Budhiraja *et al*. [55] in 6-15 years with FVC=2.16 lt. in boys and 1.80 lt, in girls, FEV1=1.95 in boys and 1.66 in girls, PEFR=3.36 lt./s in boys and 3.056 lt./s in girls) and international evidences [23, 24, 38] (Sadiq S *et al*. [23] in age groups of 7-13 years with FVC=2.28 lt. in boys and 2.18 lt, in girls, FEV1=2.13 in boys and 1.97 in girls, FEV1/FVC = 92.9% in boys and 92.89% in girls, PEFR=236.6 lt./m in boys and 221.6 lt./m in girls; M Asif *et al*. [24] in 5-14 years with maximum upto FVC=2.45 lt. in boys and 2.14 lt, in girls, FEV1=2.22 lt. in boys and 1.95 lt, PEFR=5.12 lt./s in boys and 4.63 lt./s in girls; Another Nigerian study by Oloyede IP *et al*. [38] gave mean values PEFR, FVC and FEVI were 3.95±1.55 litres per second (l/s) 1.58±0.58 litres (l) and 1.57±0.56l in the males while for the females 3.73±1.03l/s, 1.45±0.43l and 1.41±0.41l respectively) among same age groups and other factors showed that PFTs values are higher among boys than girls. Surprisingly, in current study, mean values of all spirometric values except PEFR were slightly more in girls than in boys considering other variables almost constant. These results may be attributed to lower sample size and more of inclusion of lesser age group of children in both genders. Also, few of similar carried in India (Jain SK *et al*., Vohra RS *et al*. Doctor TH *et al*.) [32, 33, 551] and in western countries studies (Dockery DW *et al*. in 6-11 years, Facchini F *et al*. in Kazakhstan, Connet GJ *et al*. in 6-18 years in Singapore) [4, 12, 29] also succeeded in establishing direct co relation with sex and lung functions.

In our study, it was observed that values of pulmonary function tests varied on individual basis as overall observed FVC values ranged from 0.87 lt. to 4.37 lt., with girls ranging 1.23 lt. to 4.37 lt. and boys ranging 0.87 lt. to 4.26 lt. Similarly, observed FEV values ranged from 0.8 lt. to 4.03 lt. with girls ranging 0.98 lt. to 4.03 lt. and boys ranging 0.8 lt. to 3.71 lt. At the same time, observed FEV1/FVC values ranged from 73.14% to 100% with girls ranging 79.67% to 100% and boys ranging 73.14% to 100%. Observed FEF25-75% values ranged broadly among other spirometric values from 0.78 lt. to 5.01 lt. with girls ranging 0.96 lt. to 5.01 lt. and boys ranging 0.78 lt. to 5.01 lt. Observed PEFR values ranged maximum among other PFTs from 1.26 lt./sec to 8.69 lt./sec with girls ranging 2.21 lt./sec to 8.69 lt./sec and boys ranging 1.26 lt./sec to 8.69 lt./sec.

Conclusion

Age, height and weight had statistically significant and positive correlation with the PFT values, both for boys and girls. Height was found to be most strongly and positively correlated with the PFT values. Overall significant difference was seen in FEV1/FVC and FEF 25-75 among boys and girls except FEV1, FVC and PEFR of the same age group. The fitted regression equations would help to predict the PFT values for the Indian children living in hilly areas at given age, height and weight. This study should be seen as a pilot study and will require data from a large population to establish normal values for our population.

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